

1. INTRODUCTION TO SKYNET

EQUIPMENT

Computer with internet connection

GOALS

In this lab, you will learn how to:

1. Observe astronomical objects with UNC's PROMPT telescopes at the Cerro Tololo Inter-American Observatory in the Chilean Andes and with other telescopes around the world in UNC's Skynet Robotic Telescope Network
2. Adjust the brightness and contrast levels of astronomical images to better view detail in them
3. Measure angles between and across objects in your images
4. Identify objects in your images that are moving through that part of the sky

BACKGROUND

A. PROMPT TELESCOPES

Dr. Dan Reichart and his students began building the **Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT)** in 2004, at the **Cerro Tololo Inter-American Observatory (CTIO)** in the Chilean Andes:

<http://skynet.unc.edu/videos/construction/>

CTIO is one of the premier observatories in the world:



The telescope at the top of the mountain is the 4-meter diameter Blanco telescope. The red X marks where Dr. Reichart's group will begin building a seventh, larger PROMPT telescope in late 2009.

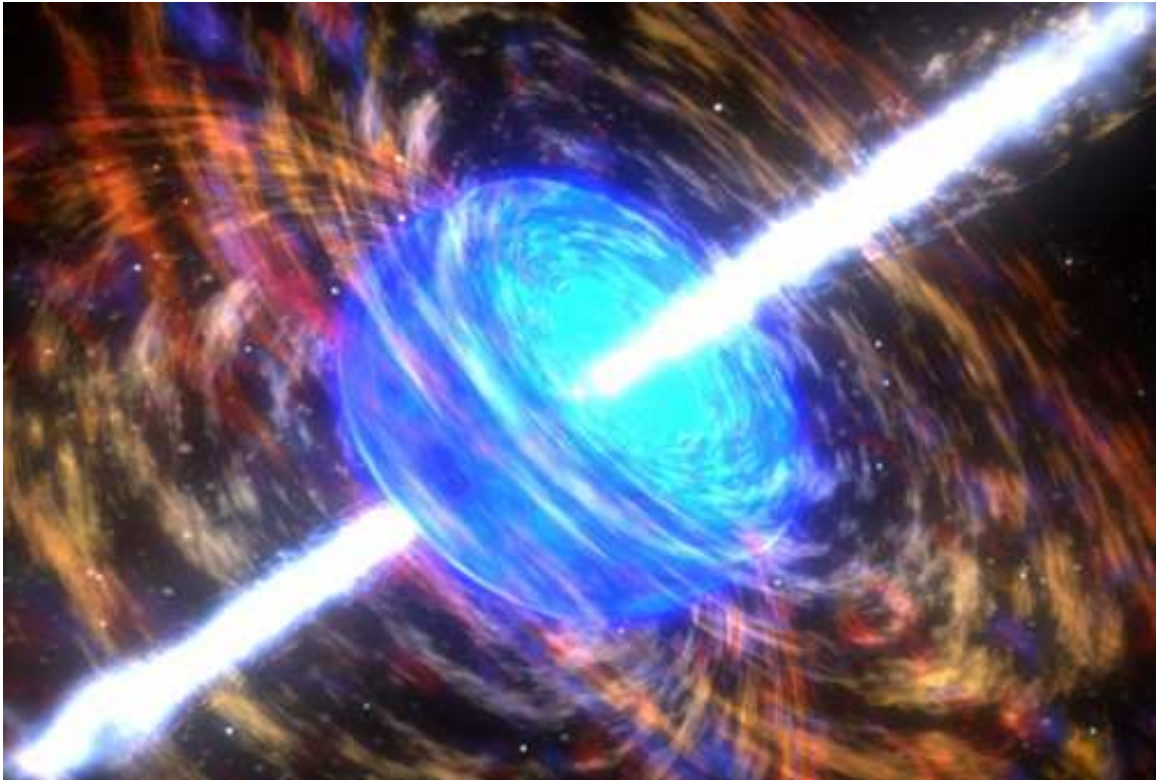
The PROMPT telescopes are unique in that they are run by computers instead of by humans. Such telescopes are called robotic telescopes.

Each evening, the telescopes' domes open automatically and the telescopes prepare to take their first observations:

<http://skynet.unc.edu/videos/domes/>

Computers also monitor the weather. If it becomes too humid or too windy, they close the domes.

Dr. Reichart's group built these telescopes to observe cosmic explosions called **gamma-ray bursts (GRBs)**. GRBs are the death cries of massive stars and the birth cries of black holes:



