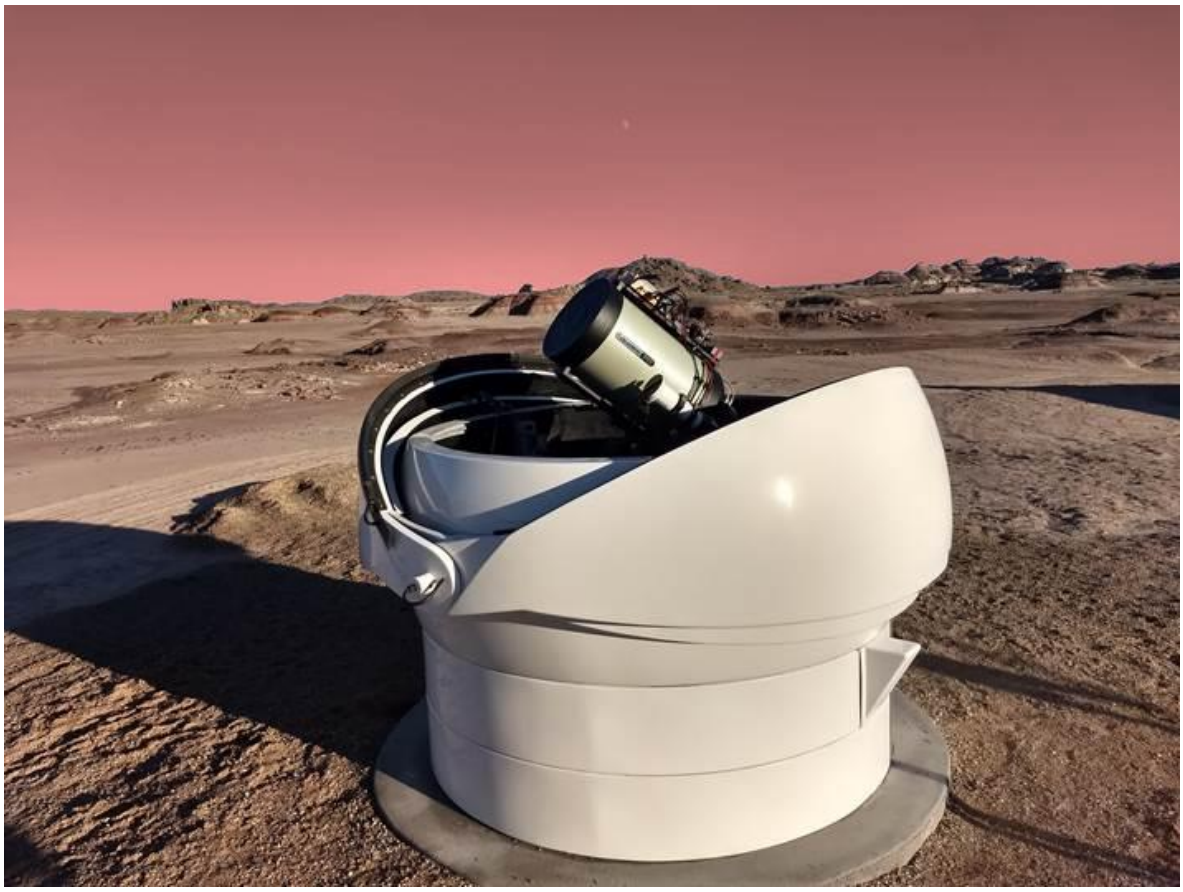
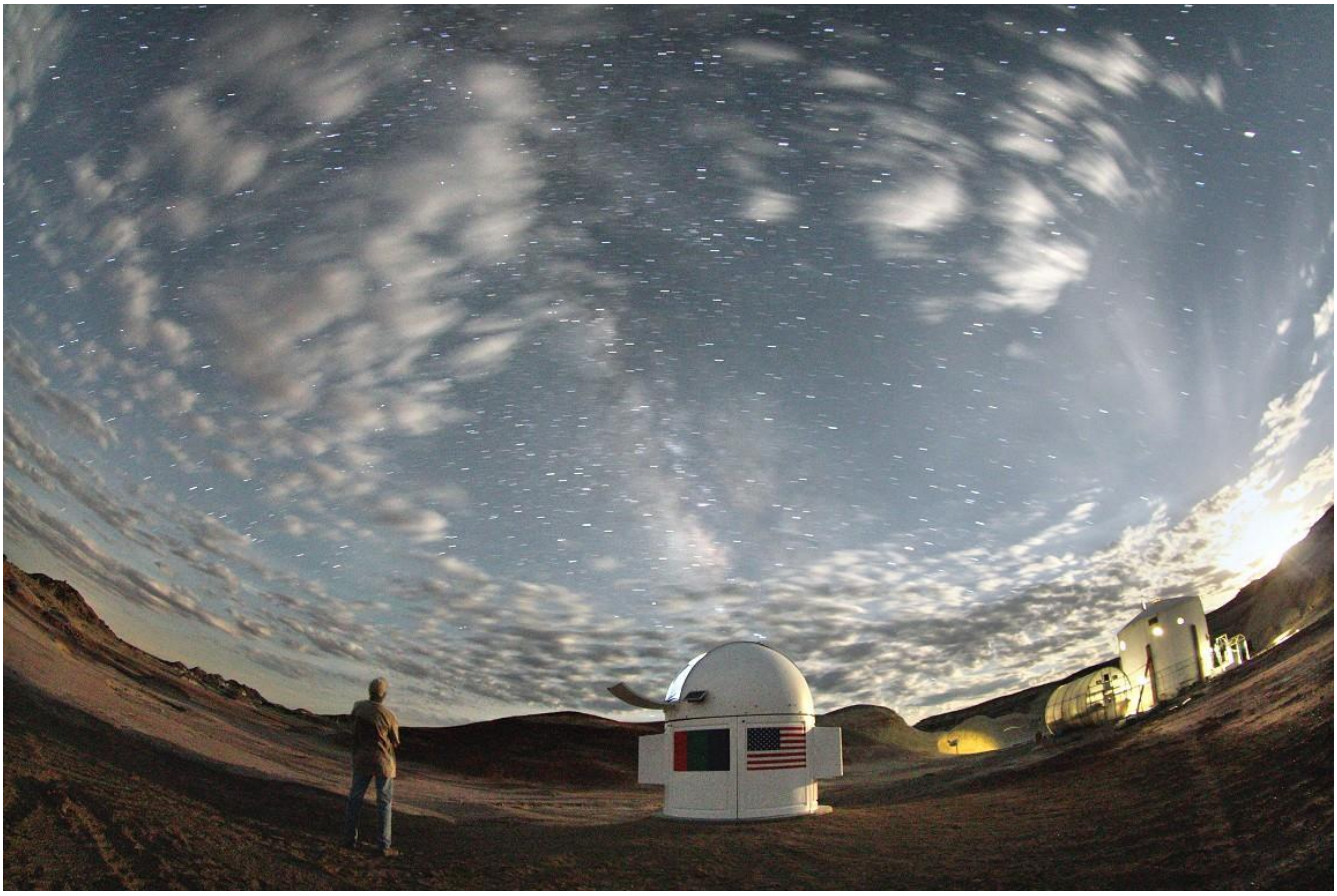


MDRS Robotic Observatory

Quick Guide

Peter Detterline Observatory Director pdetterline@moravian.edu
Revised, Gary A. Becker, July 2020 beckerg@moravian.edu



Mars Desert Research Station in 2012: Self-portrait of Gary A. Becker under moonlight. The Elon Musk Solar Observatory, dedicated to viewing the sun in Hydrogen Alpha, is in the foreground while the two-story habitat is on the right in the background near the setting moon.

Mars Desert Research Station, near Hanksville, Utah as it looks today: 1-Habitat, 2-Greenhouse, 3 Biology Lab, 4-Elon Musk Solar Observatory, 5-MDRS Robotic Observatory, 6-Solar Panels that power the station. Adam R. Jones photography…

TABLE OF CONTENTS

MARS DESERT RESEARCH STATION ROBOTIC OBSERVATORY

OVERVIEW

Welcome to the MDRS Robotic Observatory, a fully automated observatory that can be accessed via the Internet. The observatory contains two instruments. One is a Celestron, Schmidt-Cassegrain, 14-inch (356 mm) reflector with Ultraviolet, Blue, Visual, Red, and Infrared (UBVRI) filters used for **photometric** research. The second is a wide field 70mm Stellarvue refractor with **Luminescence**, **R**ed, **G**reen, **B**lue, and **Hydrogen Alpha** LRGBHα filters used for **astrophotography**. The entire observatory is completely operated via the Internet. The observatory will open and close automatically, take all of the necessary images that are programed into the system, including calibration frames, and upload them to the Internet where the participant can download them at his or her convenience. Once downloaded, the observer can then process the images.

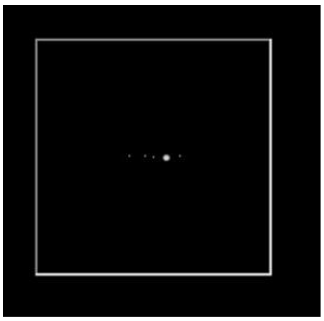
WORD LIST DEFINITIONS FROM THE OVERVIEW SECTION

Astrophotography: the imaging of astronomical objects, day or night.
Hydrogen Alpha (Hα) Filter: A device that only allows the passage of a specific wavelength of light from hydrogen in an emission state, 6563 Angstroms or 656.3nm. It is particularly important in bringing out the detail in emission nebulae (glowing clouds of gas containing hydrogen).
Luminescence Filter: A device that produces a black and white image of the object being photographed and is used to fill in background detail when more narrowband filters are used.
Photometry: The science which investigates the measurement of the intensity of light being emitted by an object, usually stated as a magnitude.

