COLOR IMAGING USING THE BYU-IDAHO MAKSUTOV-NEWTONIAN
TELESCOPE AND TRI-COLOR CCD CAMERA

by

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ABSTRACT

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The BYU-Idaho Physics Department currently owns a 10'' Maksutov-Newtonian telescope, along with a SBIG ST-7XME charge-coupled device (CCD) camera. This camera has a three-color wheel filter. Several students have studied the equipment and its manuals, trying to use the telescope and camera to their full potential. Until recently, no one has used the camera's color filters. However, now students and faculty can use the CCD camera to take detailed, colored pictures of deep space objects. In order to get a colored image from a CCD camera, the user must take three separate images using the three different color filters. Then, by applying dark images and flat field images, the user can attempt to clear up the images and reduce the noise. Finally, the user will combine those edited images to create the colored image. Certain techniques can be used to reach better image quality using picture editing software. This paper explores the astrophotography potential of the telescope and camera, as well as photo editing techniques.
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In memory of Dr. Ellis Miller
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Chapter 1

Introduction

Throughout the history of mankind, humans have looked up at the heavens in wonder and awe. The stars have always been important to humanity. Mankind has used the stars to find direction both geologically and spiritually. Whatever their use, the stars have always been mysterious dots in the sky, until Galileo pointed his telescope to the heavens and realized some celestial objects have more detail than previously thought. As the technology advanced, man’s understanding of the stars increased. With the invention of photography, astronomers can study the heavens even more, being able to rely on photographs rather than hand-drawn pictures. The most recent technology allows astronomers to take detailed, colored images of celestial objects. Using telescopes and cameras, we can study the heavens in more detail than we ever have been able to before.

Brigham Young University-Idaho currently owns a 250mm Maksutov-Newtonian telescope that is available for students to observe the stars. Likewise, the school owns a SBIG ST-7 XME CCD camera, which can take detailed images of the sky. Until recently, no one at BYU-Idaho has used the telescope and camera to take colored images. However, this equipment has the capability to take detailed and amazing images of
celestial objects. This research explores and outlines how to take and edit color images with the CCD camera.
Chapter 2

Telescopes and Cameras

2.1 Our Telescope

There are many types of telescopes. They are classified by their components, size, and shape. A telescope either uses mirrors—reflecting telescope—lenses—refracting telescope—or both—catadioptric telescopes—to capture, reflect, and magnify light (1). The telescope at the BYU-Idaho Observatory is a 250mm Maksutov-Newtonian telescope, which is a type of catadioptric telescope (2).

2.2 Our Camera

Another instrument that an astronomer, and in particular an astrophotographer, requires is some type of camera. Many camera options exist, such as DSC and DSLR cameras, but the camera at the BYU-Idaho observatory and the one I used for this project is the SBIG ST-7XME CCD camera, or simply put, a CCD camera.

In the late 20th century, CCD cameras, or charged-coupling device cameras,
became a popular tool in photography. CCDs use the photoelectric effect. When exposed to light, certain metals release electrons. CCD cameras use a silicon chip, which is covered by a grid of small electrodes. Before imaging, the camera charges this surface. As photons reach this surface, the electrodes release an electron that becomes trapped by nonconducting metal, most likely silicon. This produces an electron count. The count is what appears on the screen for the images. A brighter spot has a higher count, and a dimmer spot has a lower count. Because of this count, CCD cameras are prone to noise, or extra electrons. However, there are ways to work around this noise (3).

CCD cameras can also have filters to change the amount of light coming through the lenses. These filters are the key to color imaging with CCD cameras. The ST-7XME CCD camera has several filters built into the camera, however for my project, I only used three. These filters are the red filter, blue filter and green filter. Using the computer, one can change the filters and take different images. Later in this paper, I will address how to check to see if the computer correctly identifies the filter.
Chapter 3

Set Up

3.1 Set Up the Telescope

Before beginning any imaging, the telescope must be properly assembled. In his instruction guide, *Astrophography Using the Brigham Young University-Idaho Mak-Newt Telescope* (4), Cameron Jones explains the proper procedure to set up the telescope and its equipment. Users can find this guide at the BYU-Idaho’s Physics Department.

