Virtual Astronomical Observation and Development of a Telescope/Computer Interface

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Acknowledgements

Contents

Abstract

Direct astronomical observation is often limited due to available equipment or time. With technological advances conventional astronomical observation is becoming obsolete and computerized systems are gradually becoming the norm, even among amateur astronomers. This project focused on bridging the technological gap between conventional astronomy and the more advanced systems that are becoming commonplace. A website was constructed to store the information gathered by an eyepiece camera mounted onto a 14" Celestron Schmidt-Cassegrain telescope. It was intended that developing this system could lead to its use by other students who, after brief instruction, would be able to conduct their own personal astronomical exploration. The applications of this link pave an exciting path towards integrating advancing technology with the curiosity about the cosmos inherent in all of us.

1   Introduction

Astronomy is one of the most interesting aspects of the physical sciences in that it has a vast following of individuals that may or may not be directly involved with science in their professional lives. One would imagine that it would be somewhat rare to find a mortgage broker who dabbles in theoretical QCD in her spare time or an elementary school English teacher who studies solid state NMR spectroscopy in his basement. However, there are many backyard astronomers and sky watchers as well as magazines and journals dedicated to the amateur observer. There is something fascinating about what lies beyond our planet and taking a first hand look can be an exhilarating experience. However, our eyes are not nearly as capable of scientific study as are computers with the capacity to calculate, recall, analyze, and record. For this reason, professional astronomical study almost never entails looking through an eyepiece. Amateur astronomy is now beginning to adopt some of the same technological advances that have been used by the scientific community.

In this project I aimed to create a platform that would allow individuals without telescopes of their own to experience the endless possibilities of an observatory. I constructed a systematic method of operation to be used by approved and instructed physics students to conduct and organize their own observational experiences in astronomy.

Using the Thomas Harriot Observatory based on the roof of Small Hall I developed a website to connect the images taken through the telescope with those who would not generally have access to such equipment. This project laid the foundation for developing a system of video live-feed of images captured through the camera and uploaded automatically to the website. I have written a brief instruction manual (see Appendix A) for linking the camera to the telescope as well as the most basic instructions for taking photos and storing them online. It is hoped that this could allow students that are approved by the department to use the system on nights that it is available. By giving these individuals more freedom to explore the cosmos as they wish, as well as be able to document their explorations via CCD images, it could further the interest in astronomy and make the Thomas Harriot Observatory a point of interest for the physics department again.

2   The Equipment and Setup

Two of the most important aspects of this project are the equipment and the way in which it is integrated. Understanding how these two things work is without a doubt the very first step in understanding this project.

2.1   The Telescope

The primary component of this project was the telescope. In this project two telescopes were used. The first was a 10" Meade LX200GPS Schmidt-Cassegrain. The second was the 14" Celestron Schmidt-Cassegrain telescope of the Thomas Harriot Observatory.

The Meade 10" LX200GPS provided motor controlled slewing and focusing. Though it has a rather large optical tube assembly and is quite heavy, it is still a portable scope and it could be assembled and disassembled within a matter of minutes. Unfortunately, due to an unforeseeable problem, this telescope was not used during the latter part of the project.

The 14" Celestron of the T.H.O. added another level of technological sophistication with its preloaded GPS based guidance and tracking system. Once this telescope was calibrated properly it could be programmed to pinpoint any object in the night sky and compensate for the rotation of the earth by automatically using the motors to track the object throughout the night. This provided the user with the chance to take longer exposures with the camera and thus produce clearer results.

The Schmidt-Cassegrain design of these telescopes is a reflection design that uses two mirror systems to provide a high precision image. See Figure 1.
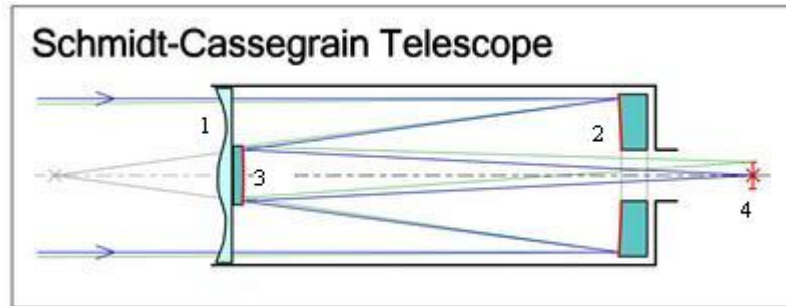
Figure 1: Schmidt-Cassegrain Design [1]

The light enters the optical tube through the Schmidt corrector plate (labeled as 1) at the front of the scope. The Schmidt corrector plate is necessary on telescopes with a spherical primary mirror (as the Schmidt-Cassegrain design does.) It is a lens that compensates for light being reflected at the edge of the mirror and focuses it at the same point as the light that is reflected from the more central regions of the primary mirror. [2]

Light from the corrector plate is reflected off the primary mirror located in the back of the tube (2). This spherical mirror reflects the light to a convex secondary mirror (3) located on the back of the corrector plate at the front of the scope. This finally reflects the light through a hole in the primary mirror and directs it to the eyepiece (4).