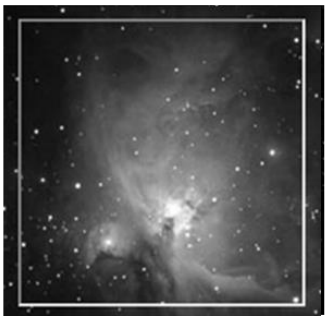
TELESCOPE SPECIFICATIONS

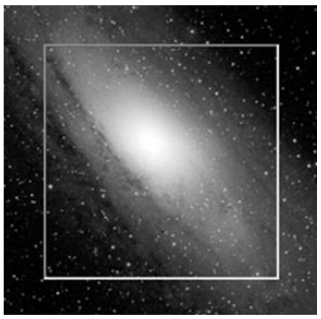
Fourteen-Inch Research Instrument: This instrument is not equipped to take color images.
Celestron, 14-inch, Schmidt-Cassegrain Edge HD Focal Length: 3910 mm
Aperture: 355.6 mm Focal Ratio: F/11

Camera
Moravian G4-16000 CCD camera with KAF-16803 CCD
Filters: UBVRI Astrodon photometric filters
Pixel size: 9x9; Array: 4096 x 4096; Binning: 1x1
CCD Gain 1.60; CCD Readout Noise 11.00; CCD Dark Current 3.00
Chip Size: 36.9mm x 36.9mm
Image Scale: 0.48 arcseconds/pixel
Field of View: 32.9 x 32.9 arc minutes
Field of View Samples: (simulation courtesy of New Astronomy Press CCD Calculator)


Jupiter


Moon


Orion Nebula


Andromeda Galaxy

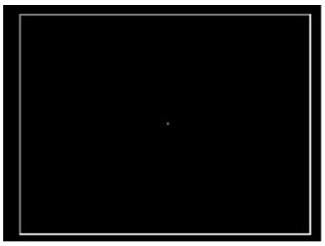
IMPORTANT:
Skynet will not switch back and forth between telescopes. That is something that the MDRS *O*bservatory Director will do. Send a request to your Professor to specify which telescope you would like to use that night.

Photo on left by Gary A. Becker…

<u>MDRS-Wide Field Astrophotography Instrument</u>: This telescope is not equipped to take research images.

Stellarvue 70 Apochromatic Refractor Focal Length: 336 mm
Aperture: 70 mm Focal Ratio: F/4.8

Camera
Moravian G2-8300 CCD camera with KAF-8300 CCD
Filters: LRGB Astronomik photographic filters
Filter: H-Alpha 6nm narrow band (Astronomik)
Pixel size: 5.4 x 5.4
Array: 3358 x 2536 pixels
Binning 1x1
Chip Size: 13.7mm x 18.1mm
Image Scale: 2.65 arcseconds/pixel
Field of View: 111.9 x 148.2 arc minutes (There are 60 minutes of arc per degree.)
Field of View Samples: (simulation courtesy of New Astronomy Press CCD Calculator)


Jupiter


Moon


Orion Nebula


Andromeda Galaxy

A few things to remember:

- Planets are too small to image through either telescope.
- The Moon is too bright. Do not attempt to image it!
- All images are monochromatic (shades of gray). Images (RGB) need to be stacked with a software program to get color astrophotos using the **Stellarvue 70** Apochromatic Refractor.
- Calibration frames **(flat, bias, and dark)** are taken automatically, but you have to calibrate them with your image by using an additional software program.

<u>Flat Frame</u>: An image or multiple images usually taken at dusk, recorded by light reflected from a white screen or the sky to correct for inconsistencies of exposure caused by the optics of the recording system, such as vignetting or dust on the telescope.
<u>Bias</u>: An image taken with a zero second exposure to record the inconsistencies of sensitivity across the chip. It removes the (read) noise generated by the pixel as it receives data from the object while an exposure is being taken.
<u>Dark</u>: An exposure of the same length as the data collecting image, but taken with the camera in a closed configuration (lens cap on) to locate the hot (over responding, bright) pixels in the image for removal during image processing.

BRIGHT PLANETS AND THE MOON

Robotic observatories normally use wide-field instruments. This makes them great for star clusters, nebulae, and galaxies, but horrible for bright planets, such as Mercury, Venus, Mars, Jupiter, and Saturn because the images are much too small to see any details. Look at the sample images of Jupiter for each telescope shown in the *Quick Guide*. Planets, such as Uranus, Neptune, and the dwarf planet Pluto, are fine because they are too small or too far away to see any detail. They will appear like "stars," but you will be able to follow their movements from night to night.

The Moon is big enough for imaging as the specification sheet shows, but unfortunately, the Moon is too bright under most circumstances. At MDRS, test photos of the Moon have only been successful using the 14-inch instrument. The shortest exposure (0.03 seconds) was used in conjunction with the hydrogen alpha filter. **DO NOT IMAGE THE MOON WITHOUT FIRST ASKING FOR PERMISSION FROM YOUR INSTURCTOR.** During the partial phases of a lunar eclipse and through totality would provide an opportunity for imaging. Your Moravian instructors will give students specific guidelines, if such a situation occurs.

SKYNET

Skynet represents a group of astronomical observatories around the world that students can use to conduct research and image the sky. The two telescopes mounted tandem on the same mount at the MDRS Robotic Observatory are part of the Skynet family and operate under the protocols which are accessed through the Skynet website, https://skynet.unc.edu/.

CREATING AN ACCOUNT

First, a student must log into the system. Your professor will have you create an account in class or send you an invitation from Skynet with a self-registration key in your email. If you receive an email from Skynet, then follow the instructions to register. Please note that registration keys can only be used once. A typical invitation email looks like this.

From: **Skynet Robotic Telescope Network** <no_reply@skynet.unc.edu>
Date: Mon, Mar 23, 2020 at 11:37 PM
Subject: Welcome to the Skynet Robotic Telescope Network - Registration
To:

Hello,

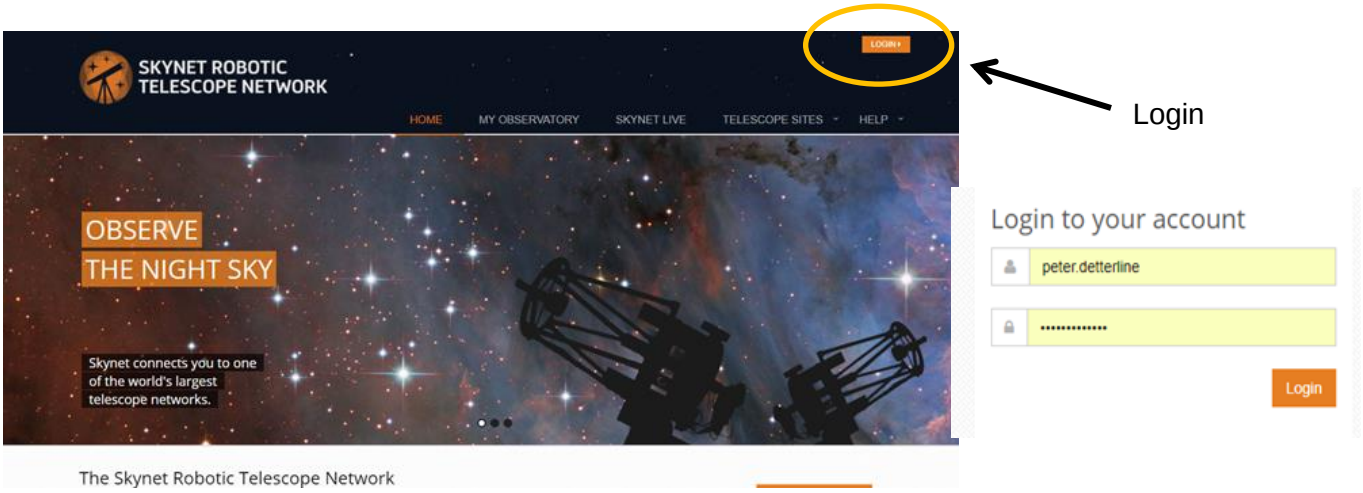
Based on your enrollment in an astronomy course or your recent visit to a Skynet observatory, you have been invited to join the Skynet Robotic Telescope Network. Your private registration key is: d**3690151d0h2**

Click here to complete your registration.

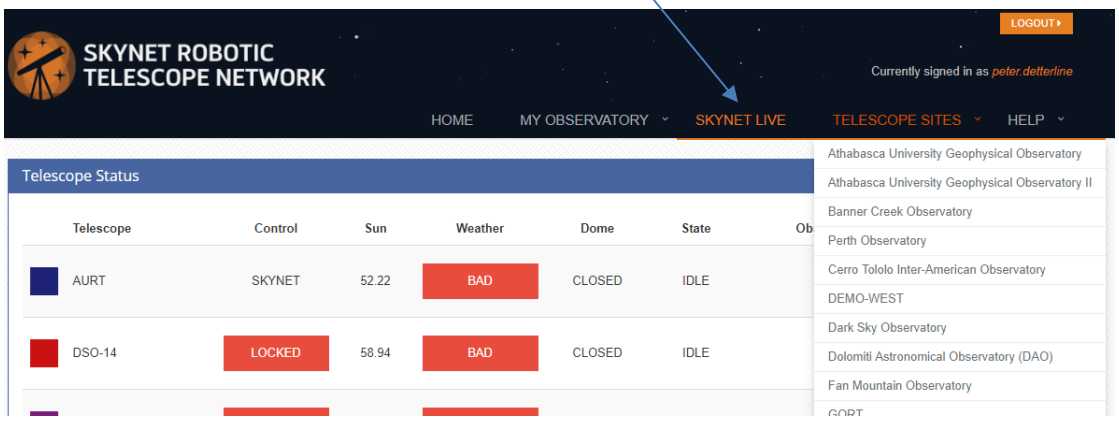
Or, visit our registration page by pointing your browser to https://skynet.unc.edu/user/register and including your registration key. This special key is unique and can only be used once. If you did not enroll in a course which uses Skynet or you have recently dropped the course, you may ignore this message.