3.2 Set Up Technology

Researchers need to set up the telescope only once per season; however, the telescope and equipment require daily steps to prepare for imaging, namely connecting the computer to the telescope and the camera. In her thesis, Kayla Cameron wrote a detailed guide to the daily set up, which I have included here (5).
3.3 Daily Set Up

1) Carefully remove tarps from telescope.
2) Uncover lens and attach Dew Shield.
3) Connect telescope to the computer.
   a. Insert 9-Pin Keyspan cable into the bottom RS232 serial port on the GTD Control Pad.
   b. Insert USB end into the computer.
4) Attach CCD camera to the telescope
   a. Remove eyepiece cover and insert CCD camera into the eyepiece so handlebars are parallel to the body of the telescope.
   b. Screw into place as tightly as possible.
   c. Secure the CCD camera
   d. Move camera away from the telescope by using the course focus knob.
   e. Tie rope around the body of the telescope, looping each end around a handle and tying the knot.
5) Connect CCD to the power supply
   a. Thread power cable under securing harness on the body.
   b. Plug cable into power socket.
   c. Plug other end into computer.
6) Connect the CCD to the computer
   a. Threat USB cable under harness.
   b. Plug cable into USB socket.
   c. Plug other end into computer.
7) Connect the Astro-Physics hand controller to the GTD Control Pad.
8) Make sure the telescope is aligned properly.
   a. Place a level on the counter-weight shaft.
   b. If not level, unscrew at least two of the cross-shaped bolts just above the GTD Control Pad. Move until level.
   c. Place level on telescope body.
   d. If not level, unscrew at least two of the cross-shaped bolts near the base of the body restrains. Move until level.
9) Connect the telescope’s power supply
   a. Plug power supply cable into 12V connection.
   b. Screw end to secure.
   c. Flip switch on power box.
10) Calibrate Astro-Physics Hand Controller
    a. Input “1” where it asks for Location and press Go To.
    b. Select “Resume Ref-Park 1.”

The BYU-Idaho Observatory offers two programs to control the telescope, and one program to control the camera. These programs are TheSky6, CCDSoft, and CCDOps, respectively. An astronomer must learn to operate each of these programs in
order to make the telescope and the cameras cooperate together. First, one must begin with TheSky6.

### 3.4 Connecting the Telescope to TheSky6

1) Open TheSky6
2) Set the location of the telescope
   a. Data>>Location
   b. If this is the first time, click on the User-Defined tab, and fill in the appropriate coordinates.
   c. If the location has already been saved, under the Predefined List, click on the User-Defined Locations box, and click on the location previously defined. Currently, the Rexburg, ID tab will suffice.

![Figure 1: TheSky6 Location Panel](image1)

3) Set the time
   a. Data>>Time
      i. There is also a clock button on one of the tool bars which will set the time to the computer’s time
   b. Either manually set the time or set the time to the computer’s time.
4) Establish a link with the telescope
   a. Telescope>>Link>>Establish

![Figure 2: TheSky6 Establish Link](image2)
Now the telescope is ready to move. The programs CCDSoft and CCDOps control the camera. Ideally, the programs are equal, but I prefer to use both programs for different tasks. Future researchers may want to try using the program MaxIm DL to stack and combine images. Here are directions to connect the camera to both programs, however you can only connect one at a time.

### 3.5 Connecting the Camera to CCDSoft

1) Open CCDSoft Version 5  
2) Connect the camera to the software  
   a. Camera>>set up…  
   b. Click “connect” on the right side of the Camera Control panel.  
3) Cool down the camera  
   a. Click “temperature” on the right side of the panel.  
   b. Set the temperature to -5.00.  
      i. According to the CCDOps manual, “Cool the CCD well below the ambient temperature so that noise will be minimized (p 25).”(6)  
   c. Check the box by “Fan on.”  
   d. Click “ok.”

![Figure 3: CCDSoft Temperature](image)

4) Wait for the temperature to drop before imaging  
   a. The Camera Control panel monitors the temperature of the camera. Wait for the temperature to drop to about -5.00 before imaging.
3.6 Connecting the Camera to CCDOps

1) Open CCDOps
2) Turn on the camera
   a. Camera>>Establish COM link
      i. The status of the camera is at the bottom right of the screen.
3) Cool down the camera
   a. Camera>>Set up…
      i. Under Cooling, set the Temperature Regulation to Active.
      ii. Set the setpoint to -5.
      iii. Under General, set the Resure dark frames to Yes.
4) Wait for the temperature to drop
   a. Again, the status of the camera is at the bottom right of the screen.
Chapter 4

Taking Images

Now it’s time to sync the telescope and focus the camera. You need to sync to a star in order for the telescope to actually find stars. It is best to choose a bright star (magnitude of 2 or less) that is relatively close to the object you wish to observe. Ideally, you should be able to sync to two or three stars once each night, but we never found it to be that easy. Each time we slewed to an object that was relatively far from the current object, we needed to sync to a nearby star so the telescope knew where it was.