It should be clear from the diagram that the light travels a much longer path than simply from the front of the tube to the eyepiece (as is the case for a refracting telescope for example.) In this case light is making a trip through the tube a total of three times before exiting through the eyepiece. With this design the telescope has a very long focal length but a relatively short tube. This allows for a larger aperture and thus more light gathering within a reasonably sized and priced telescope.

2.2   The Imaging Package

Meade makes imaging packages that are designed to work with their telescopes. For this project Meade's Autostar Suite and Lunar Planetary Imager were used. This imaging package included some remarkable features such as the ability to track an object using an interface between the imaging package installed on the computer and the telescope's motor controlled tracking system. The package also included a catalog of tens of thousands of objects including: 7840 New General Catalog objects, 5386 Index Catalog objects, 110 Messier objects, 109 objects of the Caldwell Catalog, and thousands of uncategorized objects. The camera was completely controlled by the computer and offered a multitude of adjustments that could be made for imaging. A USB cable connected the camera directly to the computer and all of the controls were manipulated through the software.[3]

2.3   The Meade LPI Camera

The camera itself is a small CCD (charged coupled device) camera with that boasts a standard VGA 640x480 resolution. The LPI stands for Lunar Planetary Imager and is best suited for imaging within the solar system. The camera is simply an eyepiece camera that replaces the position of a standard eyepiece (See Figure 2.) It connects to the computer via a three foot USB cable. There are no manual controls for the camera. All commands and adjustments are made through the computer and the Meade Autostar control package.

Meade LPI imager

Figure 2: The Meade LPI camera.   In this photo the LPI has simply taken
the place of a standard eyepiece in the diagonal of this telescope. [4]

2.4   The Computer

For this project a Dell Latitude C540 laptop computer was used to control the camera and store the photos. With wireless networking the operator could research the objects of interest while observing and taking pictures.   Using additional software or another camera this could provide video imaging that could be uploaded directly to the internet and viewed remotely.

Since only a three foot cable was provided with the camera, having wireless capabilities as well as the convenience of a laptop allowed the freedom for the orientation of the workstation in whatever way seemed necessary for the orientation of the telescope at the time.

3   Controlling the Telescope

Before snapping a photo a few things needed to be done to ensure precision and accuracy. Since the Earth is obviously rotating, if one were to focus on a particular part of the night sky the objects within the field of view would appear to be moving in a westerly direction (however slow that may actually be.) As with any other type of photography, if one wants to take a photo of a moving object a high-speed film needs to be used. With an instantaneous snapshot the object does not have the chance to become fuzzy. The downside of this is that by taking an instantaneous snapshot very little light can be gathered by the camera and thus the object would not be as highly resolved. This would not pose a problem for a situation where *lots* of light was available. However, in the case of astronomical photography very *little* light is available. Therefore taking an instantaneous snapshot is not an option. As a matter of fact, deep-sky objects or fainter objects necessitate exposure times on the order of hours! Due to Earth's rotation, however, if one focused on a single spot in the sky, all of the objects of interest would have moved nearly halfway across the visible sky in a time scale of hours. Telescope makers understand this and have developed telescopes with the ability to track an object across the night sky and allow for longer exposure times, therefore greater light gathering, and therefore better photos.   The Celestron telescope of the Thomas Harriot Observatory has this capability but it would only work if the telescope was perfectly aligned and calibrated.

3.1   Telescope Calibration

The telescope's GPS based catalog and tracking system holds a substantial amount of information about the night sky. For all practical observation purposes, to the common sky watcher the stars that are visible from Earth remain fixed in their positions in relation to other stars. However, since Earth rotates, the night sky (regardless of how relatively static it is) moves constantly.   The computerized telescope is advanced enough that it can compensate for this effect by moving at exactly the same angular speed as Earth's rotation in order to maintain a constant field of view on an object or area of interest. In order for it to properly do this the user must input the GPS coordinates of the telescope as well as the date and time (in Greenwich Mean Time). If the telescope is properly aligned then the user can choose from thousands of stored objects to which the telescope can automatically slew or simply enter the coordinates of an object of interest.

 Aligning the telescope, however tedious, was a relatively simple procedure. By entering a command for the telescope to slew to a particular object and centering the object in the field of view the user could reassign that position of the scope to that object. By repeating this procedure for a number of reference objects the telescope could be aligned to a high degree of precision. Alignment could be maintained as long as the user used proper procedures when ending the session and was careful not to accidentally assign an object to an incorrect scope position.