If you have questions regarding this email, please contact your course instructor or T.A.
Skynet Robotic Telescope Network,

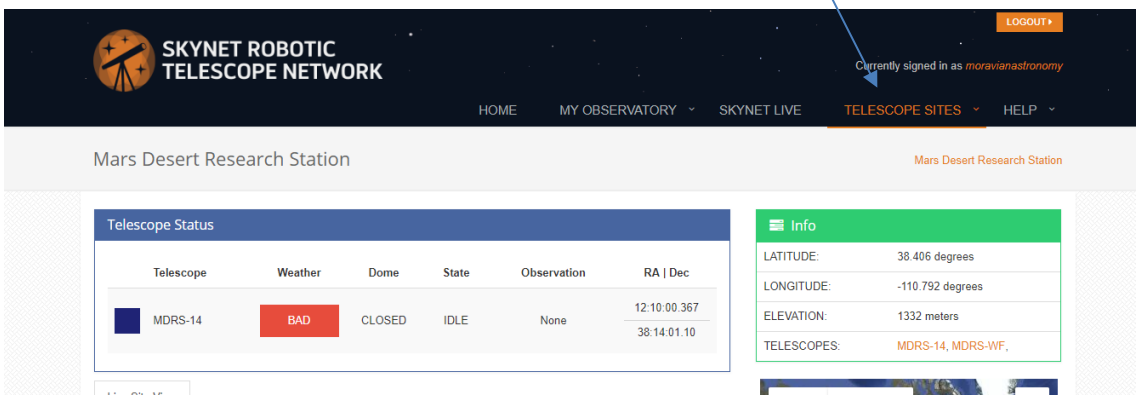
Now login at Web address: https://skynet.unc.edu/



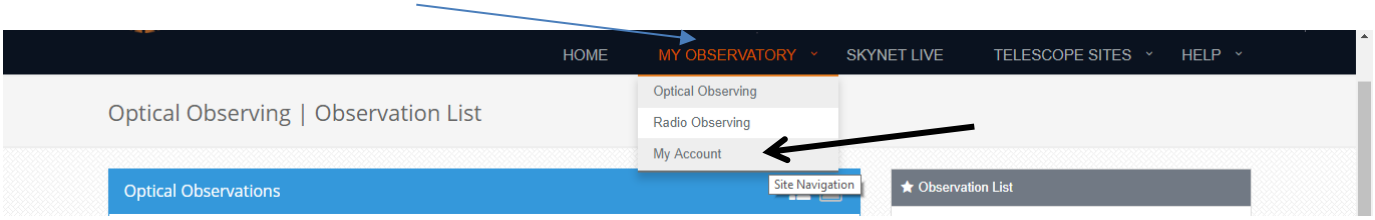
Let's explore the website. Click on **SKYNET LIVE** on the top menu. This shows the status of all of the observatories in the Skynet family. Scroll down and find MDRS. It will tell you if the telescope is currently open or closed.



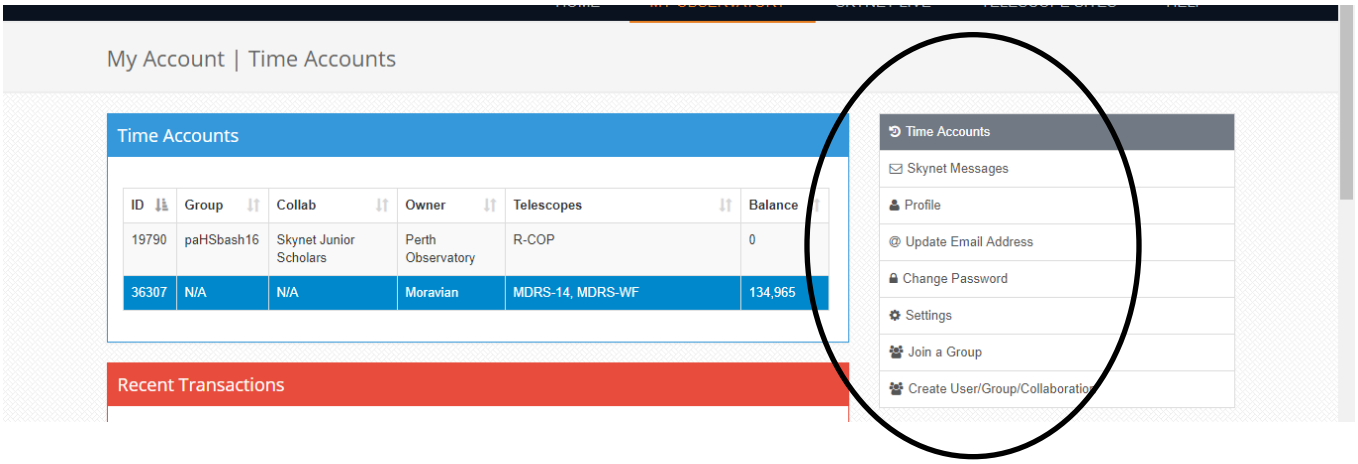
On the top menu, you can also select **TELESCOPE SITES**. From the drop-down menu select **Mars Desert Research Station**. This will give you detailed information and status on the MDRS Observatory. These sites are particularly useful because it is possible to see what object the telescope is currently imaging.



Now select **MY OBSERVATORY**, and from the drop-down menu, select **MY ACCOUNT**.

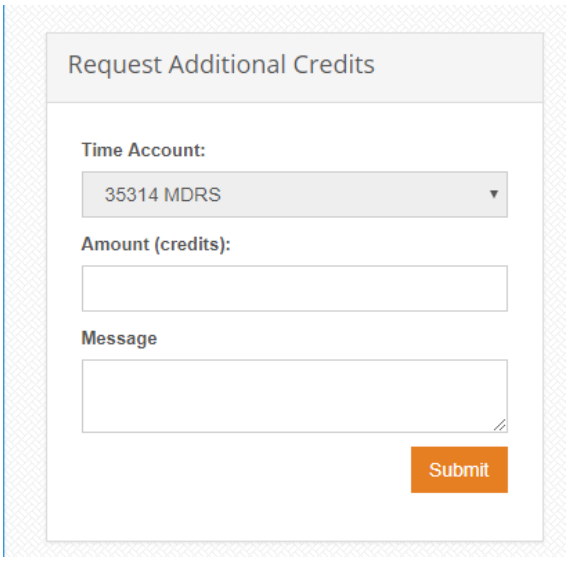


This is where you can change your password, and see how much time you have on the telescope.



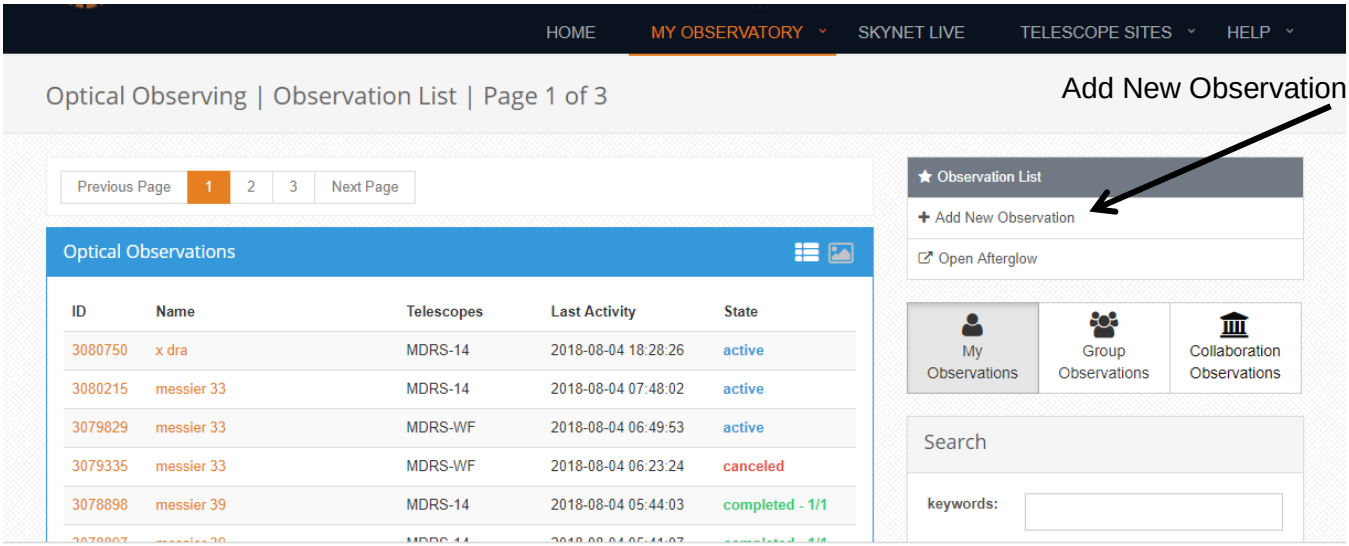
REQUESTING MORE TELESCOPE TIME

If it is discovered that you have insufficient telescope credits (time), the easiest and fastest way to request more observing time on Skynet is to contact your professor. On Skynet you can also choose **MY OBSERVATORY**, and from the drop-down menu select **MY ACCOUNT.** Scroll down the page to request additional time on the telescope (credits). Complete the form and click **SUBMIT**. Be advised that it may take longer to receive requests using this method.

