

Introduction

Modern observing and imaging techniques, with automated goto mounts and CCD (charge-coupled device) cameras, http://en.wikipedia.org/wiki/Charge-coupled_device allow detailed observation and study of celestial targets not possible to the professional community even a decade ago.

To locate and study these objects in the observatory, students will learn telescope and camera control procedures, with related software. This includes equipment startup and shutdown, and applying calibration frames (dark frames, flat fields, and bias frames), for image reduction. <http://www.astrophoto.net/calibration.php>

Imaging and Processing Overview

-Equipment and Software

Below is a list of the primary imaging equipment and software students will use at four stationary piers in the observatory. Additional equipment and procedures are potentially available, and telescope/camera combinations may vary.

Equipment

**180mm f/7 TEC refractor w/SBIG STXL-6303 CCD camera.
Losmandy Titan mount w/Gemini control.**

Focal length = 1260mm
Camera = SBIG STXL-6303
FOV = 50.2 x 75.3 arcmin
Chip size = 18.4mm x 27.6mm
Pixel size = 9u x 9u
Image scale: Bin1x1=1.47 arcsec/pixel Bin2x2=2.94 arcsec/pixel

**140mm f/7 TEC refractor w/SBIG ST-10XME CCD camera.
Losmandy Titan mount w/Gemini control.**

Focal length = 980mm
Camera = SBIG ST-10E
FOV = 35.1 x 52 arcmin
Chip size = 10mm x 14.9mm
Pixel size = 6.8u x 6.8u
Image scale: Bin 1x1= 1.43 arcsec/pixel Bin 2x2= 2.86 arcsec/pixel

**20" f/8 RCOS (Ritchey-Chrétien) w/SBIG STL-6303 CCD camera.
Paramount ME mount w/TCC (Telescope Command Center).**

Focal length = 4050mm
Camera = SBIG STL-6303
FOV = 15.6 x 23.4 arcmin
Chip size = 18.4mm x 27.6mm
Pixel size = 9u x 9u
Image scale: Bin 1x1= .46 arcsec/pixel Bin 2x2= .92 arcsec/pixel

**Meade 8" SCT @f/6.3 w/SBIG SGS Spectrograph and SBIG ST-7 CCD camera.
Losmandy G-11 mount w/Gemini.**

Focal length = 1260mm
Spectrograph = SBIG SGS
Camera = SBIG ST-7E
Chip size = 4.6mm x 6.9mm
Pixel size = 9u x 9u
Dispersion = 1.06 Angstroms/pixel
Slit width = 18 microns (hires)
Spectral range = 820 Angstroms

Rainbow Optics 200 line/mm diffraction grating

For low resolution spectra thru CCD cameras.

Software

Below is a list of the primary software students will use in the observatory for telescope and camera control, and image processing.

Telescope control

TheSky6 (Software Bisque), TCC Telescope Command Center (RCOS)

Camera control / Image acquisition

CCDSOFT5 (Software Bisque), Focus Max, Maxim DL5 (Diffraction Limited)

Image processing

CCDStack (CCDWare), Maxim DL5 (Diffraction Limited), Vspec (Astrosurf),
Rspec (Field Tested Systems)

Links:

Software Bisque <http://www.bisque.com/sc/>
Vspec <http://www.astrosurf.com/vdesnoux/>
Maxim DL <http://www.cyanogen.com/>

CCDWare <http://www.ccdware.com/>
RCOS <http://www.rcopticalsystems.com/>
Rspec <http://www.rspec-astro.com/>

Setup for Imaging

Students will gain hands on experience with the observatory's imaging equipment and software to photograph, identify, and study night sky objects. Whether imaging galaxies and star clusters, or taking photometric and spectral data, various instruments are employed according to target type, and their availability during class.

Observatory computers have an application for previewing night sky objects, and the field of view (FOV) of each telescope/camera combination. Some objects (i.e. Andromeda Galaxy) may be too large for the telescope's FOV, while others (M97, Owl Nebula) tend to get lost in the field.

Object types vary somewhat with the season, and each student will image 2-3 examples of each selected type. Students will also maintain a master folder on the desktop including all their data, in addition to detailed notes for each target imaged during the semester. Notes will include date, object, location, equipment used, software, and sky conditions.

Students will reduce and combine their raw data, usually during the day, with appropriate calibration frames (below) provided, using CCDStack and other software.

Students will also create and update an ongoing list of imaging targets, using planetarium software (TheSky6) on the observatory computers, or by searching the Internet.