3.2   Slewing to an Object of Interest

Because of the vast amount of information stored in the telescope's computer guidance system, most visible objects could be accessed by simply entering a reference number (whether it be New General Catalog, Index Catalog, Messier objects or Caldwell Catalog.) The telescope in the Thomas Harriot Observatory also has its own list of about 100 Reference objects that are commonly sought in the night sky (stars such as Betelgeuse, Sirius, Rigel, Alberio, etc.) If the scope was aligned then all of these could be accessed by simply punching in a code and the object of interest would appear in the center of the eyepiece. For taking pictures this features proved to be extremely useful because the user was not required to remove the camera in order to find the next object.

4   Creating an Image

Obviously, in order to make a meaningful representation of what the telescope sees, one has to understand a bit about the camera and its software. It is necessary to understand the controls of the camera as well as how to manipulate and combine photos in order to do with them what is desired.

4.1   Controlling the Camera

The software controls for the LPI camera were very easy to use and applying the appropriate settings (such as shutter speed, gain, offset, Region-Of-Interest, type of frame, etc.) was simplified by built in automatic adjustments. If this option was selected the software would analyze the light entering the CCD for background light, brightness, movement, etc. and adjustments would be made to the camera accordingly. Once appropriate settings were selected taking a photo was very simple. The user would press "Start" and the camera would begin taking photos and compiling them automatically. If different camera settings were desired adjustments could be made manually by the user. Each photo as well as the final compilation were saved on the hard drive of the Dell laptop computer to be accessed and archived later. The option can be selected not to have every photo saved on the hard drive. However, when the Autostar suite combines them to make the best final picture it will automatically select the best specimens to overlay. Therefore, it was chosen to have all individual photos saved on the computer.

It was suggested that 50 was the most efficient number of photos to be taken for the software to compile a reasonable picture. However, in low light conditions 50 photos might have taken hours and unless the telescope was perfectly aligned the object could have drifted out of the field of view during that time. Since the telescope was not used exclusively for this project perfect alignment was rarely seen and thus taking long exposure photos was generally not an option due to time constraints.

4.2   Making a Composite

One of the great features of the Meade camera system is that it automatically combines the images that it takes as it takes them. Whenever the user tells the camera to start taking pictures it automatically begins to select the best ones and combines them automatically. However, if a portion of the sky is desired that is broader than the field of view of the camera the photos need to

be pieced together by combining images based on common physical features seen in the images to be combined (See Figure 3.)
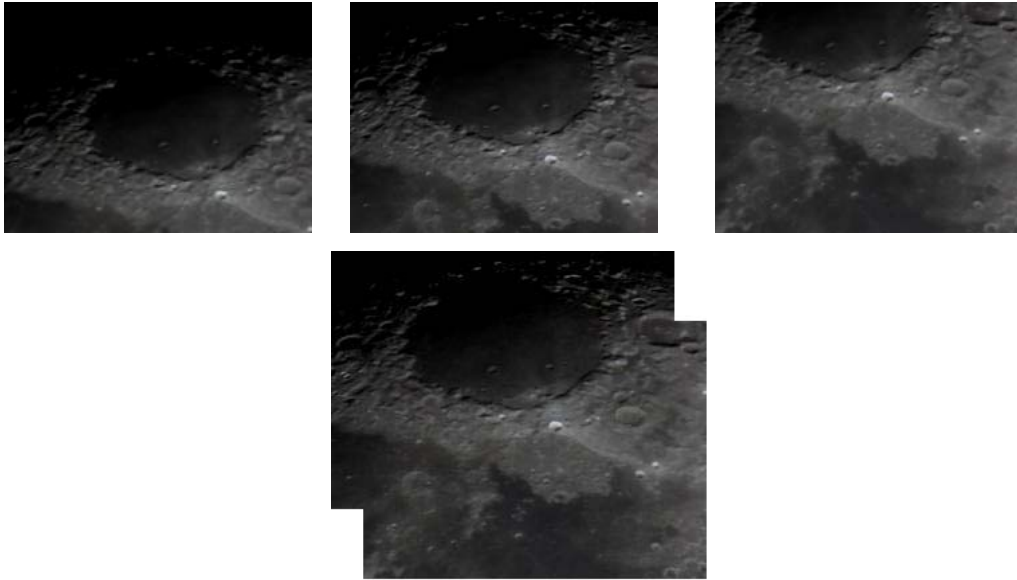

Figure 3: Moon Composite 1, Here I combined three photos to make one image
that displays a larger area than a single photo by itself. This type of composite
was used to create the larger composite of the moon shown in Figure 4.