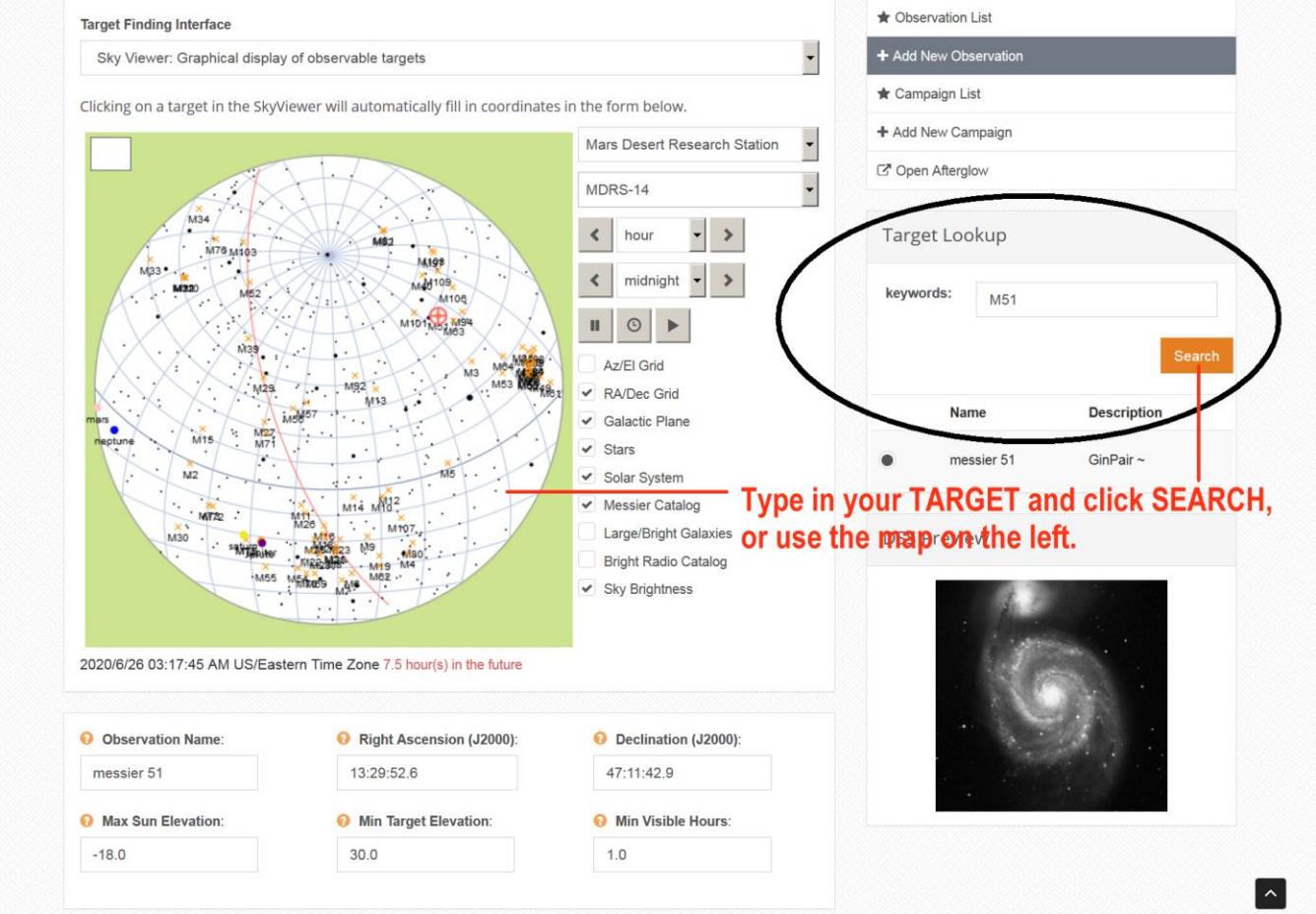


FIRST LIGHT: MAKING YOUR FIRST OBSERVATION

The best way to learn the telescope system is to make a good observation before you get started with your project. Select **MY OBSERVATORY** again. From the drop-down menu, select **OPTICAL OBSERVING**. This is where you will set up, submit, and collect your observations. Looking at **OPTICAL OBSERVING | OBSERVATORY LIST** you can see the observations that you have already completed and those that are still active (not completed) in the left-hand column. Click on **ADD NEW OBSERVATION** in the right-hand column.



Step one is to select your target. Select a target for one of the telescopes. Type the name of the object in the **TARGET LOOKUP** box; when done click **SEARCH**.



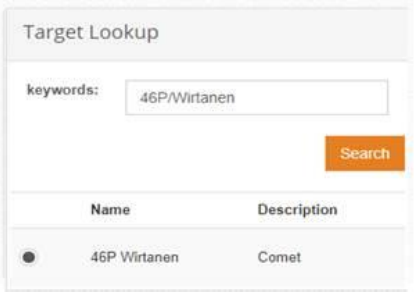
<u>USING THE MAP</u>: You can also search the map on the right and choose an object by simply clicking on it. Make sure you spend a little time researching the object so that you know whether it is a galaxy, globular cluster, open cluster, planetary nebula, etc. You should be able to do this in Google without too much difficulty. If the images appear too crowded, you can create a box with your mouse to enlarge that section. If you need to return to the original map, click on the **Add New Observation** tab and restart the process. You can look at objects at any time of the night by advancing the **hour** tab. This is important if bright moonlight will interfere with an observation. In a situation where moonlight may wash out your image, find an object that will be visible after moonset or is positioned far enough away from the moon to avoid its detrimental effects from the sky glow which Luna creates.

For comets, put in the designation and name with no spaces. Click **SEARCH**.

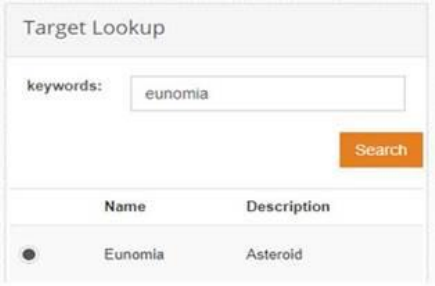
For asteroids, just put in the name. Click **SEARCH**.

For variable stars, put in the designation. Click **SEARCH**.

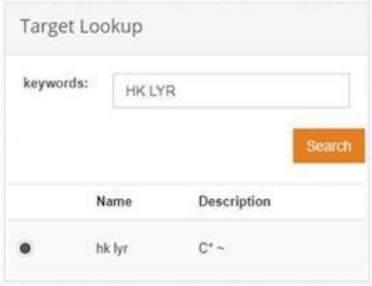
Comets



Asteroids

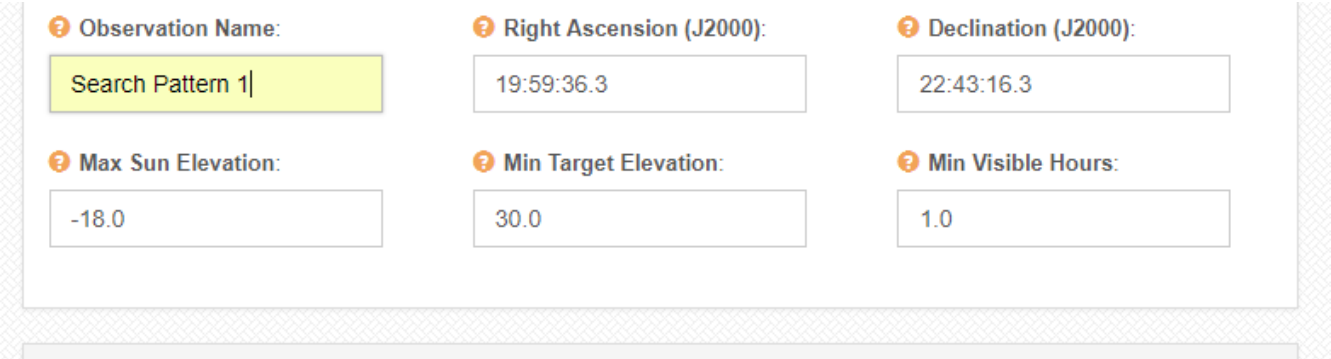


Variable Stars



IMPORTANT: For moving objects, such as comets or asteroids, it is best to have them completed the night that you submit them, and with the specific positional coordinates. If Skynet did not take those particular images that night, cancel the observation and resubmit with the new positional data.

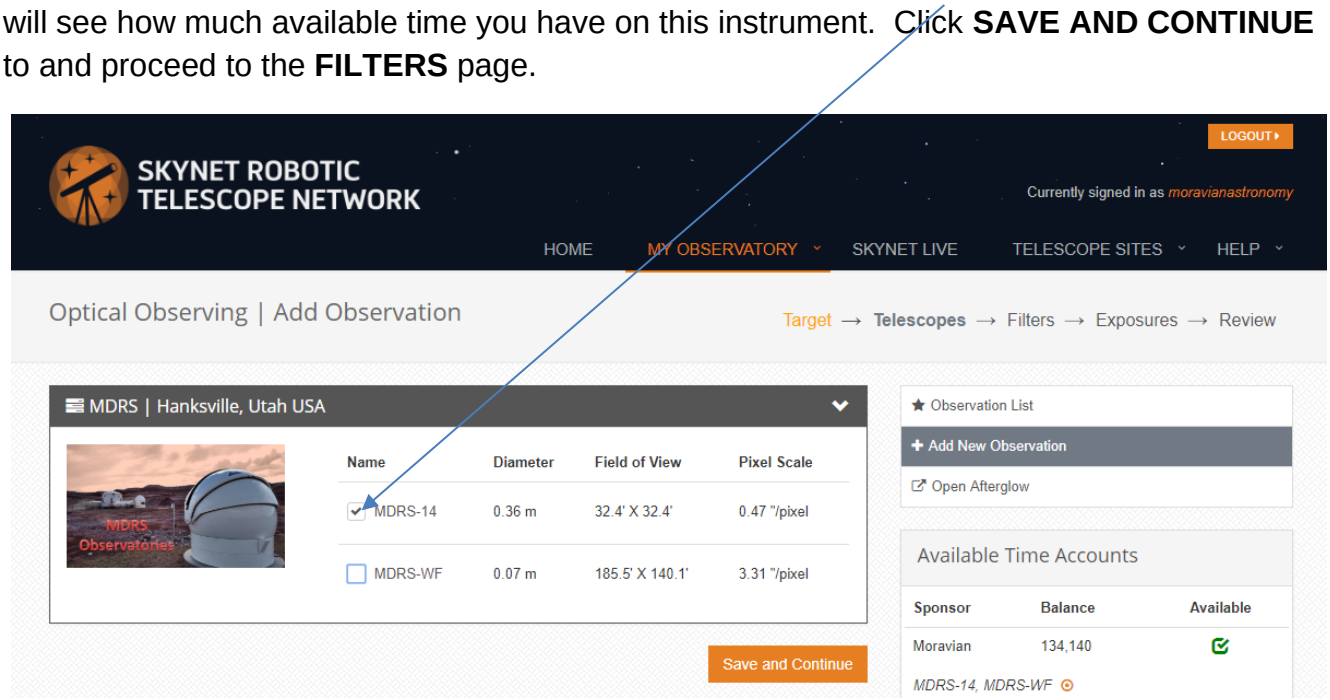
OPTIONAL: Scroll down and you'll see the coordinates of your object. You don't have to select a target, if you prefer you can just put in the coordinates. You will have to name it however. In this example I'm calling it Search Pattern 1.



At the bottom of the page, you will see a graph showing when your target is visible. The graph needs to be above the 30-degree elevation line.