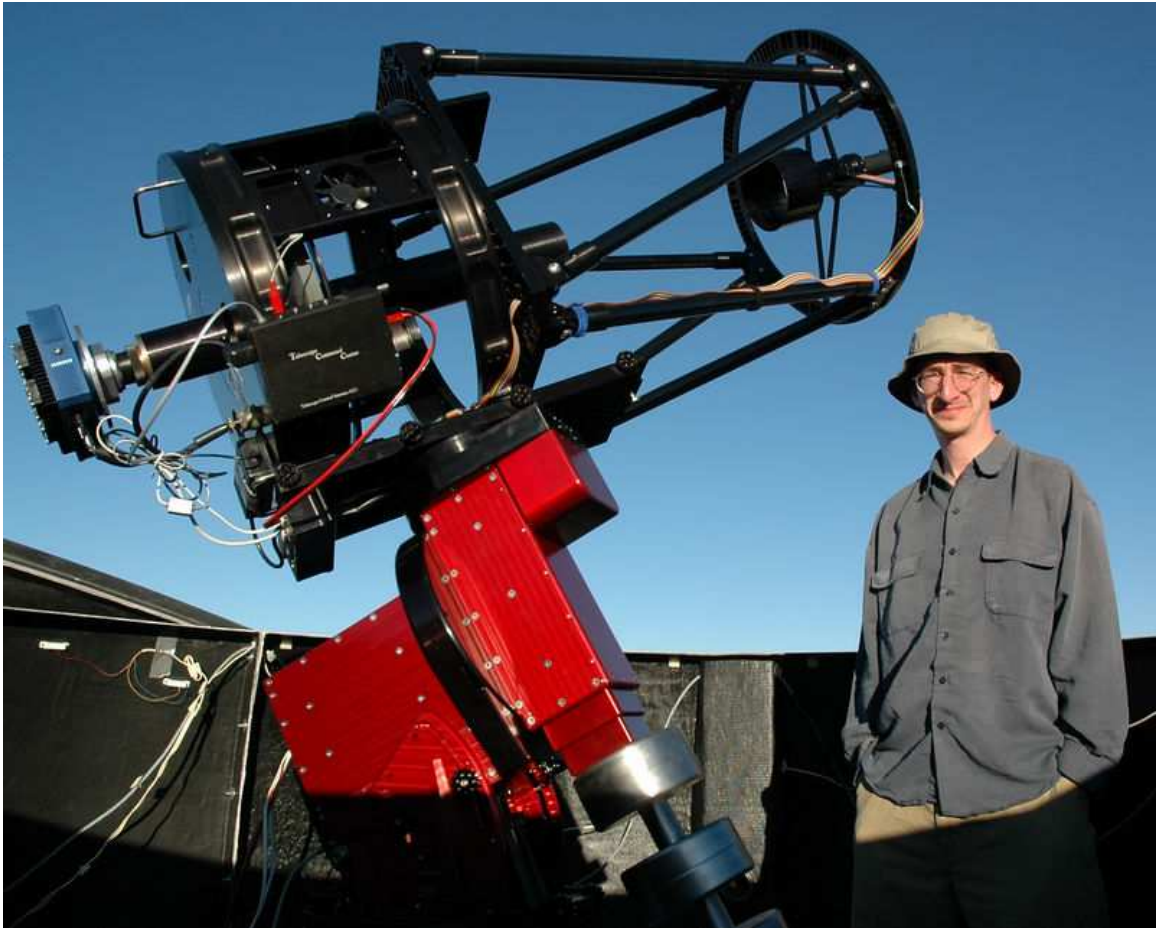
Artist's conception of a GRB in progress

GRBs are the biggest bangs since the Big Bang. They are so luminous that they can be observed with relatively small telescopes, even if very far away. However, they fade quickly, often lasting only minutes. Consequently, PROMPT was built to be fast, not big.

In 2005, UNC undergraduate Josh Haislip and Dr. Reichart used one of the PROMPT telescopes to discover the most distant explosion in the universe then known – a GRB that was 12.8 billion light years away. Since the universe is only 13.7 billion years old, this star died when the universe was only 6% of its current age. This was over 8 billion years before Earth even formed!

When not observing GRBs, which is over 90% of the time, PROMPT is used by other researchers across the state, country, and world, by students of all ages – graduate through elementary – and by the general public.

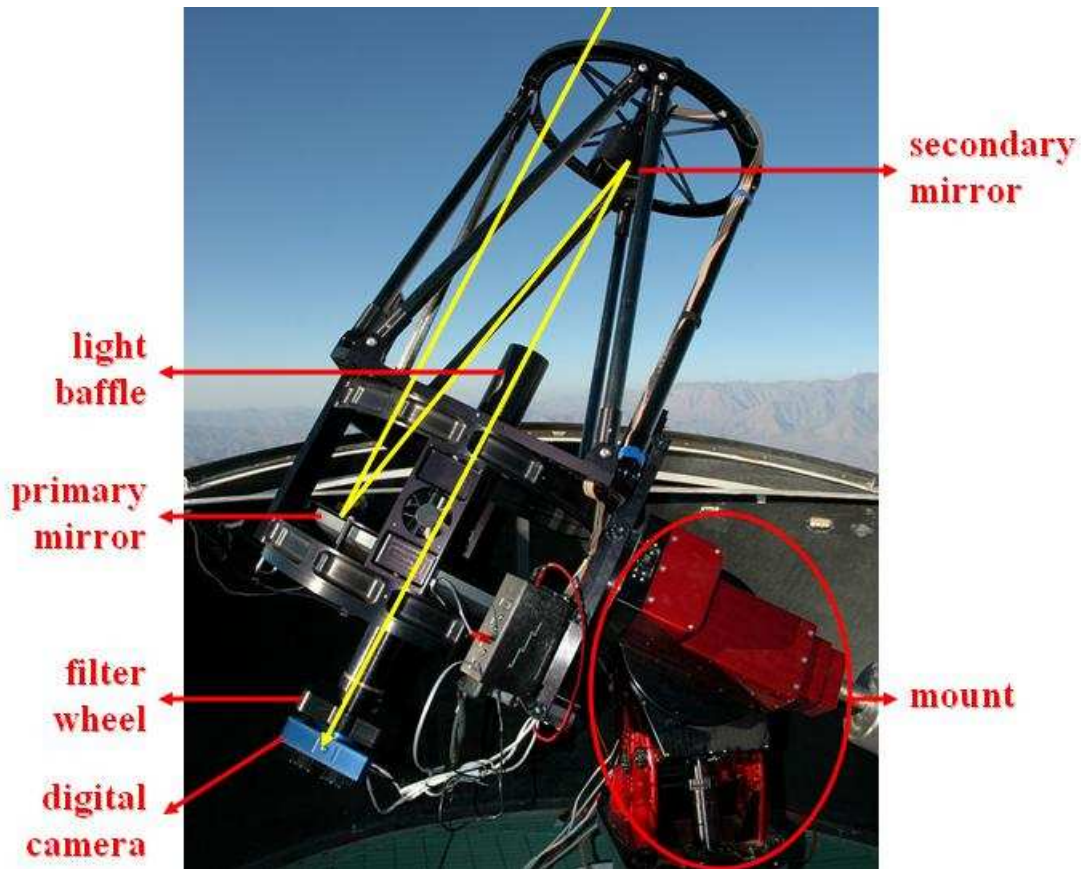
Here is one of the PROMPT telescopes up close, with Dr. Reichart next to it for scale:



The most important part of a telescope is actually the **mount** on which the telescope sits. Mounts need to be able to point well and track the motion of the sky well, or images will be off-center and distorted.

PROMPT telescopes look different from most telescopes in that they are open, instead of enclosed by a tube. This is so wind, which is sometimes strong at CTIO, can pass through the telescopes, instead of shaking them, which also distorts images.

When light from space enters one of the PROMPT telescopes, it bounces first off of a 16-inch diameter **primary mirror** and then off of a smaller **secondary mirror**. (The larger the primary mirror, the more light a telescope can collect in the same amount of time.)



The secondary mirror redirects the light first through a tube called a **light baffle** and then through a hole in the center of the primary mirror. The light baffle helps to prevent stray light from contaminating images.

Once behind the telescope, the light enters a **filter wheel**, which can rotate different colors of glass into the path of the light, so only that color of light can pass through:



Finally, light of the selected color enters a **digital camera** and is recorded. Astronomical digital cameras are called **charge-coupled devices (CCDs)** and are similar to regular digital cameras except that (1) they are designed to work at much lower light levels, and (2) they only take black and white images.

Consequently, if you want to make a color picture with a CCD, you must take three pictures – one using a red filter, one using a green filter, and one using a blue filter – and then combine them into a color picture using a computer:

Red Filter



Green Filter



Blue Filter



RGB Combined



Notice how objects with a lot of red in their color are brightest in the red filter, objects with a lot of green in their color are brightest in the green filter, and objects with a lot of blue in their color are brightest in the blue filter. White objects have equal amounts of red, green, and blue.

PROMPT is a complicated system. It can fail in many ways, some of which you may encounter this semester.

However, PROMPT's control software – called **Skynet** – is well written and can identify most failures as they occur. If Skynet identifies a failure, either (1) it corrects it itself, or (2) if it cannot, it communicates the failure to Dr. Reichart's group (by both email and text message).

Dr. Reichart's group can correct most failures remotely, and relatively quickly – usually within minutes to hours.

If a failure occurs that cannot be corrected remotely, Dr. Reichart's group works with staff at CTIO to correct it as quickly as possible. But this usually takes longer – hours to even months, depending on the severity of the failure. Fortunately, such failures are rare.

Otherwise, Dr. Reichart's group travels to the site to maintain and improve the equipment at least once per year.

Whether due to failure or maintenance, if any of the PROMPT telescopes go offline this semester, we will continue our labs on the remaining telescopes.

If daytime, you can usually view the PROMPT site here:

<http://skynet.unc.edu/promptcam/>

If daytime, you can sometimes view individual PROMPT telescopes here:

<http://skynet.unc.edu/video/>

B. SKYNET ROBOTIC TELESCOPE NETWORK

Like PROMPT, Skynet was developed and continues to be improved upon by Dr. Reichart's group.

Skynet is unique in that it can control not only UNC's PROMPT telescopes, but a wide variety of telescopes. As of January 2010, 12 telescopes spanning three continents have joined UNC's Skynet Robotic Telescope Network:

Telescope	Site	Diameter	Availability	Owner
Dolomiti	Dolomiti Astronomical Observatory, Italy	16-inch	Poor	Carlo Magno Zeledria Hotel
DSO-14	Dark Sky Observatory, NC	14-inch	Good	Appalachian State University
HSC	Hampden-Sydney College Observatory, VA	16-inch	Poor	Hampden-Sydney College
GORT	Hume Observatory, CA	14-inch	Fair	Sonoma State University
Morehead	Morehead Observatory, NC	24-inch	Poor	UNC
PARI-16	Pisgah Astronomical Research Institute, NC	16-inch	Poor	Pisgah Astronomical Research Institute
PROMPT-1	CTIO, Chile	16-inch	Excellent	UNC
PROMPT-2	CTIO, Chile	16-inch	Excellent*	UNC
PROMPT-3	CTIO, Chile	16-inch	Excellent	UNC
PROMPT-4	CTIO, Chile	16-inch	Excellent	UNC
PROMPT-5	CTIO, Chile	16-inch	Excellent	UNC
TTT	Coyote Rim Ranch, CO	14.5-inch	Poor	Jack Harvey

** For the two weeks that the moon is more than half full. For the two weeks that the moon is less than half full, UNC sells this telescope's time to help pay PROMPT's operating costs.*

Telescopes with excellent availability are open for at least part of >75% of nights. Telescopes with good availability are open for at least part of 50% – 75% of nights. Telescopes with fair availability are open for at least part of 25% – 50% of nights. Telescopes with poor availability are open for at least part of <25% of nights.

The availability of some of these telescopes will increase as we continue to better integrate them into Skynet. New telescopes are in the process of being integrated into Skynet as well.

You are welcome to observe with any of the Skynet telescopes. Availability and image quality are usually best with the PROMPT telescopes. However, PROMPT is in the southern hemisphere and consequently cannot image all northern sky objects.