Typically, a user would use one program for the camera. However, as stated earlier, I prefer to switch between the two programs available. The focus tool in CCDSoft is ideal to use to sync and focus the telescope. I also sometimes use CCDSoft to take images, particularly flat field images. However, I like to use CCDOps to take and combine RBG images because of the easy access editing tools it contains.
4.1 Sync and Focus the Telescope Using CCDSoft

1) Open the focus tools
   a. Camera>>Set up…
   b. Click on the “Focus Tools” tab on the Camera Control panel.
2) Under Focus Tools, set the seconds to 1 or 0.5

![Figure 6: CCDSoft Camera Control, Focus Tools]

3) Click Take Image (not the tab, the box under Focus Tools)
   a. This will continually take images that will appear on the screen. However, these images are never saved.
4) Use TheSky6 to locate a star with which to sync the telescope
   a. This star should be fairly bright and should be near the object you wish to image. Often times we used stars such as Vega, Deneb, and Altair.
5) Locate the binoculars on the tool bar. Clicking on this will open the Find panel.
6) At the bottom, type in the name or the coordinates of the star. Then click “Find.”
   a. You can also click on the object on the star map on the screen rather than typing in the name.

![Figure 7: TheSky6 Find Tool]
7) Once TheSky6 has found the star (or another celestial object), and it’s a star that
TheSky6 can identify, the Object Information panel should take place of the Find
panel.
   a. This panel gives a lot of information about the object, such as its name, its
      magnitude, its type of object, as well as many other pieces of information.
8) Slew to this star by clicking on the icon on the bottom of the panel that looks like
   a telescope.
   a. If you place the mouse over this button, the word “slew” will appear.
   b. Another panel will appear that shows the telescope is slewing. There also is a
      button that aborts the telescope from slewing if a problem arises.
      i. Watch the telescope as it slews. It typically knows where the base of the
         telescope is. But if it seems to get too close to the base, abort slewing. The
         biggest danger with slewing is the cords. Watch the cords and move them
         out of the way if the telescope is slewing. If there is a problem, then abort.

Figure 8: TheSky6 Object Information General

9) Use the finder scope and the control pad to bring the star onto the screen
   a. Since the telescope has not yet been synced, it is very unlikely that the star
      will appear on the computer screen. This is why you must use the finder
      scope and the control pad. The finder scope is often times inaccurate and
      constantly requires alignment with the telescope. However, when it does
      work, it is very useful.
10) Use the control pad to center the star on the screen
    a. By clicking “6,” crosshairs will appear on the screen, which can help you
       guide the star to the center of the screen.
11) On the Object Information panel, click on the Telescope tab.
12) Under the Startup box, click Sync
13) Use the two knobs on the telescope to focus the telescope
    a. We found the best way to do this is to turn the computer screen towards the
       telescope. Then, the person at the telescope can focus and look back at the
       screen to see if the image is becoming more clear or not. Recognize that there
       is a delay between what the camera sees and what appears on the screen.
14) On CCDSoft, on the Camera Control Panel under the Focus Tools tab, click “Abort,” which is the button underneath “Take Image.”

![Object Information in TheSky6](image)

**Figure 9: TheSky6 Object Information, Telescope**

Now the telescope is ready for imaging. Find an object to image the same way you find a star with which to sync the telescope. I will explain how to take images in CCDSoft, and then in CCDOps.

### 4.2 Taking Images in CCDSoft

1) Camera Control>>Take Image
   a. Under Exposure, set the exposure time.
   b. Under Series, select the number of images you wish to take
   c. Under Filter, choose the filter you wish to use
      i. A user must manually change the filter in this program.
   d. Under Image, make sure the Filter says “Light.”
      i. If you are taking a dark frame, you want this part to actually say “Dark.” If you are taking a flat field frame, this should say “Flat.” If you are taking biased frames, this should say “Biased.”
2) Camera Control>> AutoSave
   a. Change the file name.
      i. Recognize that the series of images you take will have the same name, just different numbers. So be detailed in your name.
   b. Change the file location.
   c. Click the “Auto Save on” box.
   d. Under Save As, make sure FITS is checked.
3) Camera Control>> Take Image
   a. Click on the Take Series button

4.3 Taking Images in CCDOps

1) Camera>> grab
   a. Set the exposure time in units of seconds.
   b. Set Dark Frame to Also.
      i. This will take dark frames along with your light frames
   c. Under Special Processing, click on Color Grab.
      i. This will automatically take images for all three filters.
   d. Click OK.
2) The Color Grab Setup panel should appear
   a. Click on “Set Name/Dir..” to change the location of where the images are being saved as well as the name of the images.
      i. Each image will be saved as a .r, .b, and .g file for the red, blue, and green filter images respectively. They will each have the same name, but can still be distinguished.
   b. Click OK.
Chapter 5

Noise Reduction

Seeing that an image from a CCD camera is simply a photon count, it is plausible that there would be a significant amount of noise. This noise can be classified into several categories. Using flat field frames, biased frames, and dark frames, one can try to overcome the noise no matter the origin.