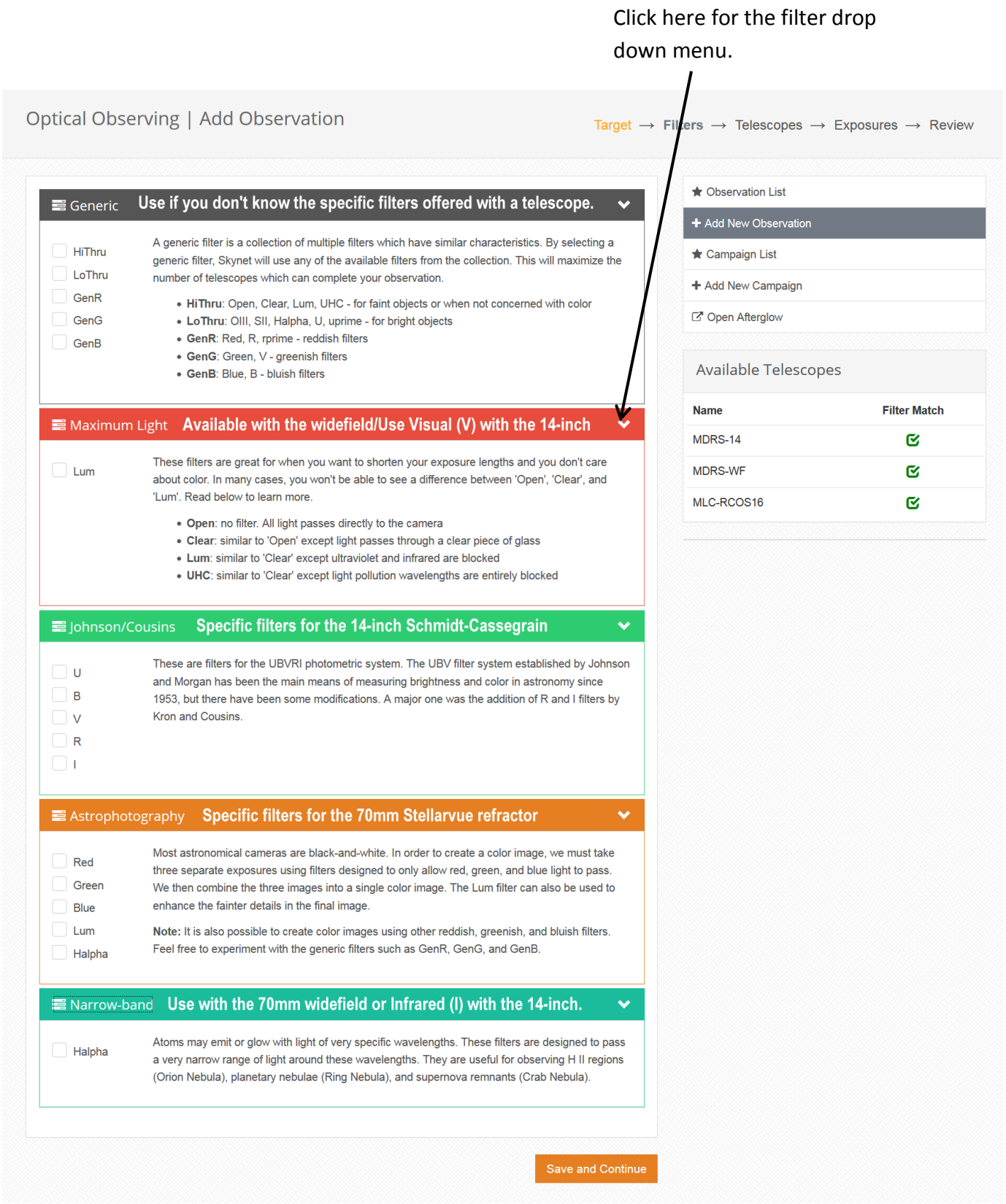
IMPORTANT: If the object line is below 30 degrees or not on the graph, the image will not be taken. Another target needs to be selected. Select, **SAVE AND CHOOSE TELESCOPES**. This will direct you to the next page.

Select the MDRS telescope that you want to use by checking the box. On the right side you will see how much available time you have on this instrument. Click **SAVE AND CONTINUE** to and proceed to the **FILTERS** page.

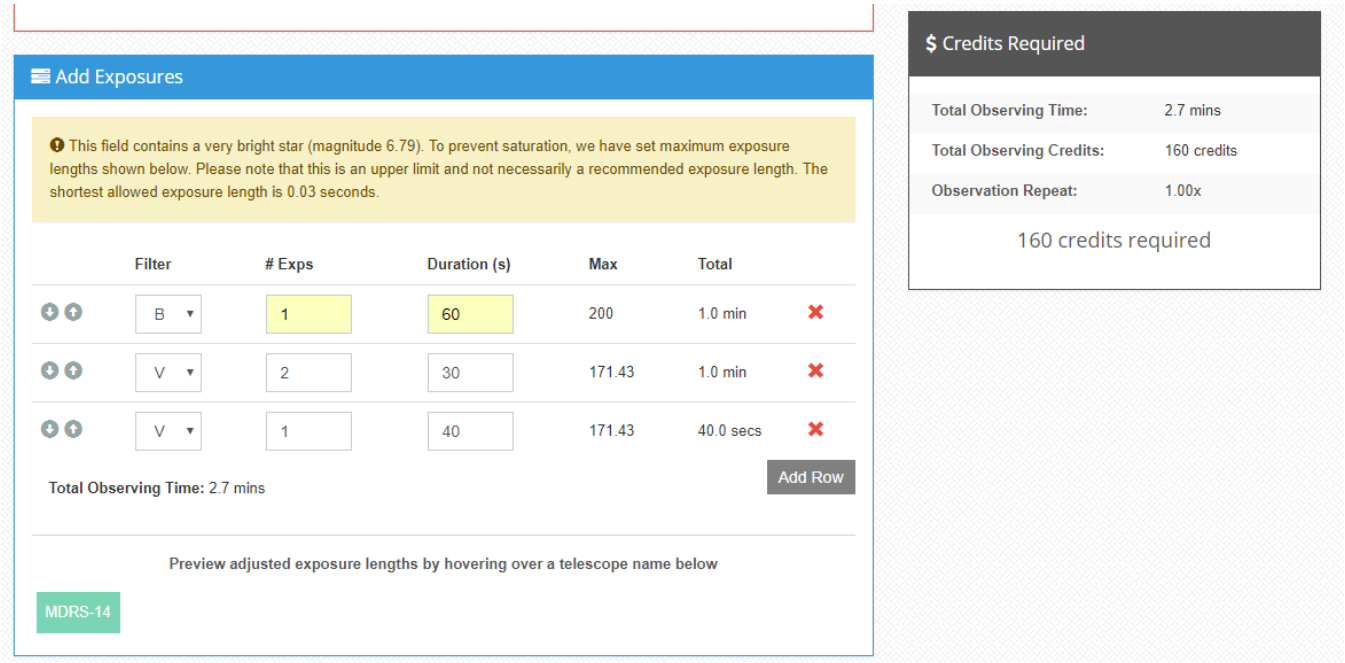


Filters: Select the filters you want to use for your observation. Make certain the filters match the telescope that you have chosen. For black and white images, select either “V” for visual or “L” for luminescence.

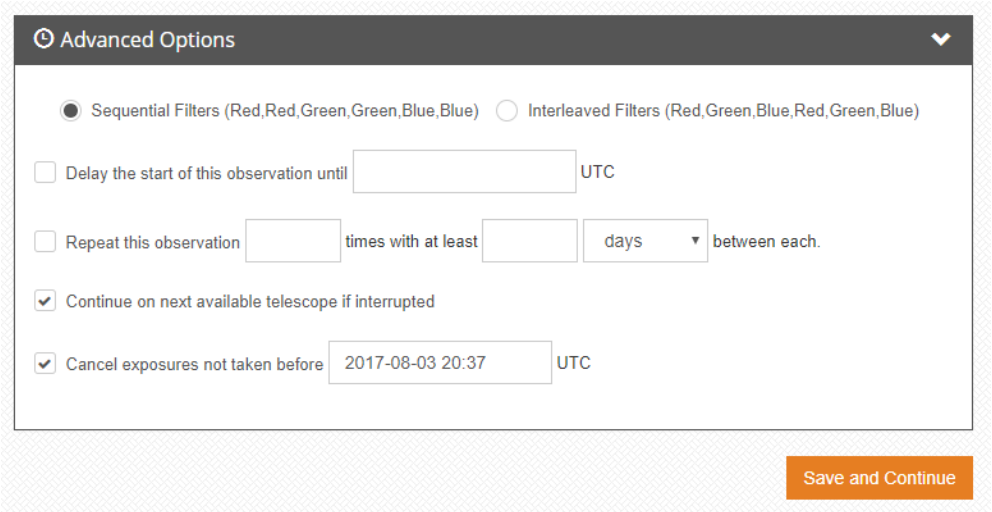
Click **SAVE, AND CONTINUE** to advance to the next page.


Click here for the filter drop down menu.
Optical Observing | Add Observation
Target → Filters → Telescopes → Exposures → Review
Generic
Use if you don't know the specific filters offered with a telescope.
HiThru
LoThru
GenR
GenG
GenB
A generic filter is a collection of multiple filters which have similar characteristics. By selecting a generic filter, Skynet will use any of the available filters from the collection. This will maximize the number of telescopes which can complete your observation.
HiThru: Open, Clear, Lum, UHC - for faint objects or when not concerned with color
LoThru: OIII, SII, Halpha, U, uprime - for bright objects
GenR: Red, R, rprime - reddish filters
GenG: Green, V - greenish filters
GenB: Blue, B - bluish filters
Maximum Light
Available with the widefield/Use Visual (V) with the 14-inch
Lum
These filters are great for when you want to shorten your exposure lengths and you don't care about color. In many cases, you won't be able to see a difference between 'Open', 'Clear', and 'Lum'. Read below to learn more.
Open: no filter. All light passes directly to the camera
Clear: similar to 'Open' except light passes through a clear piece of glass
Lum: similar to 'Clear' except ultraviolet and infrared are blocked
UHC: similar to 'Clear' except light pollution wavelengths are entirely blocked
Johnson/Cousins
Specific filters for the 14-inch Schmidt-Cassegrain
U
B
V
R
I
These are filters for the UBVRI photometric system. The UBV filter system established by Johnson and Morgan has been the main means of measuring brightness and color in astronomy since 1953, but there have been some modifications. A major one was the addition of R and I filters by Kron and Cousins.
Astrophotography
Specific filters for the 70mm Stellarvue refractor
Red
Green
Blue
Lum
Halpha
Most astronomical cameras are black-and-white. In order to create a color image, we must take three separate exposures using filters designed to only allow red, green, and blue light to pass. We then combine the three images into a single color image. The Lum filter can also be used to enhance the fainter details in the final image.
Note: It is also possible to create color images using other reddish, greenish, and bluish filters. Feel free to experiment with the generic filters such as GenR, GenG, and GenB.
Narrow-band
Use with the 70mm widefield or Infrared (I) with the 14-inch.
Halpha
Atoms may emit or glow with light of very specific wavelengths. These filters are designed to pass a very narrow range of light around these wavelengths. They are useful for observing H II regions (Orion Nebula), planetary nebulae (Ring Nebula), and supernova remnants (Crab Nebula).
Save and Continue
Observation List
Add New Observation
Campaign List
Add New Campaign
Open Afterglow
Available Telescopes
Name
Filter Match
MDRS-14
MDRS-WF
MLC-RCOS16