PROCEDURE

A. OBSERVE WITH SKYNET

To observe with Skynet, go to:

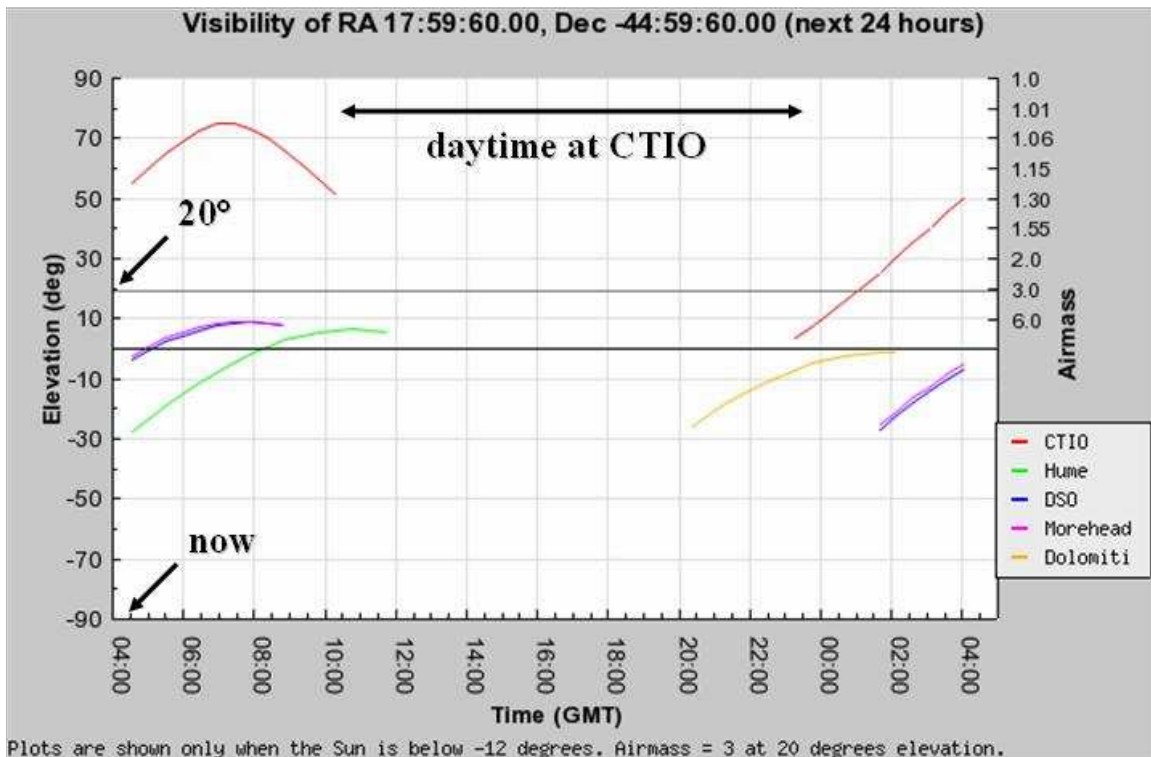
<http://skynet.unc.edu>

Your instructor will provide you with a username and password.

Next, watch the following tutorial:

<http://skynet.unc.edu/ASTR101L/videos/observe/>

Remember, for an object to be observable, it must be greater than 20° above the horizon for at least part of the night at at least one of the Skynet sites. For example, in the following observability chart, the selected southern sky object is observable from CTIO, but not from Skynet's northern hemisphere sites:



Also remember, the more telescopes that you select, the more likely that Skynet will be able to observe your object quickly. Depending on telescope availability, it will take anywhere from seconds to days to get your images.

Choose Acceptable Telescopes:
[\[Back\]](#)

- Morehead
- Prompt3
- Prompt4
- Prompt5

Also remember to request only one exposure per observation:

Add Exposures
[\[Back\]](#)

Color Band	Num. Exps	Duration (sec)
Open	<input type="text" value="1"/>	<input type="text" value="80"/>

Multiple durations may be specified as a comma-separated list (e.g. 10,20,40)

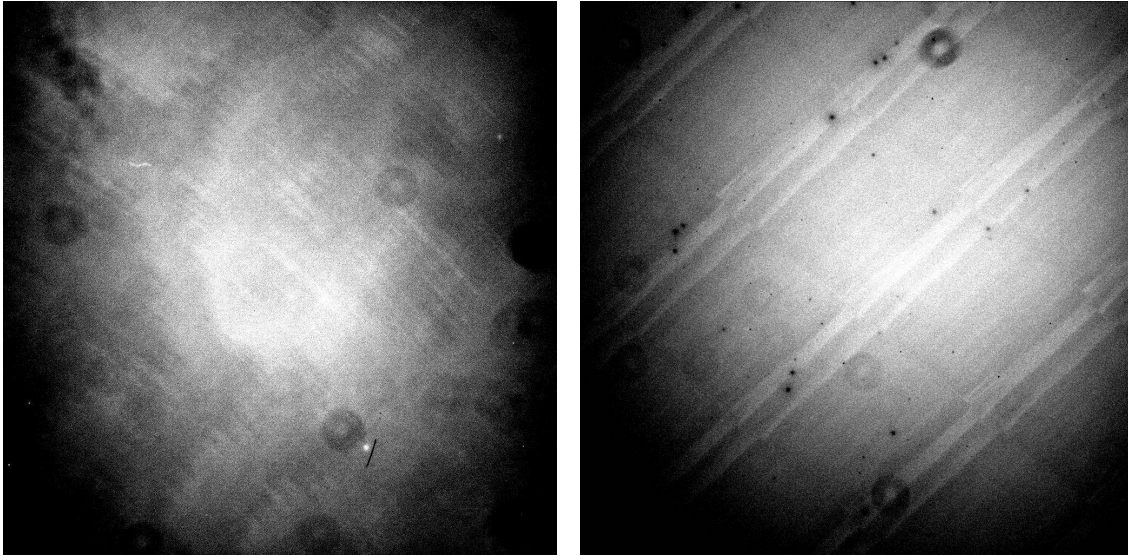
Repeat these exposures time(s) with minutes between groups of exposures.