5.1 Flat Field Frames

The first kind of noise comes from physical conditions of the equipment. Because of the environment, telescope lenses as well as the camera filters sometimes get dust on them. These can cause doughnut shaped smears in the images. To counteract this, one must take flat field frames. This is arguably the most difficult noise-reducing frame to take. My colleagues and I experimented with two different methods of taking flat fields.

The first method is to take images of the sky at sunset. As the sun sets, take images of the sky starting closer to the Zenith than the horizon. Make sure the photon
count is half or less of its maximum. You can check this by looking at the lower right corner of the image produced. Also, make sure that under Camera Control>>Take Image>>Filter in CCDSoft, the option “Flat” is selected. Take as many 10-15 second exposures as possible (our average was about 16), moving the telescope slightly more towards the horizon with each exposure to avoid appearing stars. Later, in the editing section, I will explain how to combine them into a master flat and then how to apply the master flat to the image.

The problem with this technique is that the astronomer only has one chance during the night to take flat fields. Also, if an astronomer wants to take colored images, he must take flat fields using each filter. This is not always possible because the sun sets quickly.

The second technique my colleagues and I attempted does not have the time restraint of the first technique. However, this way is not always successful. For this technique, anytime after the sun has completely set, stretch a white t-shirt over the front of the telescope. We bounded the t-shirt using bungee cords. Next, secure a few pieces of wax paper over a white flashlight. Shine the flashlight onto the t-shirt and take images as described in the first technique. However, as you take these images, watch the screen. You may need to move where the flashlight is shining. We sometimes experienced giant light doughnuts or grainy pictures. This method was sometimes successful, but not always. It may be a good idea to try both techniques each night to get decent flat field frames.
Since this research, the BYU-Idaho Physics department has purchased an Aurora Flat Field foil, a professional tool used to easily take flat field images any time of night, and without a t-shirt. This tool uses electroluminescence to take flat field images. However, it has not yet been tested on the telescope. Future students can take the opportunity to test and use this tool in their work.

5.2 Bias Images

Biased images are images taken with the shutter closed for zero seconds. It factors out underlying noise. In CCDSoft, take them the same way you take regular pictures, but this time, under Camera Control>>Take Image>>Filter, be sure bias is selected. Take around ten of these to combine later for a master bias. I was unable to take this kind of image in CCDOps.
5.3 Dark Frames

Another kind of noise comes from thermal noise and hot pixels in the camera, or pixels that have a higher than average electron count. To account for this, photographers take dark exposures. A dark exposure is taken with the shutter closed. It should be the same length of exposure as the image you are taking. Take a dark exposure right before or after the images. In CCDOps, the program automatically takes the dark frames and subtracts them if you have that option selected. In CCDSoft, take them the same way you take regular pictures, but this time, under Camera Control>>Take Image>>Filter, sure dark is selected.

5.4 Combining and Applying Flats, Biases, and Darks

1) Open CCDOps
2) To make masters
   a. Utility>>Average Images…
      i. Use this to create a master flat or a master bias. You can also use this to create a master dark if you took darks on CCDSoft.
      ii. Make sure that with the flats, you create a master red flat a master blue flat, and a master green flat.
      iii. Create a master flat using the same technique that includes all of the filters.
3) To apply the flats
   a. Utility>>Average Images…
      i. Find the master flat and follow the instructions to apply.
4) To apply the darks and biases
   a. Utility>>Dark Subtract…
      i. I often was not successful with using darks from CCDSoft. I also had troubles with biases as well. But, I found another technique to edit out hot pixels, which I will explain later.
Chapter 6

Combining and Editing

6.1 Combining .r, .g, and .b Images to Create the RGB Image

CCD cameras only take black and white images. The camera collects photons, and this photon count shows up on the computer screen, with the more photons being the brighter spots. In order to take color images, one must use filters to block out certain colors of the light and let only a range of wavelengths through.

When taking pictures with CCDOps, the .r file corresponds to the red filter, .b corresponds to the blue filter, and .g corresponds to the green filter. As of 2012, the filters are aligned correctly to the computer. However one may want to check this. To do so, open the CCDOps program and click on the filter tab at the top. Then, click on the different filters available and look into the camera with the cap off. Looking at the light reflected by the filters, not the light passing through the filters, one notices that the green filter looks magenta, the red filter looks turquoise, and the blue filter looks yellow orange. When I was checking this, I noticed there was a lunar filter. It’s a reddish color. I did not experiment with it, but a future student can consider using this.
The images that come from each filter appear as black and white images. The computer takes these images and assigns a color to it. The user must tell the computer which color to assign which image.