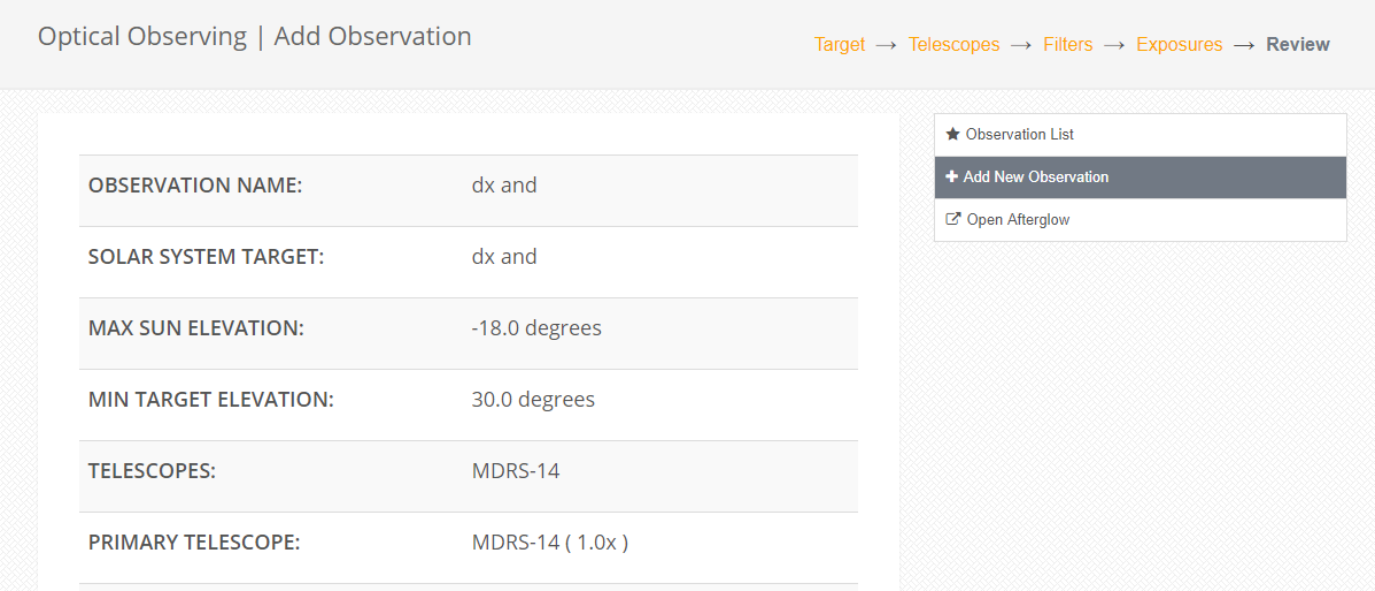
Exposures: Next is the exposure page or the length of time that the astrophotos will be taken. Set the exposure time and the number of pictures that are to be taken. In this example I'm taking one exposure of 60 seconds duration with a blue filter (B), two exposures of 30 seconds in length with a visual filter (V), and one exposure of 40 seconds with a V filter. This accumulates to a total of 2 minutes, 40 seconds of observing time or 160 credits. Each credit represents a second of imaging time through the telescope. Note how much time this observation will "cost," and also how many credits of time you have left for future imaging.



Scroll down and note the **Advanced Options** box. This allows you to repeat observations which is a huge time-saver for variable stars. Click **SAVE AND CONTINUE**.

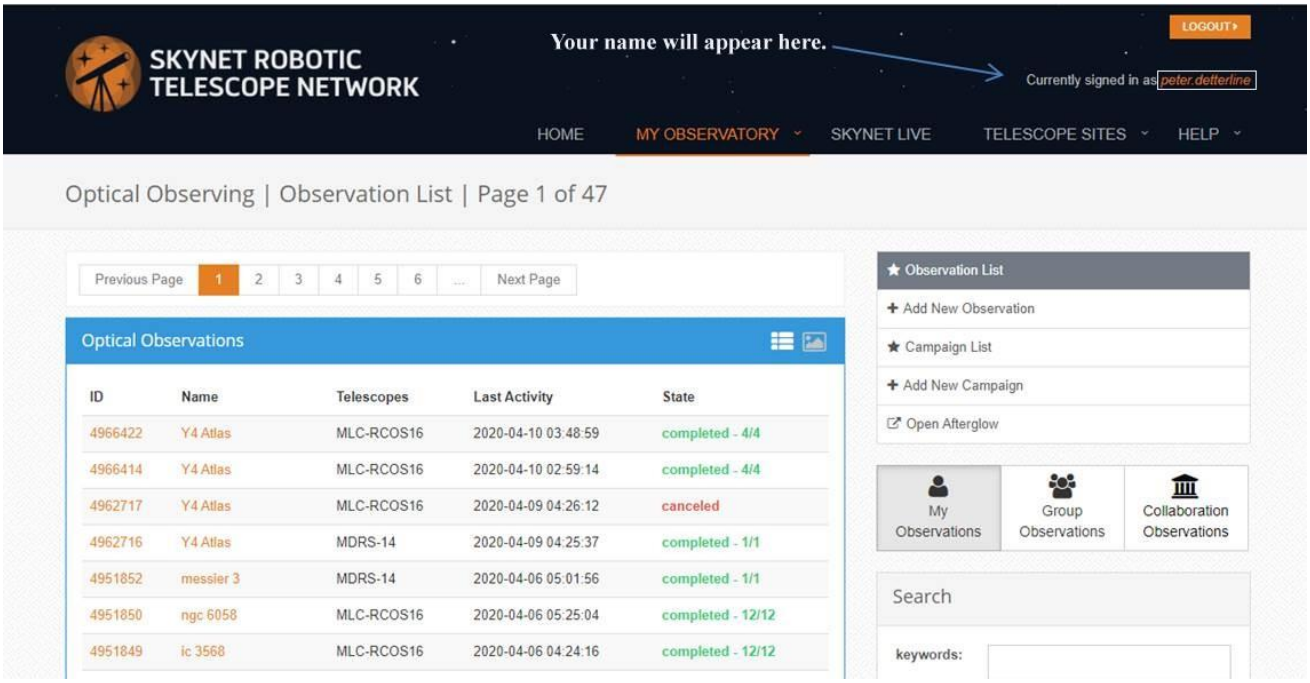


The last page is the summary of the observation submitted. Examine everything carefully, and when satisfied, scroll down and click **SUBMIT**. Congratulations, your first light image is in the queue!