We generally aim for targets at least 30 degrees above the horizon during imaging, to photograph thru the least amount of earth's atmosphere. This "air mass" decreases with an object's distance above the horizon. [http://en.wikipedia.org/wiki/Air_mass_\(astronomy\)](http://en.wikipedia.org/wiki/Air_mass_(astronomy))

Cameras and Binning

Observatory CCD cameras are cooled to -10C to help eliminate electronic noise. Each camera contains two imaging chips; one for photographing, one for autoguiding, which keeps the target stationary during the exposure. <http://en.wikipedia.org/wiki/Autoguider>
Both CCD imaging chips are controlled via image acquisition software.

CCD "binning" (combining adjacent pixels) is controlled separately on each chip. When binned 1x1 each pixel (picture element) <http://en.wikipedia.org/wiki/Pixel> acts as an individual photo site. When the chip is binned 2x2, every 4 pixels are combined into a larger, more sensitive pixel. This is useful for autoguiding and imaging faint objects.

Binned 1x1 Each pixel = 1 photo site.

This is the highest resolution possible for the camera, and is used for most imaging.



8x2 pixels

Binned 2x2 Every 4 pixels = 1 photo site.

This increases speed at the cost of resolution, and used mostly with the autoguide chip.



4x1 pixels

Calibration Frames Dark-frames, Flat fields, Bias frames

Purpose

CCD images are electronic images and require special processing to eliminate noise and compensate for uneven illumination across the field. The goal is to eliminate these issues as much as possible, to bring out the greatest detail in the data. The following provided calibration frames are applied to images.

Dark frames http://en.wikipedia.org/wiki/Dark-frame_subtraction are images taken with the camera's shutter closed, at the same exposure, temperature, and binning as the light frames. These images record the same noise in the CCD, as the light frames. This noise is then subtracted from each frame for a cleaner image. Generally, 8-12 dark frames are median combined to create a master dark. Master darks are reusable and stored in folders on the desktop.

Flat fields http://en.wikipedia.org/wiki/Flat-field_correction are images taken of an evenly illuminated surface (white card) or field (blue sky), thru the same optical path as the light frames. Uneven illumination in the image may result from variations in pixel sensitivity, vignetting in the optical path, or tiny dust specs on or near the imaging chip. Flats are divided out of the light frames, to smooth the field and correct for these issues. The observatory is equipped with lighting and diffusers for creating flat fields. Flat fields are taken nightly, to be used with dated files. ~16 flats are bias subtracted and median combined to create a master flat.

Bias frames http://en.wikipedia.org/wiki/Bias_frame are exposures of zero length, to record only the background noise of the particular camera. Bias frames are taken at the same temperature as flat fields. A master bias created from ~16 images, is subtracted from individual flat fields, before creating the master flat.

During the semester, selected images are posted on CSM Astronomy website's "Student Projects" page, to present and update students' ongoing work in the observatory.

<http://collegeofsanmateo.edu/astronomy/studentprojects.asp>



Powering On Equipment

Below are the steps for powering on the observatory equipment in preparation for imaging. These steps are the same for future imaging, regardless of exact target or imaging technique employed.

Refractors and 8”SCT Startup Procedures –TEC 140 & 180, 8” Meade

Follow steps in exact order, to assure all drivers & programs integrate properly.

Inside:


Open **TheSky6**, close **Tip of the Day**, and set to computer clock. Computers are synced to NIST time. <http://www.time.gov> Open **CCDSOFT** and click **Camera_Setup** to bring up the **Camera Control** window.

Outside:

Turn on the power strip at the pier. Power on the CCD camera (rocker switch) from the power supply, then confirm the fan is running on the CCD camera. Power on the Titan mount, and select the appropriate startup mode (“Warm Start”) from the hand controller. Remove the telescope cover.

Inside:

In **CCDSOFT Camera Control** window select **Connect** and wait for camera connection. Select **Temperature**, and **Temperature regulation>ON**. Change **Temperature set point** to -10.0 and hit **OK**. Continue setup while the camera cools.

From **TheSky6**, select **Telescope>Link>Establish** and wait for the bulls eye near Polaris, confirming the connection. Left click on a bright star (1-3 mag.) near your first target, and slew there with the green slew **button**  in TheSky6 Object Information window.



TheSky6 screen -Software Bisque

Outside:

Center the bright star just slewed to, in the telescope’s finder scope, using the Titan mount’s hand controller **N S E W** buttons.

Inside:

In **CCDSOFT Camera Control** window, select **Focus Tools**, 1 second exp., **Bin 1x1**, **Continuous**, and **Imager chip**. Hit **Take Image** to take continuous images. In **CCDSOFT** main window, choose **Image>Show Cross Hair**, to identify the CCD image center.