![Image of M27 through different filters](image)

**Figure 15**: M27 through the red filter, green filter, blue filter and then combined

### 6.2 Combining RBG and a Few Tricks

1) Open CCDOPs  
   a. Utility>>RGB Combine…  
      i. In the RGB Combine panel, click on Set Name at the top.  
         1. Find the corresponding red, green, and blue files.  
         2. If the files are in the same folder and are .r, .g, and .b files, setting one name will actually set all three of them.  
         3. If the files are not .r, .g, and .b, then click the arrow by Files of types, and choose All Files (".").  
      ii. Click Do It
1. An image should appear on the screen with red, blue, and green components. Notice that these are not aligned correctly.

iii. Align the images
   1. Next to the three Set Name buttons, type in numbers to move each image horizontally and vertically. This is kind of a guess and check game.
   2. Use the cross hairs to better align the image
      a. Display>>Show crosshair
iv. Change the factor of each color
   1. If you know how to which color the telescope is most sensitive, you can change the factors of the colors under the boxes on the right. If you don’t know, then just keep the boxes at 1.00.

v. When you have aligned the picture completely, save it with a new name.

Besides combining images and reducing noise, CCDOps also has a few capabilities to further edit the material. Determining which techniques to use will depend on the image. In CCDOps, go to Utility>>Filter Utilities… for a few editing techniques.
The options that I frequently used include Smooth, Sharpen, DDP, Remove Cool Pixels, and Kill Warm Pixels. A user, however, must experiment with the options to reach maximum picture value.
Chapter 7

At the End of the Day… Well, the Night

Because the BYU-Idaho Observatory has such nice equipment, it is important to treat it with care, especially when closing up for the night. It’s easy to want to rush putting things away because of fatigue. But, in order to keep the equipment operational for future students, one must take care and clean up.

7.1 Shutting Down

1) Shut down the telescope
   a. Using the hand pad, move the telescope as best as you can to park position.
   b. On TheSky6
      i. Telescope>>Link>>Terminate
      ii. If it asks if it should slew the telescope to someplace, say no.

2) Shut down the camera
   a. For CCDSoft
      i. Camera Control>>Setup>>Temperature
         1. Check the box by “Fan on.”
         2. Click “ok.”
      ii. Allow the camera to warm up to past 0, then click Disconnect
         1. Check the box by “Fan on.”
         2. Click “ok.”
   b. For CCDOps
i. Camera>>Set up…
   1. Under Cooling, deactivate the Temperature Regulation.
   2. Allow the camera to warm up to past 9

ii. Camera>>Shut Down
3) Carefully disconnect all of the cords and safely wrap them up.
4) Disconnect the camera, place the cap on the camera, and place the camera back in its box.
5) Take off the finder scope.
6) Take off the dew shield.
7) Secure the telescope shield onto the end of the telescope.
8) Secure the canvas tarp over the telescope.
9) Secure the blue tarp over the canvas and telescope using bungee cords to tie it down.
10) In light of the recent dome, make sure the dome is locked up and the key is safely on the desk or a designated location for the key.
Chapter 8

Problems with Observing

8.1 Weather

Unlike other types of scientists, astronomers are sometimes limited to when they can observe. Weather plays a huge role in the success of observing. We generally had good weather. However, a few times we had to cancel observing due to thunderstorms or unexpected cloud coverage. We also had to deal with the smoke from a local brush fire for a few nights. These limitations made it crucial for us to observe on clear nights.

8.2 Autoguide

The earth rotates as the night progresses, which changes the view in the telescope. This isn’t a problem for short exposures, such as 30 seconds, or even up to 90 seconds. But as the time beings to approach 160 seconds, the images become elongated and blurry. This poses a problem for fainter images, such as galaxies and faint nebulae.
Computerized telescopes often have autoguiding feature to compensate for the earth’s rotation. Our telescope includes these features. However, we could not get them to operate. We spent many nights trying to figure out the problem using CCDOps and CCDSoft. However, we could never get it to work properly. We were stuck with 90-second exposures at best. This was not always adequate for maximum quality pictures.

8.3 Atmosphere

Observing is not always an easy task. Many problems arise which an astronomer must learn to overcome. First, he must realize that the atmosphere naturally distorts light. The best way to compensate for this is to choose objects closer to the Zenith and farther away from the horizon. This reduces the amount of atmosphere between the telescope and the object.

Besides the regular problem of the atmosphere, the sky is not always clear—clouds, dust, and even smoke can hinder imaging. During one of the weeks of our project, a brush fire broke out several miles east of the observatory. It was far enough that we couldn’t see the flame, but it was close enough for the smoke to hinder our observing. Astronomers must be ready and flexible to accommodate for such occasions.
Chapter 9

Future research

9.1 True Color Imaging

As the light from distant stars and galaxies travel through the atmosphere to reach telescopes, some of the light is bent, absorbed, or refracted. This changes the appearance of heavenly objects. Furthermore, the way the software combines the three images may be more favorable for one color and cheat another. So, the question stands: how can one achieve true color imaging?