This is an interesting way to present the photos. Using the Microsoft program Paint I was able to combine images to make composites of the moon, for example (see Figure 3 above.) Essentially I took the paint program and shrunk the raw photos to a more manageable size and lined up the identifiable physical characteristics of each photo in order to make an image of a much larger area of the moon. This was used in the larger moon composite of Figure 4.
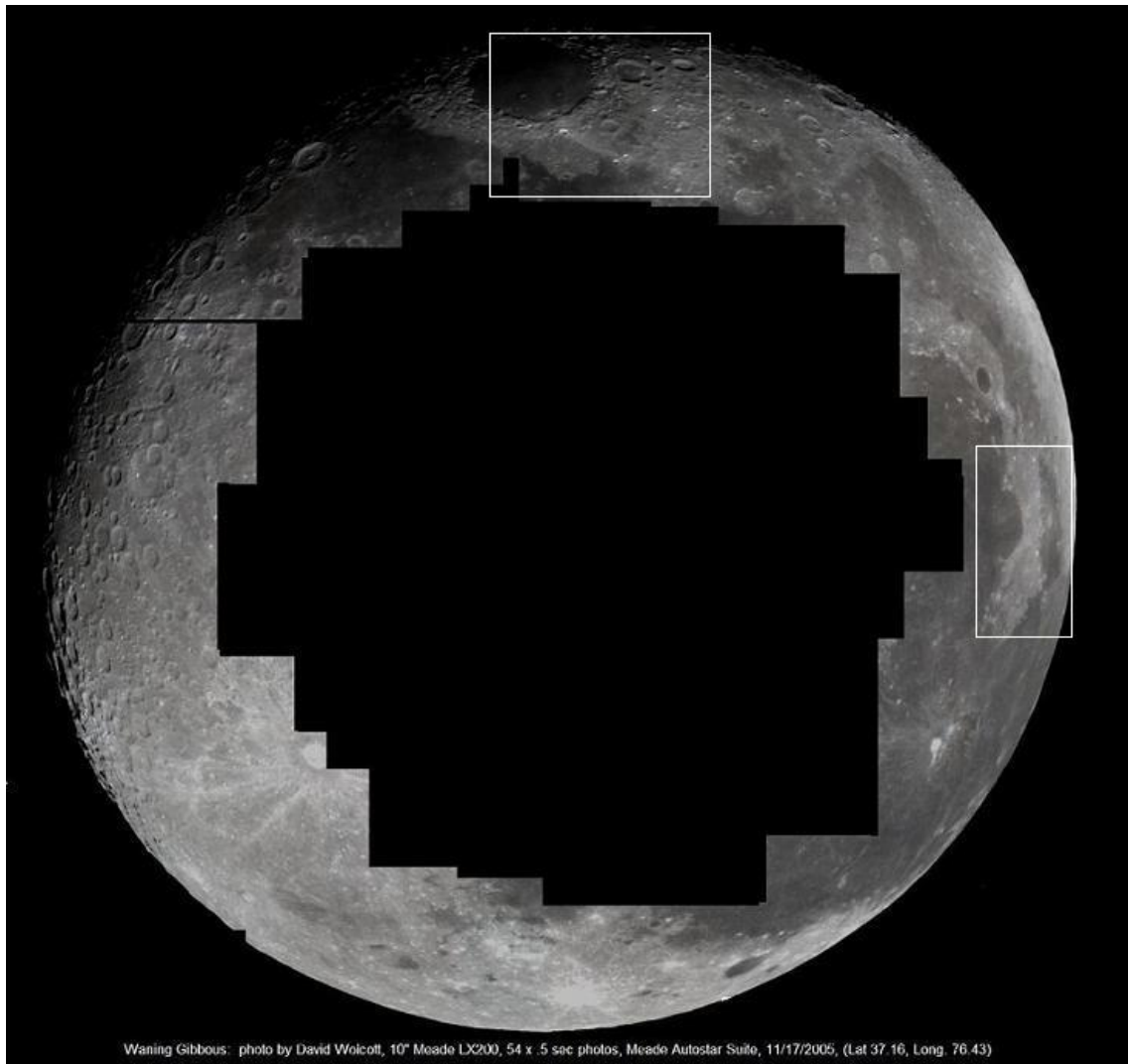
Figure 4: Moon Composite. This image was created by combining 54 separate photos of the moon and pieced together using Microsoft Paint. With each photo the common physical characteristics seen in the individual photos were aligned in such a way that the resulting photo encompassed the entire area of the moon.

One possible application to this would be to have a full composite of the surface of the moon with links to the individual photos. The individual photos would not be compressed in size and would thus provide a more detailed image than the ones used for the composite. This would essentially provide an option of "Zooming In" to a particular area of the moon. If so desired, one could research some of the obvious visible physical characteristics of the surface of the moon and perhaps have detailed photos such as the ones in Figure 3. (For example, the white boxes of Figure 4 represent areas in which a composite was created detailing that section of the moon as in Figure 5.)

Figure 5: Crater Proclus and Details. Using the method of combining photos (as in Figure 3) I created a detailed composite of one section of the moon. By creating links to established areas of the moon in a large composite and having the links go to a detailed image such as this one could create a virtual map of the moon and it could be accessed by "zooming in" (clicking on the link) to find details about that area of the moon.

The only difficulties would arise in the development of the site from which the composite and its component images would be managed. In order for the main composite to be a reasonable size and for the detailed images to be detailed, the website portion would be quite complex in terms of the number of individual pages as well as the network of links that connect them all.