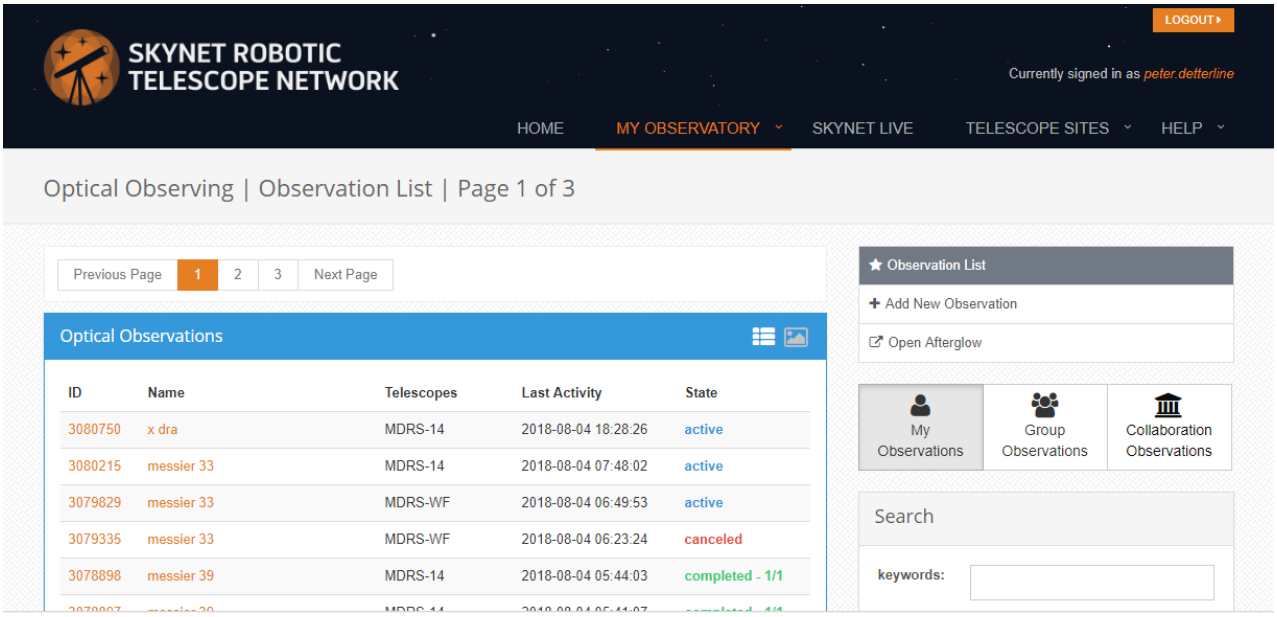


DOWNLOADING AND SUBMITTING AN IMAGE TO YOUR INSTRUCTOR

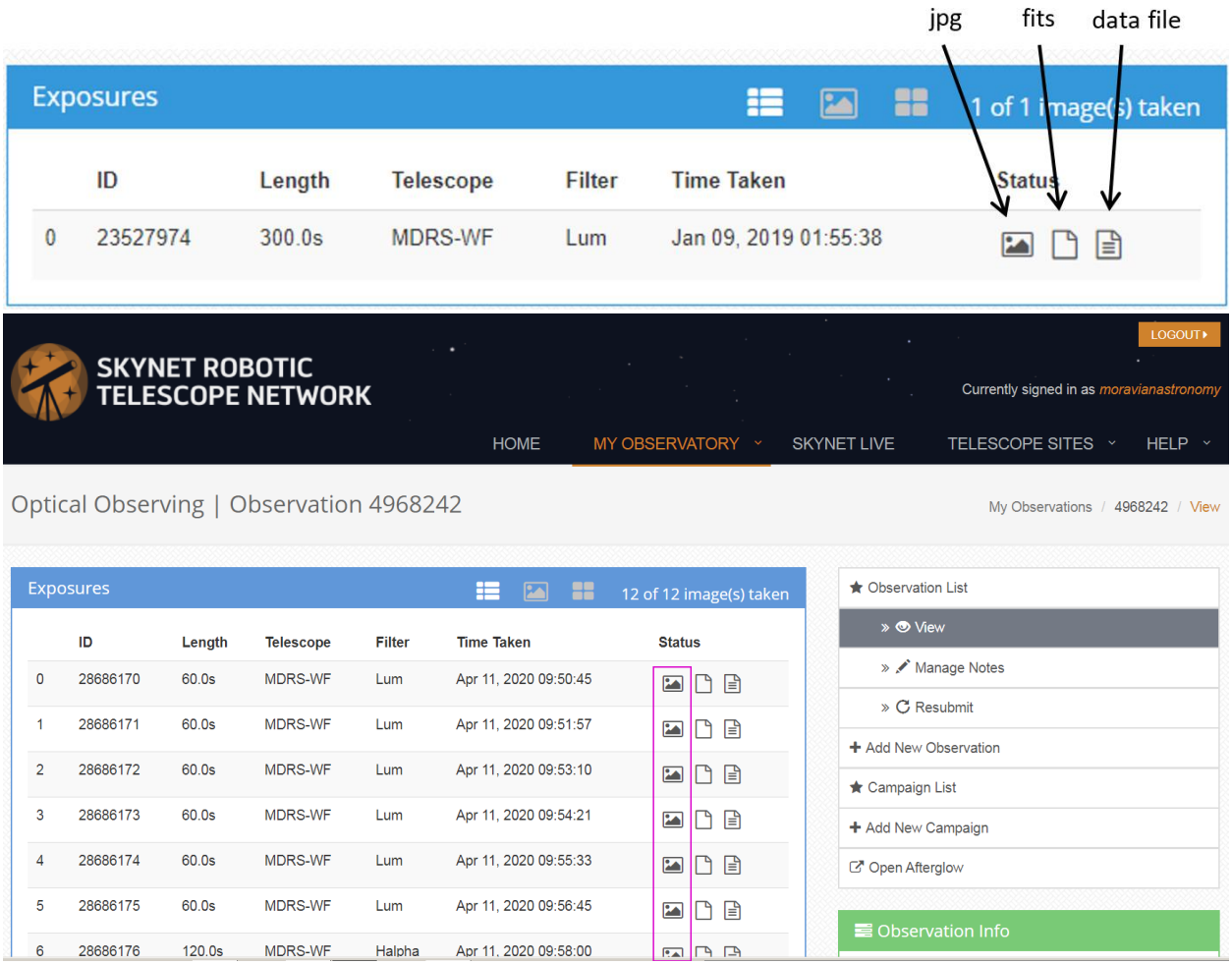
1. **Do not use your mobile phone to send screenshot images. Use your MacBook or Windows Operating System.**
2. **Go to Skynet**, https://skynet.unc.edu/
3. **Log into Skynet**. That should take you right to your observations. If it does not happen, then go to the top of the screen and click on **my observatory/optical observations**.
4. **Send a screenshot of your observations page to your instructor. That way your instructor can see the pictures that you have taken.** Make sure that your name appears on the picture so that it can be determined that it is your page. The following image is an example of what should be sent. Your name must appear on the screenshot.



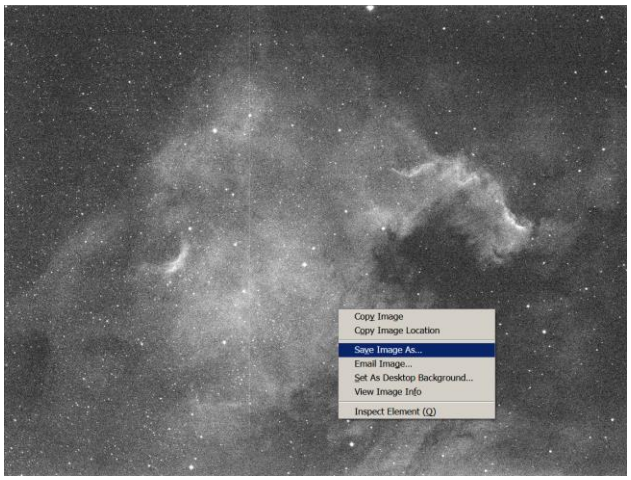
5. **<u>If under the status column</u>** (far right) of your observations, your images are indicated as **ACTIVE**, if they are still waiting to be taken; **COMPLETED**, if they are ready to be downloaded; and **CANCELED,** if for some reason they will not be taken. See the image above and below.



6. **<u>Click on the object's name</u>** (colored orange) of a completed observation. That will bring up the particular set of individual photos that were taken for your object.
7. **<u>Find the jpg images</u>:** Under the **status** column of that object's images, there will be three small icons. The far left one looks like it has a mountain and a black dot in it. Those are the jpg images.



8. **<u>Left click on each of the jpg icons and pick the photo that looks the best to you</u>.** Only the best image is to be sent, not all of them, unless more are requested.
9. **<u>Left click on the jpg image icon which has been chosen as the best</u>**, and it will enlarge to show you a full-sized photo of your object, fit to your particular computer screen. See the image below.

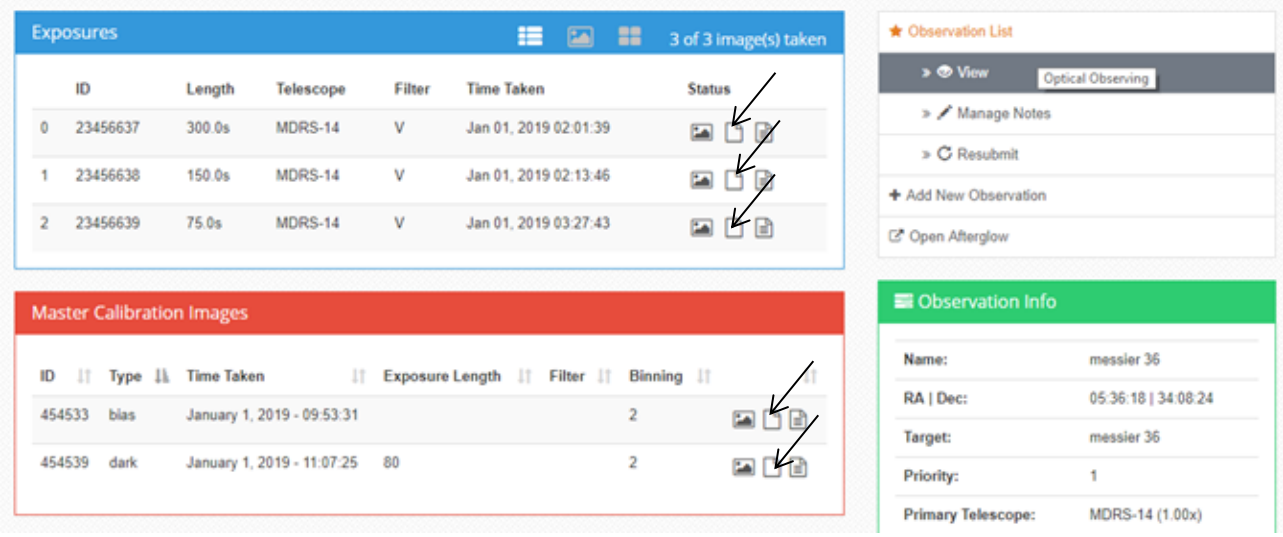


10. **<u>Save your image to your Desktop</u> or to a special file that you have created.** Then send the image to your instructor as an attachment with an email. The data of your image will be contained with the photo. Send it any other way, and it will not be accepted for credit.

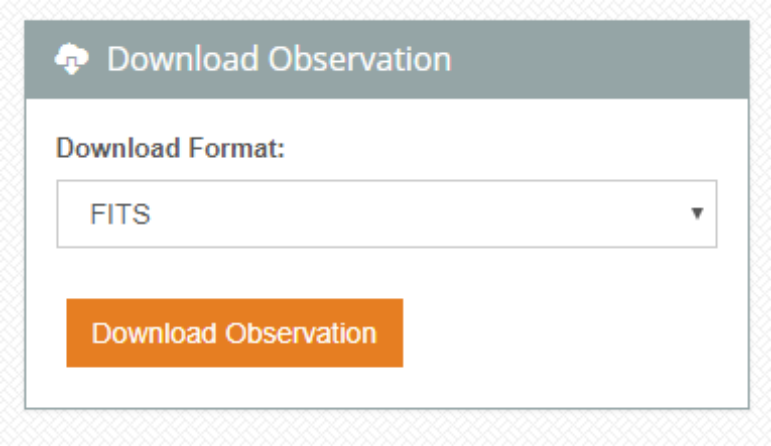
STOP RIGHT HERE IF YOU HAVE ONLY BEEN ASKED TO SUBMIT AN UNPROCESSED IMAGE. CONTINUE, IF YOU ARE TO PROCESS YOUR IMAGE.

PROCESSING AN IMAGE

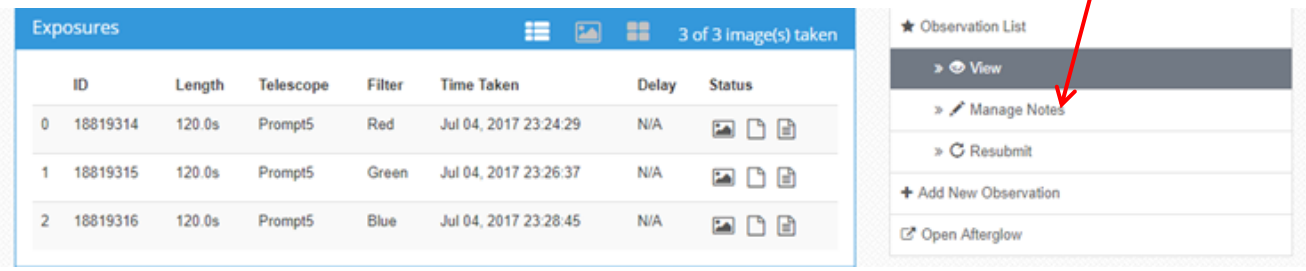
For more advanced processing you will be downloading the fits files, not the jpeg images. Download the fits files for each image, by clicking on the photo icon in the middle, directed to by the arrows. You will also need to download the calibration frames. To do this, you'll need to click on each image. These files are huge! At MDRS this can be problematic for Internet time allotments. There is a faster and better way to do this if you have multiple images such as these. Please see below.



Scroll down that page and look on the right-hand side until you find **DOWNLOAD OBSERVATION.** Click that button, and it will download all of the target fits observations as a zip file. YOU NEED TO HAVE A PROGRAM THAT CAN OPEN ZIP FILES ON YOUR COMPUTER. Keep in mind that it will NOT download any of the calibration frames; you will still have to do that one at a time.



Resubmitting an Image: If you need to make further observations of this target, simply click **RESUBMIT** (red arrow), and it will take you to the summary page without having to go through all of the other filters and exposure choices (although you can go back to those pages if you wish). On the Summary page, scroll down and click **SUBMIT,** and your observations will be back in the queue.



There are various software packages that can be used for processing your images, some of which are mentioned at the end of this manual under the software section. Obviously, I can't go through the specific procedures for all of these programs, so it is expected that the user be familiar with the techniques for their particular software. In this guide I will give specific procedures for processing, using AstroImage J.