A few techniques exist to check the color quality of a camera. One of the most favorable ways involves a G2 star. Our sun is a G2V star. Finding one of such stars in the sky will produce the same spectrum of light as our sun. If a student wishes to check the true color quality of a camera, one can locate a G2 star and take several exposures of this star with the various filters. Using these images, and possibly a combination of them, the student can find the proper ratio between the filters to achieve more appropriate color imaging. However, the angle at which the telescope is pointing away from the Zenith
will actually change the color ratio of image. At locations closer to the horizon, the starlight must get through more atmosphere, causing even more bending and refraction of the light. This is left open to future research.

9.2 LRGB Techniques

Besides the techniques described earlier, astrophotographers have other tricks to achieve even better images. One of such tricks is called the LRGB technique, which stands for luminance, red, green, and blue. A photographer must use the same technique described above, but he also must take a clear filter image for the same amount of time. Then, he somehow combines this with the color image to bring out more detail. One possible project might be to research this technique and determine its usefulness with the telescope (7).

9.3 DSLR Cameras

BYU-Idaho only owns a CCD camera for the observatory. However, there are other camera options available. A very common camera other than the CCD camera is the DSLR camera. This is a digital camera and does not require the combination of the .r, .b, and .g frames to create a colored image. On the contrary, the digital camera does all of this automatically, and less work is required of the user. If the school was to purchase a DSLR camera in the future, or if a student owned a personal DSLR camera, he or she could use the telescope for astrophotography. However, the camera may require an adapter to attach the DSLR camera to the telescope. Other DSLR cameras used in the past have required adaptors for the various telescopes at the observatory.
9.4 Autofocus

As each night progressed, the temperature dropped. Change in temperature causes the telescope to physically lengthen or contract, changing the length of our instrument. This disrupts the focus of our images. For this reason, we had to readjust the focus occasionally throughout the night. This becomes problematic for astrophotography if one forgets to change the focus periodically. Some companies have produced autofocusing tools for telescopes. The BYU-Idaho observatory purchased an autofocusing tool. A possible research opportunity would be to install this and learn how to use it with BYU-Idaho’s telescope.

9.5 Autoguide

Seeing that autoguide is essential to long exposures, it may be beneficial to try to fix it. One possibility is that the telescope was not properly polar aligned. Polar alignment is essential for the telescope to keep track of the earth’s movement. In the CCDOps manual, the first few steps included polar alignment. Perhaps a future research project would include polar aligning the telescope and exploring the autoguide feature. This would greatly benefit the BYU-Idaho observatory.

9.6 24” Telescope

The BYU-Idaho observatory has more than just the 10” telescope available to students. In fact, the observatory was first built to house a 24” telescope. However, over
the years, the technology used to maneuver this telescope as well as the knowledge to run
the telescope have been lost through the rotation of professors. Marianne Kackstaetter,
Brad Keller, and I have created a program in LabView that allows users to more easily
run the telescope for observatory. However, there is still more work to be done. If
interested, a student can find out more information by reading Marianne’s thesis located
in the BYU-Idaho physics department.
Bibliography


Appendix A

This appendix contains several successful pictures I imaged and edited using the equipment at the BYU-Idaho observatory. With each image, I include the name of the object, the camera software, and the exposure time.

Figure 20: M13 CCDSoft 60 seconds
Figure 21: NCG 7000 CCDOps 60 seconds

Figure 22: M81 CCDSof 60 seconds
Figure 23: M27 CCDSoft 60 seconds
Appendix B

Daily Set Up

1) Carefully remove tarps from telescope.
2) Uncover lens and attach Dew Shield.
3) Connect telescope to the computer.
   a. Insert 9-Pin Keyspan cable into the bottom RS232 serial port on the GTD Control Pad.
   b. Insert USB end into the computer.
4) Attach CCD camera to the telescope
   a. Remove eyepiece cover and insert CCD camera into the eyepiece so handlebars are parallel to the body of the telescope.
   b. Screw into place as tightly as possible.
   c. Secure the CCD camera
   d. Move camera away from the telescope by using the course focus knob.
   e. Tie rope around the body of the telescope, looping each end around a handle and tying the knot.
5) Connect CCD to the power supply
   a. Thread power cable under securing harness on the body.
   b. Plug cable into power socket.
   c. Plug other end into computer.
6) Connect the CCD to the computer
   a. Thread USB cable under harness.
   b. Plug cable into USB socket.
   c. Plug other end into computer.
7) Connect the Astro-Physics hand controller to the GTD Control Pad.
8) Make sure the telescope is aligned properly.
   a. Place a level on the counter-weight shaft.
   b. If not level, unscrew at least two of the cross-shaped bolts just above the GTD Control Pad. Move until level.
   c. Place level on telescope body.
d. If not level, unscrew at least two of the cross-shaped bolts near the base of the body restrains. Move until level.