5   The Website

The website was constructed using templates from the College's IT department. These templates were modified using Macromedia Dreamweaver. This very powerful program provided the platform for archiving the images taken as well as constructing a user-friendly site that allowed for easy navigation. As a program Dreamweaver utilizes HTML coding as well as PHP scripting within the HTML. These powerful languages support the creation of very dynamic sites.

Understanding and modifying the code proved to be very tedious. However, by working with the PHP code, a great deal was learned about the structure of a website . With some assistance from the IT department a reasonable web platform was established and a basic user-friendly site was constructed. Though the video feed feature has yet to be fully developed the current site contains many archived photos as well as some detailed composites and a discussion board. Though currently restricted to those with a William and Mary login and password it is hoped that once the live feed feature is developed more people will be granted access. The current website can be found at :

http://dbwolc.people.wm.edu

6   Future Applications

There are a few really interesting things that could possibly be done with this system including a live-video feed from the telescope's eyepiece, a virtual "map" of the moon, and a student friendly platform of usage that would allow students to use the equipment and document their explorations by saving photos.

6.1   Creating a Video Webcam Using the Telescope

Using the telescope and another type of camera designed for broadcasting, a system could be established in such a way that a live video image from the telescope's eyepiece would be uploaded in real time to a website. Using an approved login one could access this video by simply logging in to the website. This would provide many people with virtual access to a significantly large telescope.

6.2   Map of the Moon

Using the methods outlined in section 4 of this paper it would not be a stretch of the imagination to believe that one could create an online map of the surface of the moon. Depending on the amount of time at hand, it would be possible to make a very detailed outline of the surface of the moon. Since it is not possible to zoom with a telescope this effect must be done by shrinking the original photos and have the user "zoom in" to the originals. Therefore, the number of detailed portions of the surface would depend on the size reduction of the original photos from the telescope.

6.3   Student Use and Database

Perhaps one of the most exciting possible expansions of this project would be to setup a system by which students (with approval from the physics department as well as instruction) could use the telescope of the Thomas Harriot Observatory to take photos of their own and store them in an online database. This would provide incentive for students to pursue knowledge about astronomy as well as gaining understanding about astrophotography and telescopes. The idea is that students would be able to go up to the observatory, sign out the camera and computer, and take/save photos of whatever region of the sky they so desired. The photos would be stored online (as in a website such as the one I have created) and could thus be available to anyone. [See Appendix A for a sample instructions manual on how one would operate the camera once he/she was granted access to the equipment by the department.]

7   Conclusion

Ultimately this project proved to be a very educational experience. The knowledge gained about astronomy, computers, CCD imaging, and telescopes is far more substantial than any single class could have provided. From the countless hours spent on the roof of Small Hall in the dark to the hundreds of on-line documents read for this project, it is considered a success regardless of whether or not the live feed is ultimately achieved. The interface created serves as a platform for further expansion and the goal of live feed could easily be obtained by simply using additional software or a different imager. The images collected speak for themselves as far as showing the exciting possibilities that exist in expanding on the processes described in this paper.