In **TheSky6** main window, choose **Telescope>Motion Controls**, and move the telescope using **N S E W** arrows, to center the star on the cross hair. After centering the star, in **TheSky6 Object Information** window, choose **Telescope>Sync>Confirm**. The telescope is now synced to **TheSky6** ready for slewing, focusing, autoguider calibration, and image acquisition.

20" RC Startup Procedures –20" RCOS

Follow steps in exact order, to assure all drivers & programs integrate properly.



20" RCOS telescope

Inside:

Open **TheSky6**, close **Tip of the Day**, and set to computer clock. Computers are synced to NIST time. <http://www.time.gov> Open **CCDSOFT** and click **Camera_Setup** to bring up the **Camera Control** window.

Outside:

Remove both the primary and secondary mirror covers, and place in the computer room. Turn on the pier power strip. Confirm the camera's green power LED, and that the fan begins running. **ME mount:** Turn on with the rocker switch located on the mount's control panel and confirm 2 beeps, then 2 Blue & 1 Orange LED on the panel. This confirms both axes are activated. ME motors make a humming noise.

Inside:

From **TheSky6** go to **Telescope > Link > Establish** then select **Yes** to send the mount to the factory set Home position. Audible beeps on both axes indicate when the mount has found Home position. A bulls eye appears in **TheSky6**, showing the telescope's home position. Goto commands now function from a pre-established pointing model, to aid in accurate target positioning. <http://en.wikipedia.org/wiki/Tpoint>

In **CCDSOFT Camera Control** window hit **Connect** then set temperature to -10C. Start **RCOS TCC** (Telescope Control Center) application. Start **FoxusMax** application for focusing. The mount, telescope, CCD, and other applications are now connected and ready for operation.

Focusing and Autoguider Calibration

Focusing and autoguiding (to keep the target stationary during the exposure) assure clear images and round stars. Both operations are performed using the same 6-7 mag. star.

Focusing Run

Purpose

Stars are round, pixels are square, and in astroimaging we want a star's focused light to cover as few pixels as possible. This yields the sharpest stars, with the strongest signal. Focus is most negatively affected by poor "seeing" conditions, the result of various turbulences in earth's atmosphere.

To achieve accurate focus we use FocusMax <http://www.focusmax.org> software, which takes repeated images, each at a different focus position. FM then measures the star's diameter at each position, to find best focus. Focus Max then chooses the star's smallest diameter, measured as Half Flux Diameter or HFD, for the final focus position.

<http://users.bsdwebsolutions.com/~larryweber/ITSPaper.htm>

We operate three different focusers with FocusMax, in the observatory:

TCF-S <http://www.optecinc.com>

Feather Touch <http://www.starlightinstruments.com>

RCOS <http://www.rcopticalsystems.com>

Procedure

With the telescope synced to the sky and the CCD camera powered on and cooled, find and slew to a 6-7 magnitude star near your first target. In **TheSky6**, clicking on any star will give the magnitude of that star. The chosen star should be fairly isolated, to avoid confusion with other field stars, during these operations.

In **CCDSOFT** take a 1 second confirmation image under **FocusTools**, to see your selected star in the field. Open **FocusMax**, which will auto-connect to the camera via **CCDSOFT**. The current focus setting, in microns, will be displayed in the FocusMax "Position" window (i.e. 1420), under the Focus tab.

When focusing is initiated, **FocusMax** controls **CCDSOFT** to take images and measure HFD at the various focuser positions. This entire procedure and the results, are displayed in real time. To initiate focusing, hit the **Focus** button located lower right of center, in the Focus tab.

When finished the new focus position will be displayed with the camera focused, and ready for imaging.



FocusMax window.

Autoguider Calibration

Purpose

While the telescope mounts are accurately polar aligned and tracking at the sidereal rate http://en.wikipedia.org/wiki/Sidereal_time, tracking errors can occur during imaging due to very small gear imperfections. These errors must be corrected to prevent blurring of the image. Autoguiding keeps the telescope pointed precisely at the target, to within a fraction of a pixel, during the exposure.

During calibration, the guide chip, located next to the imaging chip, is “taught” to recognize these tiny errors. Precise corrections, to sub-pixel accuracy, are then sent to the mount, while the imaging is taking place.

This calibration is performed on the imaging chip, with its larger field of view providing more calibration stars. Guiding, during the imaging run, is then performed on the autoguider chip. Both autoguider calibration and autoguiding, are carried out in CCDSoft. (https://www.bisque.com/help/CCDSOFT/afxcore/autoguide_settings.htm).