9) Connect the telescope’s power supply
   a. Plug power supply cable into 12V connection.
   b. Screw end to secure.
   c. Flip switch on power box.

10) Calibrate Astro-Physics Hand Controller
    a. Input “1” where it asks for Location and press Go To.
    b. Select “Resume Ref-Park 1.”

Connecting the Telescope

1) Open TheSky6
2) Set the location of the telescope
   a. Data>>Location
   b. If this is the first time, click on the User-Defined tab, and fill in the appropriate coordinates.
   c. If the location has already been saved, under the Predefined List, click on the User-Defined Locations box, and click on the location previously defined. Currently, the Rexburg, ID tab will suffice.

3) Set the time
   a. Data>>Time
      i. There is also a clock button on one of the tool bars which will set the time to the computer’s time
   b. Either manually set the time or set the time to the computer’s time.

4) Establish a link with the telescope
   a. Telescope>>Link>>Establish

Connecting the Camera to CCDSoft

1) Open CCDSoft Version 5
2) Connect the camera to the software
   c. Camera>>set up…
   d. Click “connect” on the right side of the Camera Control panel.
3) Cool down the camera
   a. Click “temperature” on the right side of the panel.
   b. Set the temperature to -5.00.
      i. According to the CCDOps manual, “Cool the CCD well below the ambient temperature so that noise will be minimized (p 25).” (6)
   c. Check the box by “Fan on.”
   d. Click “ok.”
4) Wait for the temperature to drop before imaging
   a. The Camera Control panel monitors the temperature of the camera. Wait for the temperature to drop to about -5.00 before imaging.
Connecting the Camera to CCDOps

1) Open CCDOps
2) Turn on the camera
   a. Camera>>Establish COM link
      i. The status of the camera is at the bottom right of the screen.
3) Cool down the camera
   a. Camera>>Set up…
      i. Under Cooling, set the Temperature Regulation to Active.
      ii. Set the setpoint to -5.
      iii. Under General, set the Resure dark frames to Yes.
4) Wait for the temperature to drop
   a. Again, the status of the camera is at the bottom right of the screen.

Sync and Focus the Telescope Using CCDSoft

1) Open the focus tools
   a. Camera>>Set up…
   b. Click on the “Focus Tools” tab on the Camera Control panel.
2) Under Focus Tools, set the seconds to 1 or 0.5
3) Click Take Image (not the tab, the box under Focus Tools)
   a. This will continually take images that will appear on the screen. However, these images are never saved.
4) Use TheSky6 to locate a star with which to sync the telescope
   a. This star should be fairly bright and should be near the object you wish to image. Often times we used stars such as Vega, Deneb, and Altair.
5) Locate the binoculars on the tool bar. Clicking on this will open the Find panel.
6) At the bottom, type in the name or the coordinates of the star. Then click “Find.”
   a. You can also click on the object on the star map on the screen rather than typing in the name.
7) Once TheSky6 has found the star (or another celestial object), and it’s an star that TheSky6 can identify, the Object Information panel should take place of the Find panel.
   a. This panel gives a lot of information about the object, such as it’s name, it’s magnitude, it’s type of object, as well as many other pieces of information.
8) Slew to this star by clicking on the icon on the bottom of the panel that looks like a telescope.
   a. If you place the mouse over this button, the word “slew” will appear.
   b. Another panel will appear that shows the telescope is slewing. There also is a button that aborts the telescope from slewing if a problem arises.
      i. Watch the telescope as it slews. It typically knows where the base of the telescope is. But if it seems to get too close to the base, abort slewing. The biggest danger with slewing is the cords.
Watch the cords and move them out of the way if the telescope is slewing. If there is a problem, then abort.

9) Use the finder scope and the control pad to bring the star onto the screen
   a. Since the telescope has not yet been synced, it is very unlikely that the star will appear on the computer screen. This is why you must use the finder scope and the control pad. The finder scope is often times inaccurate and constantly requires alignment with the telescope. However, when it does work, it is very useful.

10) Use the control pad to center the star on the screen
    a. By clicking “6,” crosshairs will appear on the screen, which can help you guide the star to the center of the screen.

11) On the Object Information panel, click on the Telescope tab.