In the following tutorial, you will learn how to check your images once they have been taken:

<http://skynet.unc.edu/ASTR101L/videos/check/>

If any of your images are of poor quality for any reason, re-observe them.

Images can be of poor quality due to clouds blocking all of the light:

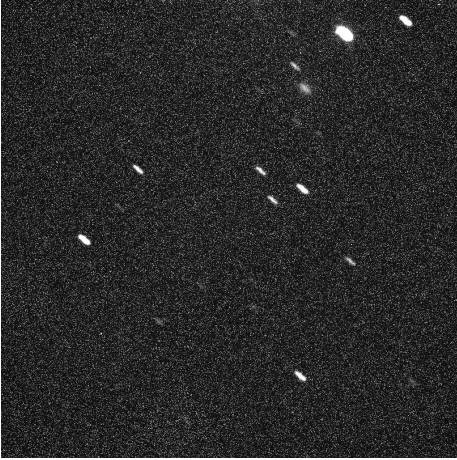


(When this occurs, all that remains to be seen is the response pattern of the CCD and out-of-focus dust on the camera window.)

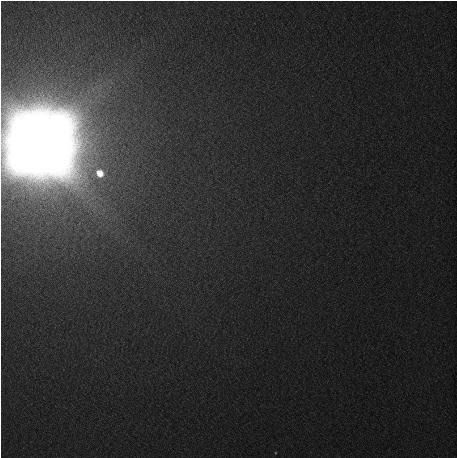
Due to clouds blocking some of the light (left vs. right):



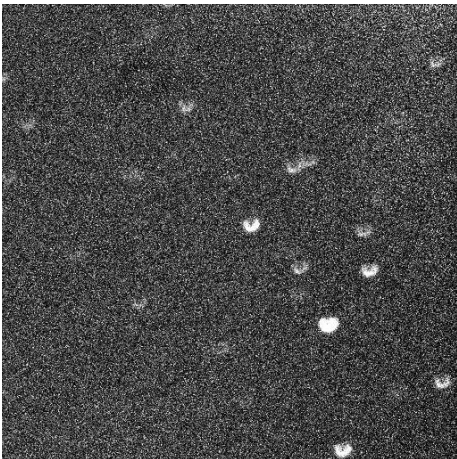
Due to wind or mount misbehavior distorting or streaking the images:



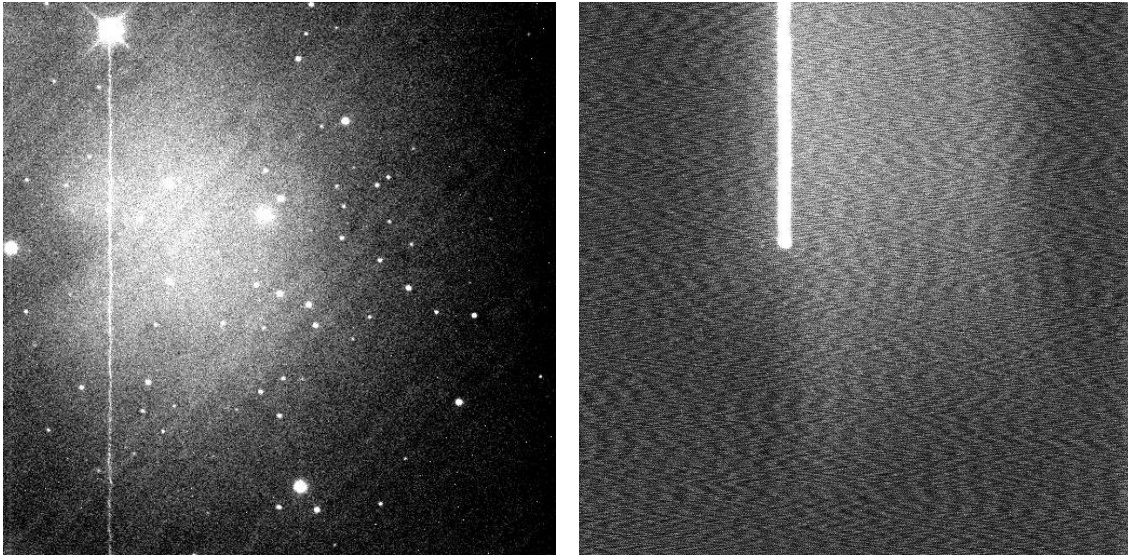
Due to mount misbehavior off-centering the images:



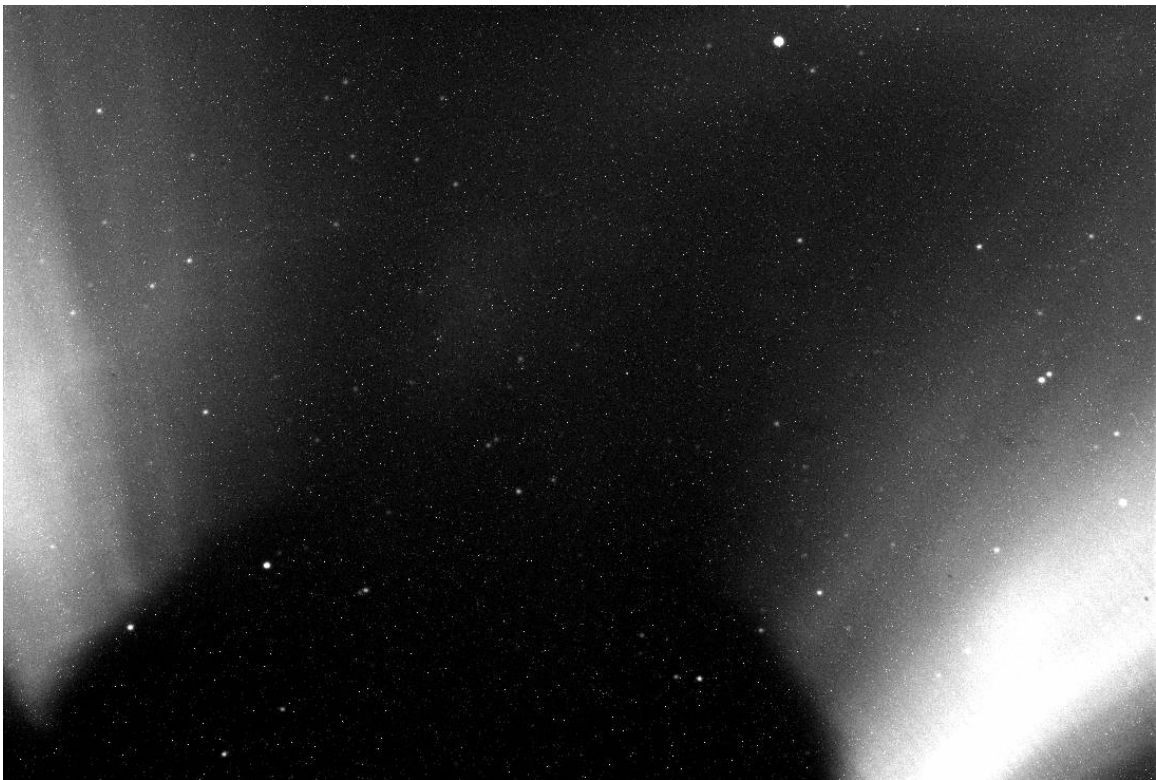
Due to focus misbehavior:



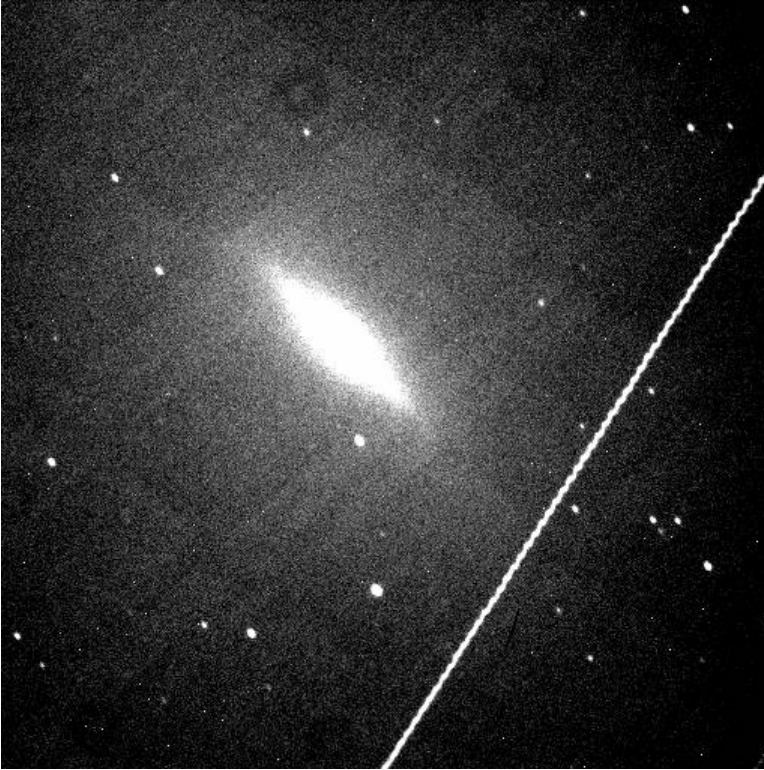
Due to camera shutter sticking:



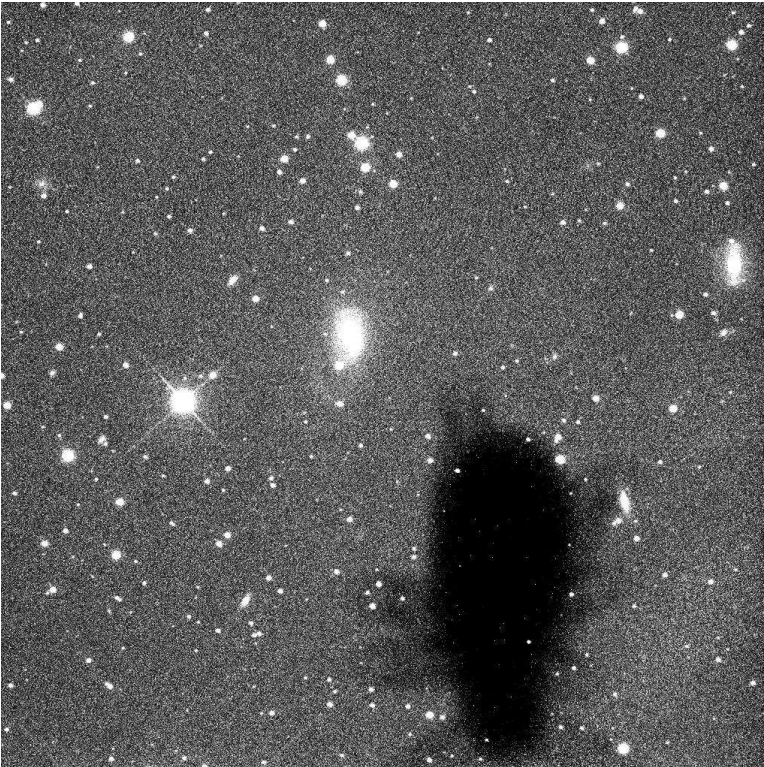
Due to proximity to the moon or someone leaving a light on at the telescope:

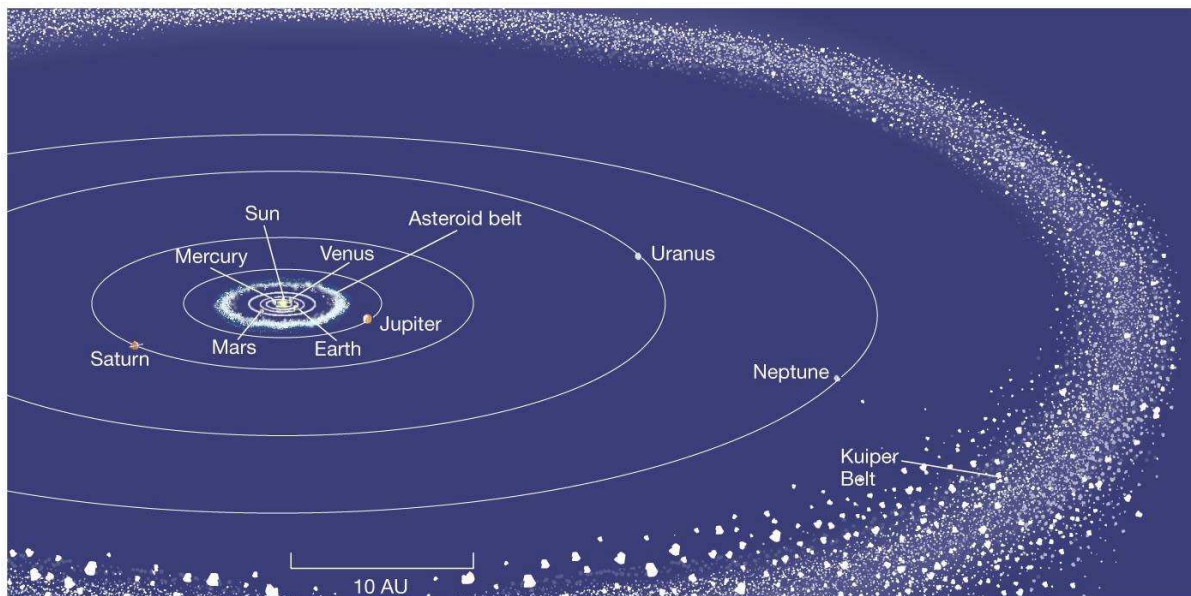


Due to a satellite moving through that part of the sky during the exposure:



And even due to a bug sitting on the camera window!





Observe all observable planets. If observable from CTIO, use PROMPT.

Note: If not observable this time of year, do not observe it!

Planet	Location	Filter*	Exposure Duration (seconds)**
Mercury	Inner Solar System	U	0.03
Venus	Inner Solar System	U	0.03
Mars	Inner Solar System	U	0.1
Jupiter	Outer Solar System	U	0.1
Saturn	Outer Solar System	V	0.1
Uranus	Outer Solar System	V	1
Neptune	Outer Solar System	V	3

* U lets much less light than V through the filter wheel. It is useful for bright objects.

** For PROMPT. Other telescopes might require longer exposures.



The solar system's seven large moons

Aside from Earth's moon, all of the solar system's large and medium-sized moons orbit Jupiter, Saturn, Uranus, or Neptune. Different filters and exposure durations can be used to better observe and observe more of these moons, but often at the expense of over-exposing the significantly brighter planets.

Observe large and medium-sized moons around all observable planets. If observable from CTIO, use PROMPT.

Note: To observe a planet's moons, observe the planet, not the moons. The moons should be in the image.

Note: If not observable this time of year, do not observe it!

Planet	Location	Filter*	Exposure Duration (seconds)**
Jupiter	Outer Solar System	V	0.03
Saturn	Outer Solar System	Open	0.03
Uranus	Outer Solar System	Open	1
Neptune	Outer Solar System	Open	1