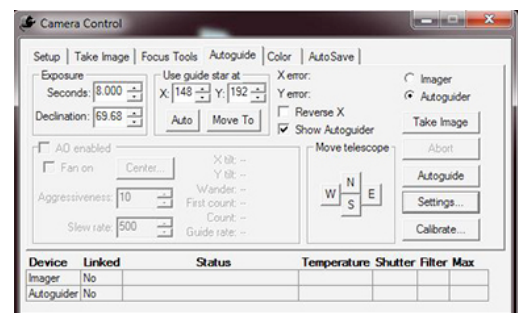
The calibration procedure teaches the autoguider how far to move the mount, (% Pixel) and in which direction (X,Y), to keep the selected guide star centered on a particular X-Y position, during imaging. The goal is round stars, and here are the steps.

Procedure

In CCDSoft, in the **Take Image** tab set the **Imager** chip to Bin 2x2 and set **Reduction** to **Auto Dark**. These settings create a strong signal and apply a dark frame (to eliminate noise) to each image. Use the same 6-7 mag. star used earlier for focusing. Take about a 2-4 second exposure with **Focus Tools/Imager/Take Image**. This will take an image, apply a dark frame to the image, and be ready for calibration.

Note: If the calibration star is not the brightest star in the field, the autoguider may get confused, and fail calibration. It's also possible to subframe (crop) the image somewhat (about 50%) to isolate the calibration star. Subframing is achieved thru left_click_drag around the star. The calibration star moves right-left-up-down during the procedure and must remain the brightest star in the field.

With your chosen calibration star centered, in the **Autoguider** tab choose the **Imager** chip, where the calibration will be performed, then **calibrate>calibrate**. “Move” times determine how long the mount is slewed for each calibration step, and are preset at about 20 seconds. Calibration will now be performed on the X and Y axis. Watch for the “**successful**” message in the **Status** window, confirming calibration.



CCDSOFT autoguider control tab.

You are now ready to autoguide the camera using a guide star. Under the **Settings** tab set **Aggressiveness** to 5 to make all corrections at 50% of the calculated amount. This is helpful in preventing overcorrections, and to avoid “chasing” poor atmospheric seeing. http://en.wikipedia.org/wiki/Astronomical_seeing

Before proceeding with imaging (Lab 1), go back to the **Take Image** tab, select **Imager** and reset **Bin** to 1x1 and **Reduction** to **None**. This returns the imaging chip to the default settings. We are finished with the imaging chip, for calibration.

Shutdown Procedures

These procedures are carried out at the end of each imaging session, to power down all equipment, and return to the startup positions.

Refractor and 8" SCT Shutdown Procedures –TEC 140 & 180, 8" Meade

Follow steps in exact order.

Inside:

In **CCDSOFT**, choose **Setup>Temperature>Temperature regulation> OFF>OK**.
Set the **Take Image**, **Focus Tools**, and **AutoSave** tabs to default, startup positions.

In **TheSky6** choose **Telescope>Link>Terminate**. Exit **TheSky6**, and say **NO** to **Save Changes**. In **CCDSOFT Camera Control** window, hit **Setup> Disconnect**, leave the **Camera Control** window open, and exit the program.

Outside:

With the Titan mount hand controller, hold down **Menu** button, scroll to **Park Mount** and release **Menu** button. Hold down **Menu** button again, scroll to **Park CWD** (Counter Weight Down) and release **Menu** button. This parks the mount, pointing to Polaris. Power off the Titan mount on the control box. Power off the CCD camera with the rocker switch on the power supply. Turn off the power strip and replace the lens cover.

20" RC / ME Mount Shut down procedure - 20" RCOS

Follow steps in exact order.

Inside:

In **CCDSOFT**, turn off Temperature control under **Setup>Temperature** tab in the **Camera Control** window. In **TheSky6**, go to **Telescope > Options > Park** to slew to the park position.

Outside:

Wait for the slew to finish, then turn off the **ME** (toggle switch on the control panel), and replace 3 telescope covers: primary mirror, secondary mirror, and thru tube.

Inside:

In **CCDSOFT** reset all parameters to default, startup positions. Go to **Setup>Disconnect**.
Exit **TheSky6** and say **No** to "Save changes to Normal."
Exit **RCOS TCC** application.
Exit **FocusMax** application.
Exit **CCDSOFT** application.
Turn the pier power strip **Off**, which also cuts power to CCD camera fan.