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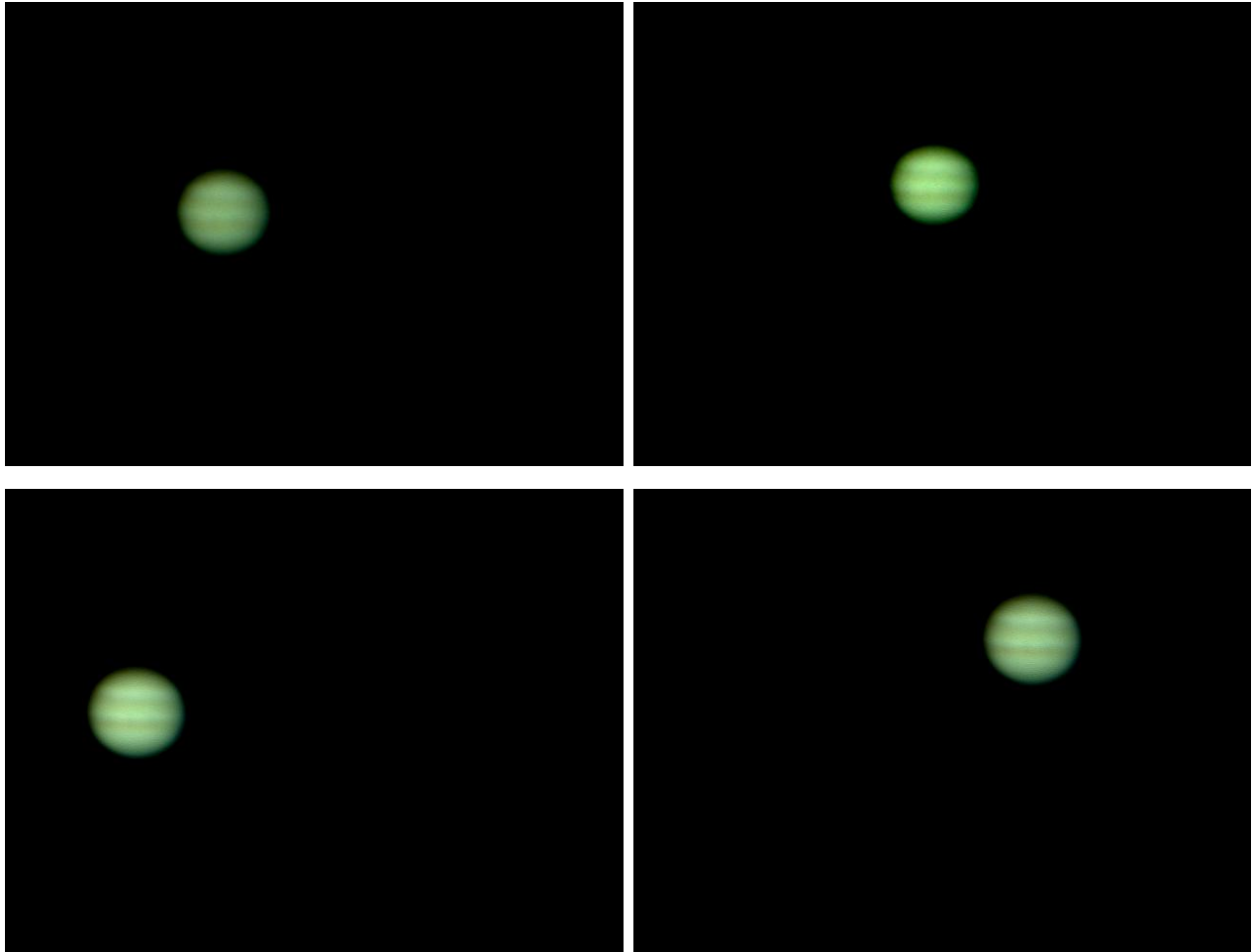
Image Gallery

Figure 6: Photos of Jupiter. In this set of four photos of Jupiter taken on March 23, 2006 each photo was taken with different camera settings. Though the camera can automatically adjust the gain, offset, exposure, etc., it is possible to manually set these parameters. With these photos I was manipulating them to try to get the best overall image.
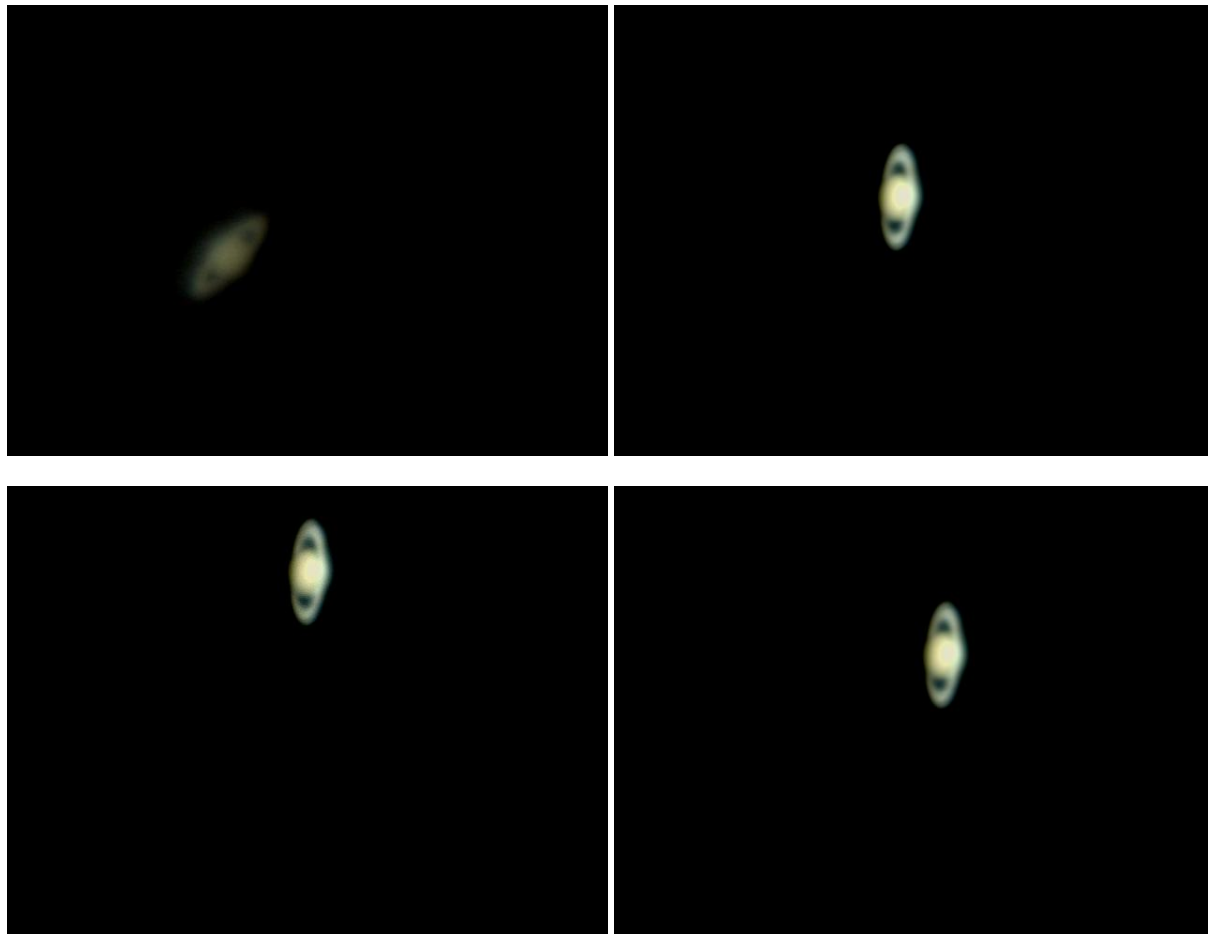
Figure 7: Saturn. Here I have done the same sorts of adjustments that I did with the photos of Jupiter.