Download the user guide for AstroImage J here:
http://www.astro.louisville.edu/software/astroimagej/guide/AstroImageJ_User_Guide.pdf

If you have a Mac computer, this link will help you with the installation.

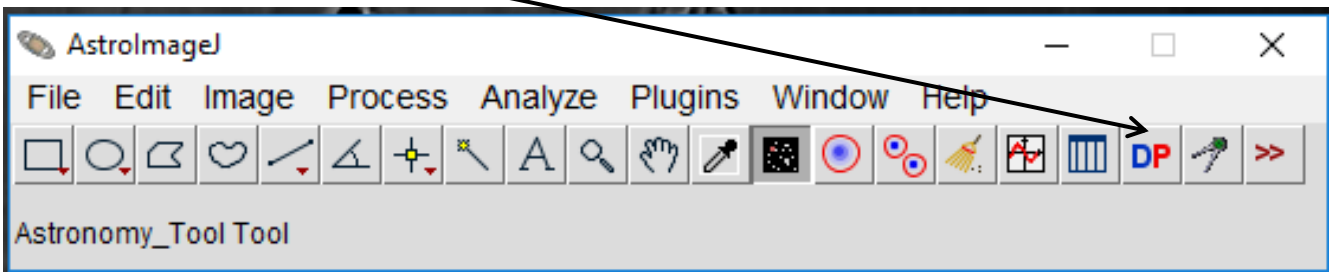
http://astroimagej.1065399.n5.nabble.com/OS-X-10-12-and-10-13-Installation-Workaround-for-AIJ-td567.html

CALIBRATING IMAGES

The first step in processing is to calibrate the images using bias, dark, and flat field frames. Skynet already creates master frames for these images which is a big-time saver. All you have to do is apply them to your image. This is an important step regardless of what telescope you are using.

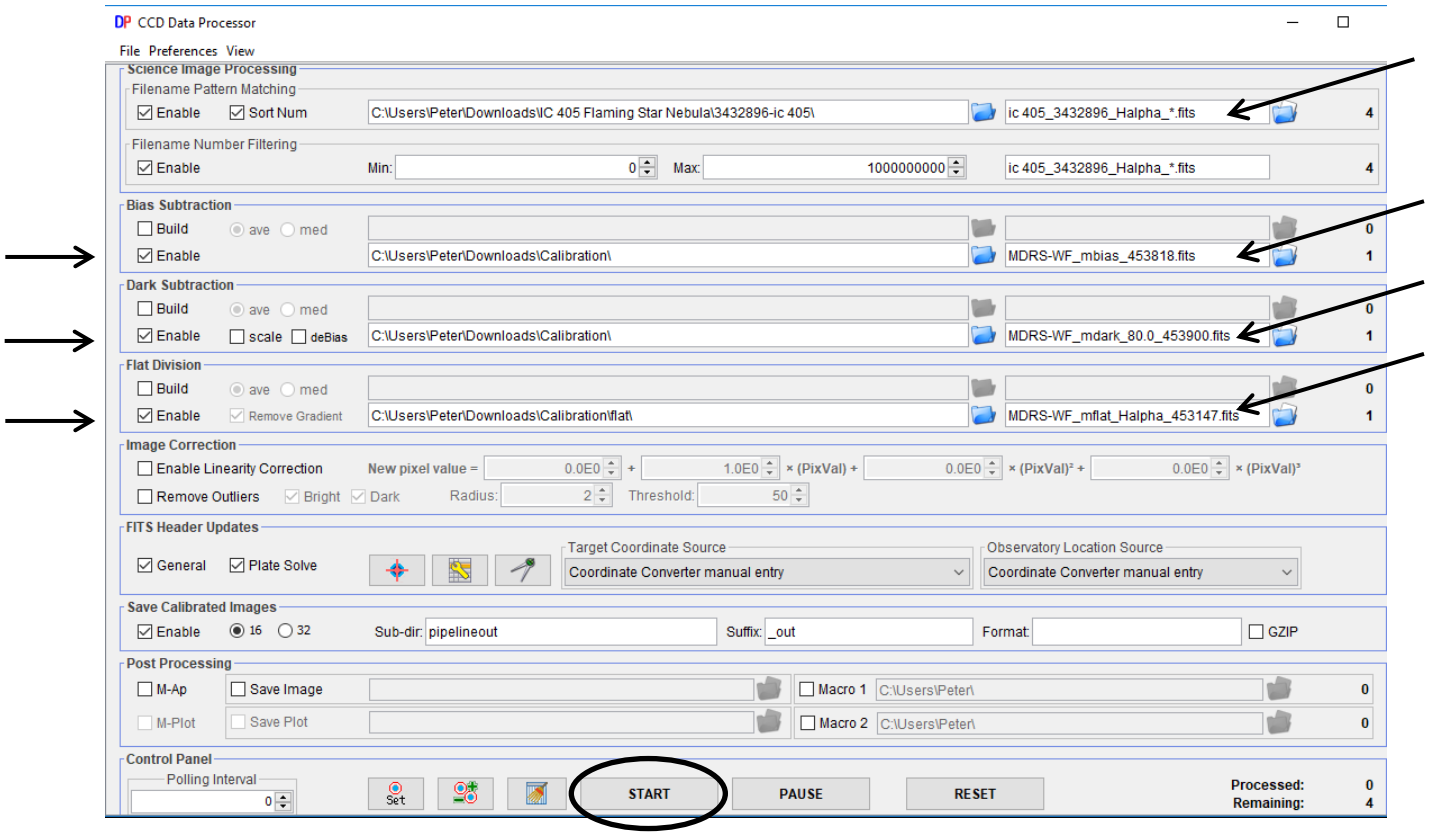
Download the Calibration Frames: You can download the master calibration frames as shown in the section under downloading images. Make certain you also download the fits files, and put them in a single folder on your computer, along with your images, in order that everything is together.

Open AstroimageJ and under the tab **PROCESS**, click on the **DATA REDUCTION FACILITY** or use the **DP** shortcut.

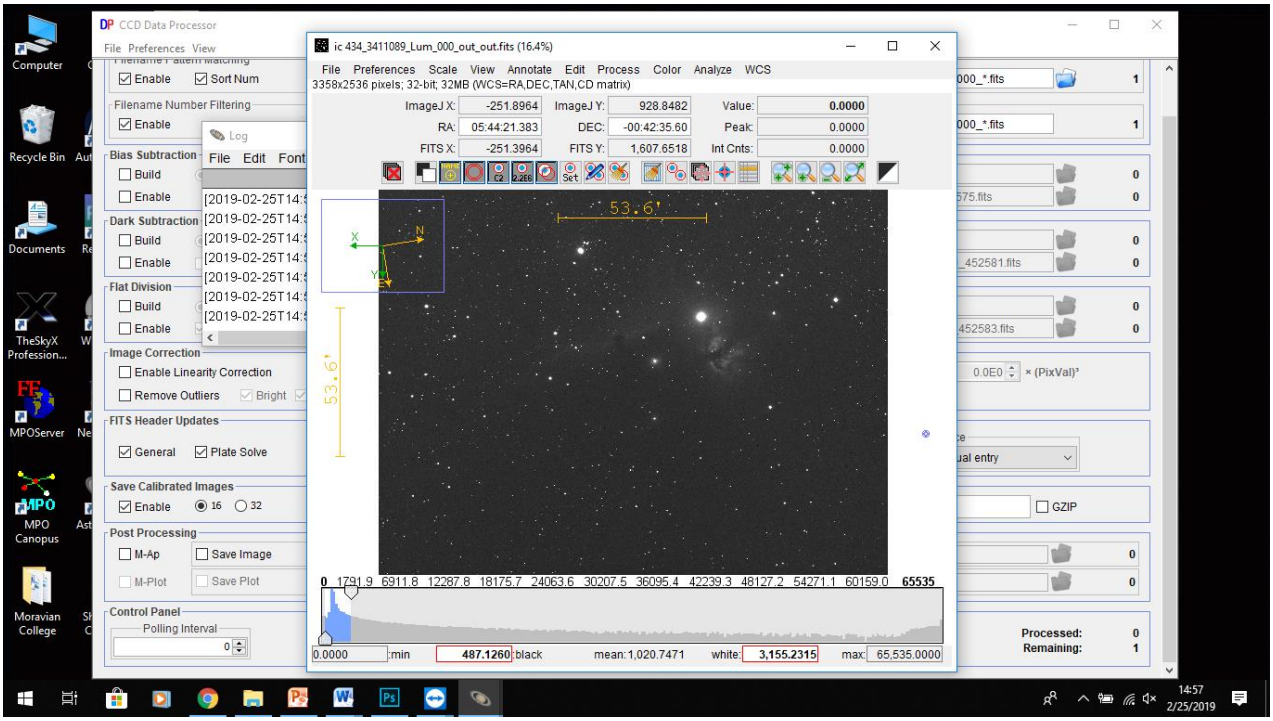


Two files will open with lots of numbers. We don't need the **DP Coordinate Converter** right now. You can close it out.

<u>CCD Data Processor</u>. This is what you'll be using to calibrate the images. Fields are provided to define the directory/folder locations and file names of data to be processed. Click on the folder icon, and go to the folder where your files are downloaded, and select the image(s). Detailed instructions can be found in "Chapter 6" of the *AstroImage J User Guide*. Skynet has already created master calibration frames so you do not have to build them, just enable them. Press **START** when ready.



The final image(s) will come up. Notice the final name is already different and is designated in a folder labeled **PIPELINE OUT**. Your image is now calibrated.



SOFTWARE AND RESOURCES

Skynet

Website where you will be making and collecting observations with the robotic telescope.
Homepage: https://skynet.unc.edu/

AstroImage J

This is the freeware package I recommend in this manual.
Homepage: https://www.astro.louisville.edu/software/astroimagej/
User guide: http://www.astro.louisville.edu/software/astroimagej/guide/AstroImageJ_User_Guide.pdf

Image processing Resources for Astronomy Teaching

A great list of astronomy imaging software, both freeware and for purchase. Also has resources for remote telescopes and Citizen Science Projects.
https://webhome.phy.duke.edu/~kolena/imagepro.html#ip

American Association of Variable Star Observers

The AAVSO is an amazing source for finding observing projects and submitting data.
Homepage: https://www.aavso.org/

IAU Minor Planet Center

Professional site with data on asteroids and comets. Also, it is a good place to check on or submit new discoveries.
Homepage: https://www.minorplanetcenter.net/iau/mpc.html