12) Under the Startup box, click Sync

13) Use the two knobs on the telescope to focus the telescope
    a. We found the best way to do this is to turn the computer screen towards the telescope. Then, the person at the telescope can focus and look back at the screen to see if the image is becoming more clear or not. Recognize that there is a delay between what the camera sees and what appears on the screen.

14) On CCDSoft, on the Camera Control Panel under the Focus Tools tab, click “Abort,” which is the button underneath “Take Image.”

**Taking Images in CCDSoft**

1) Camera Control>>Take Image
   b. Under Exposure, set the exposure time.
   c. Under Series, select the number of images you wish to take
   d. Under Filter, choose the filter you wish to use
      i. A user must manually change the filter in this program.
   e. Under Image, make sure the Filter says “Light.”
      i. If you are taking a dark frame, you want this part to actually say “Dark.” If you are taking a flat field frame, this should say “Flat.”
      If you are taking biased frames, this should say “Biased.”

2) Camera Control>> AutoSave
   f. Change the file name.
      i. Recognize that the series of images you take will have the same name, just different numbers. So be detailed in your name.
   g. Change the file location.
   h. Click the “Auto Save on” box.
   i. Under Save As, make sure FITS is checked.

3) Camera Control>> Take Image
   j. Click on the Take Series button
Taking Images in CCDOps

1) Camera>> grab
   a. Set the exposure time in units of seconds.
   b. Set Dark Frame to Also.
      i. This will take dark frames along with your light frames
   c. Under Special Processing, click on Color Grab.
      i. This will automatically take images for all three filters.
   d. Click OK.
2) The Color Grab Setup panel should appear
   a. Click on “Set Name/Dir..” to change the location of where the images are
      being saved as well as the name of the images.
      i. Each image will be saved as a .r, .b, and .g file for the red, blue,
         and green filter images respectively. They will each have the same
         name, but can still be distinguished.
   b. Click OK.

Combining and Applying Flats, Biases, and Darks

1) Open CCDOps
2) To make masters
   a. Utility>>Average Images…
      i. Use this to create a master flat or a master bias. You can also use
         this to create a master dark if you took darks on CCDSoft.
      ii. Make sure that with the flats, you create a master red flat, a master
           blue flat, and a master green flat.
      iii. Create a master flat using the same technique that includes all of
           the filters.
3) To apply the flats
   a. Utility>>Average Images…
      i. Find the master flat and follow the instructions to apply.
4) To apply the darks and biases
   a. Utility>>Dark Subtract…
      i. I often was not successful with using darks from CCDSoft. Also, I
         had troubles with biases as well. But, I found another technique to
         edit out hot pixels, which I will explain later.

Combining RBG and a Few Tricks

1) Open CCDOPs
   b. Utility>>RGB Combine…
      i. In the RGB Combine panel, click on Set Name at the top.
         1. Find the corresponding red, green, and blue files.
         2. If the files are in the same folder and are .r, .g, and .b files,
            setting one name will actually set all three of them.
3. If the files are not .r, .g, and .b, then click the arrow by Files of types, and choose All Files (".").

ii. Click Do It
1. An image should appear on the screen with red, blue, and green components. Notice that these are not aligned correctly.

iii. Align the images
1. Next to the three Set Name buttons, type in numbers to move each image horizontally and vertically. This is kind of a guess and check game.
2. Use the cross hairs to better align the image
   a. Display>>Show crosshair

iv. Change the factor of each color
1. If you know how to which color the telescope is most sensitive, you can change the factors of the colors under the boxes on the right. If you don’t know, then just keep the boxes at 1.00.

v. When you have aligned the picture completely, save it with a new name.

**Shutting Down**

1) Shut down the telescope
   c. Using the hand pad, move the telescope as best as you can to park position.
   d. On TheSky6
      i. Telescope>>Link>>Terminate

2) Shut down the camera
   a. For CCDSoft
      i. Camera Control>>Setup>>Temperature
         1. Check the box by “Fan on.”
         2. Click “ok.”
      ii. Allow the camera to warm up to past 0, then click Disconnect
         1. Check the box by “Fan on.”
         2. Click “ok.”
   b. For CCDOps
      i. Camera>>Set up…
         1. Under Cooling, deactivate the Temperature Regulation.
         2. Allow the camera to warm up to past 9
      ii. Camera>>Shut Down

3) Carefully disconnect all of the cords and safely wrap them up.
4) Disconnect the camera, place the cap on the camera, and place the camera back in its box.
5) Take off the finder scope.
6) Take off the dew shield.
7) Secure the telescope shield onto the end of the telescope.
8) Secure the canvas tarp over the telescope.
9) Secure the blue tarp over the canvas and telescope using bungee cords to tie it down.
10) In light of the recent dome, make sure the dome is locked up and the key is safely on the desk or a designated location for the key.