Figure 8: Phase of Venus on December 9, 2005. Notice that since Venus is an inferior planet it can go through phases just like the moon. Since it was nearing Earth and between the Earth and the Sun it went through a phase as the moon does. Even though only about 30% of its surface was illuminated, because of its close proximity it still was at its highest visual magnitude of the year [6].

Appendix A
(Student User Manual)

Basic Instruction for taking photos using the THO and the Meade LPI.

The first step would be to open the observatory, start a session with the telescope computer, and perform the proper alignment and calibration procedures. This guide assumes that the user will have been approved by the department and properly instructed on the use of the telescope and the first step will require no guidance.

This guide also assumes that the MEADE software has been properly installed and tested with the computer that is to be used.

1. Connect the camera to the computer (before starting the computer):

The first step is to connect the camera to the computer. Before starting the computer connect the camera to it via the USB cable. Since the cable is only three feet long it is a good idea to have already established a position within the dome at which you plan to work. One established turn on the computer and wait for the software to load. This will be indicated by a message that appears in the lower right hand tool bar of the computer screen. It will indicate "USB Hardware Found. Meade LPI camera."

2. Start the Meade Autostar Suite software:

Once the camera has been identified by the computer you can start the Meade Autostar program. You will be greeted with a screen that will look similar to Figure 9.
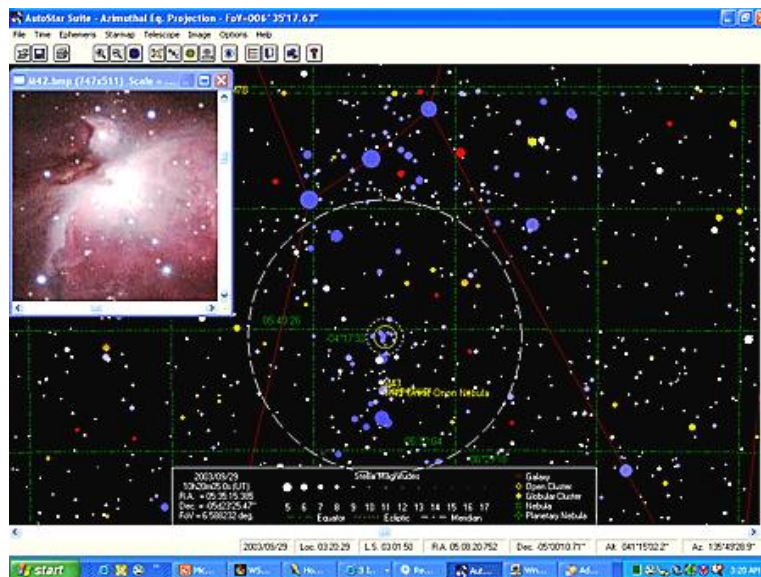

Figure 9: Meade Autostar Suite. Once the program is opened the user will be greeted with a screen similar to this one. What is shown is the night's sky at that GPS location (which is established when the software is installed) at that time. By clicking on one of the objects (dots) the Autostar suite will display information about that particular celestial object (the box in the upper left hand side of the photo.) [3]

3. Open the LPI controller

Once the Autostar suite has been opened, navigate to the "Image" button of the toolbar at the top and select "LPI Imager." If the camera was connected properly a screen should appear that looks like Figure 10.
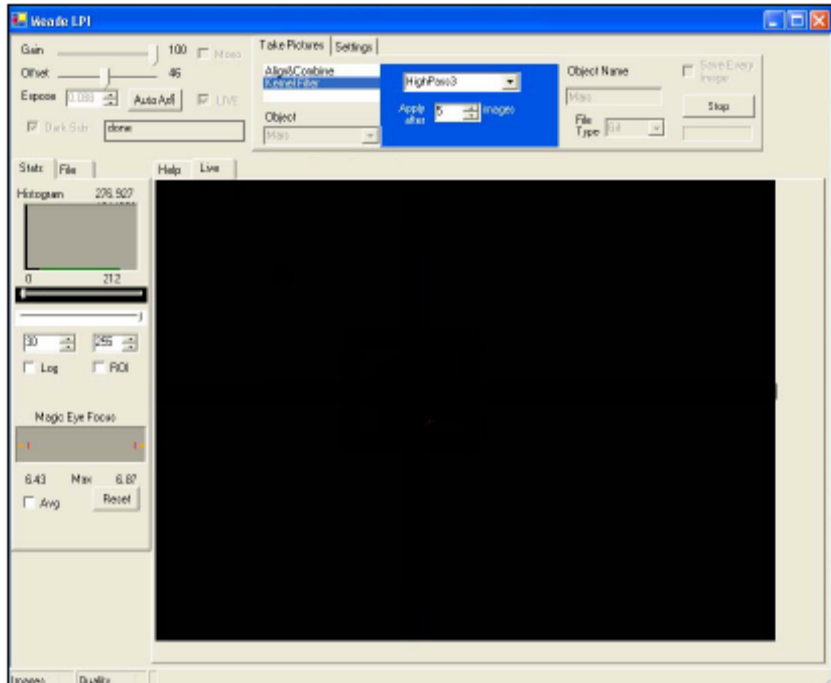

Figure 10: Meade LPI Control Center. It is from this screen that the camera is controlled and manipulations to the image parameters are made.[3]

From this control center all image parameters are controlled and the camera itself is controlled exclusively from this screen.

4. Connect the Camera to the Telescope

The camera will simply replace an eyepiece in the eyepiece diagonal of the telescope. Simply loosen the eyepiece and replace it with the camera. Tighten the thumb screws to secure the camera. In the case of the T.H.O. orient the camera such that the USB cable hangs down in the opposite direction of the telescope's optical tube.

If the telescope is properly aligned, slew to an object of interest and the image should appear in the screen shown in Figure 10. (Very precise focus is needed in order for the LPI to produce high quality images. The most effective way of focusing is to have the telescope already in focus for the LPI through the use of the Parfocal Ring. This is provided with the camera as well as instruction on how to set the focus. Unfortunately this method requires daytime calibration and I therefore assume that the scope will either already be properly focused or the student will have been given proper instruction on how to do this as needed.)

5. Start Taking Pictures

When the object of interest is found, focused, and centered in the screen the user can start taking pictures.

1. Click on the "Auto Adj" button. This tells the computer to do what it thinks is best in terms of the Exposure, Gain, and Offset.

2. Click on the dropdown menu just below the word "Object" and select the type of object that is to be photographed. Type in the name of the object in the box "Object Name." This will aide in organizing the photos in the database.

3. Click "Start" and the program will automatically start taking photos, compiling them, and saving them in the specified location (which can be changed in the "settings" menu.) The amount of time elapsed as well as the number of photos actually taken will be displayed in the lower left hand corner of the LPI control center screen.

The values for all of the settings of an object within the solar system may look something like this.
Sample:
Exposure: 0.125 sec
Gain: 100
Offset: 50
Track: Off
Combine: Off
Save Every Image: On
Dark sub: Off
Min Quality: 75
Evaluation Count: 20
Mono: Off
Object: Jupiter
Images: 50 taken in 180 sec
File Type: GIF

Keep in mind, THESE SETTING ARE **NOT** OPTIMUM SETTINGS FOR ALL CASES. THIS IS JUST AN EXAMPLE.

6. Putting the Photos on the Website

This step would most likely be controlled by a single person. It would be advantageous for all of those using the camera to save their files in a common directory on the computer so that when an image gallery is created online (as the one in the website http://dbwolc.people.wm.edu) the webmaster would not have to search for files from different sessions scatter across the hard drive. In the case of said website, using an IT template called "Image Gallery" made adding a folder of photos to the page very easy.

7. Shutting Down

Before shutting down the telescope the student must take all the necessary steps of removing the camera from the scope and shutting down that system **before** shutting down the scope. With a camera attached to the eyepiece of the scope, whenever the scope is cycling through its ending procedures the tube will move. If the camera is still attached when this happens it could damage the telescope motors, eyepiece diagonal, the camera itself, the computer, etc. ALWAYS remove the camera and shut down that system before shutting down the telescope.

Ending a session with the camera is very easy.

- -Simply remove it from the telescope
- -Make sure the program is stopped
- -Shut down the Autostar program
- -Unplug the camera from the computer
- -Replace the black lens cap to the front of the camera
- -Replace everything in the case as it was originally

Once again it is assumed that the student will know how to properly end a session with the telescope and follow proper procedures in shutting it down.