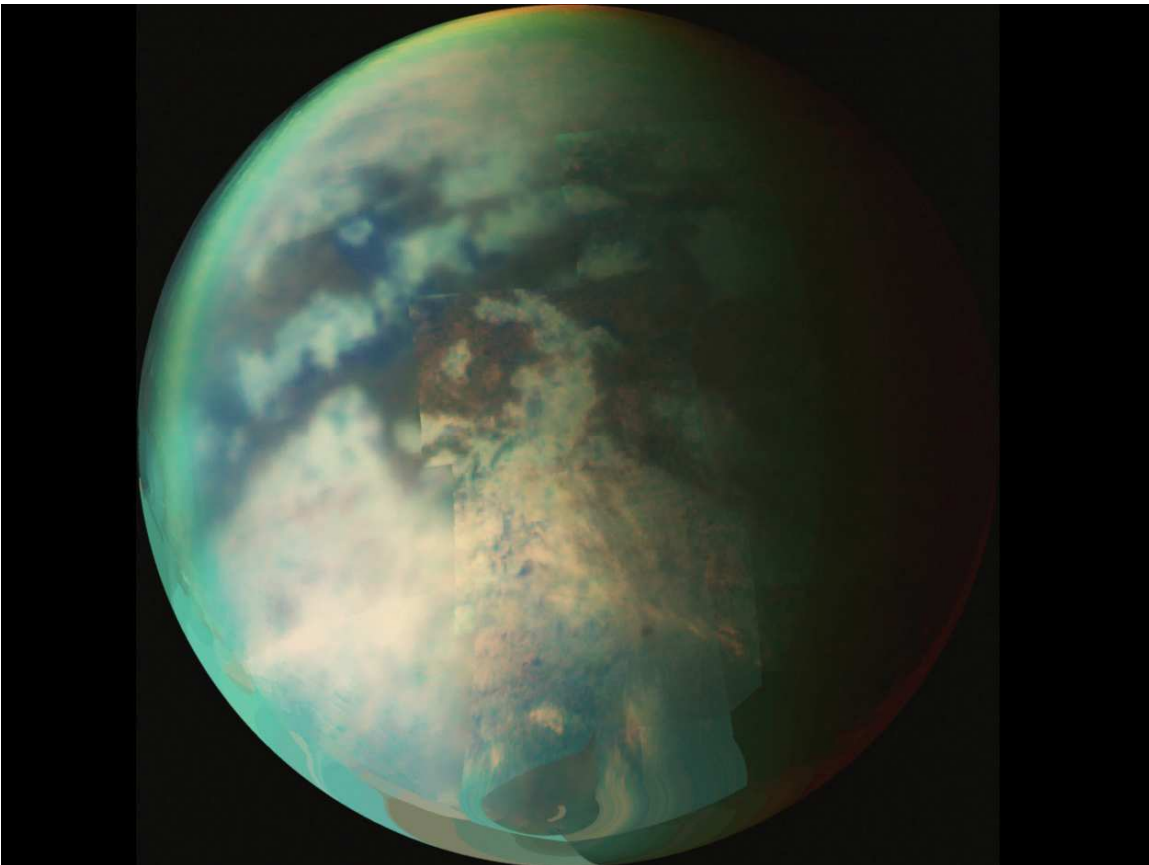
* *Open lets much more light than V through the filter wheel. It is useful for faint objects.*

** *For PROMPT. Other telescopes might require longer exposures.*

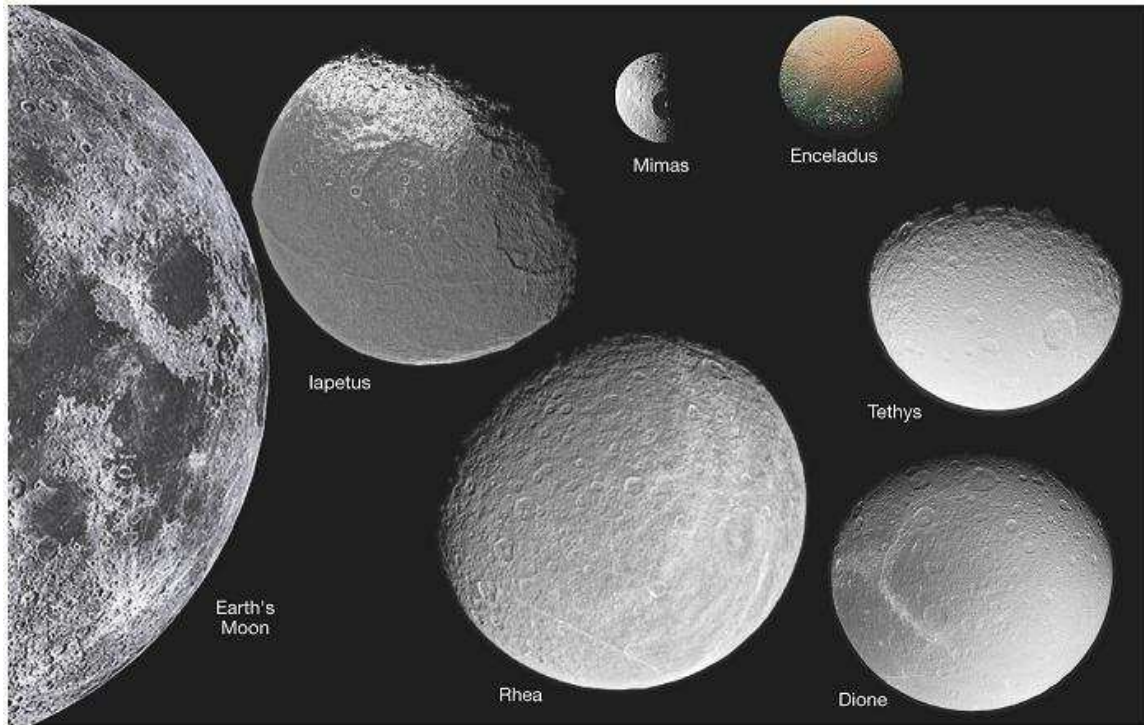
Jupiter has four large moons (left to right: Io, Europa, Ganymede, and Callisto), but no medium-sized moons:



Saturn has one large moon (Titan):



And six medium-sized moons:

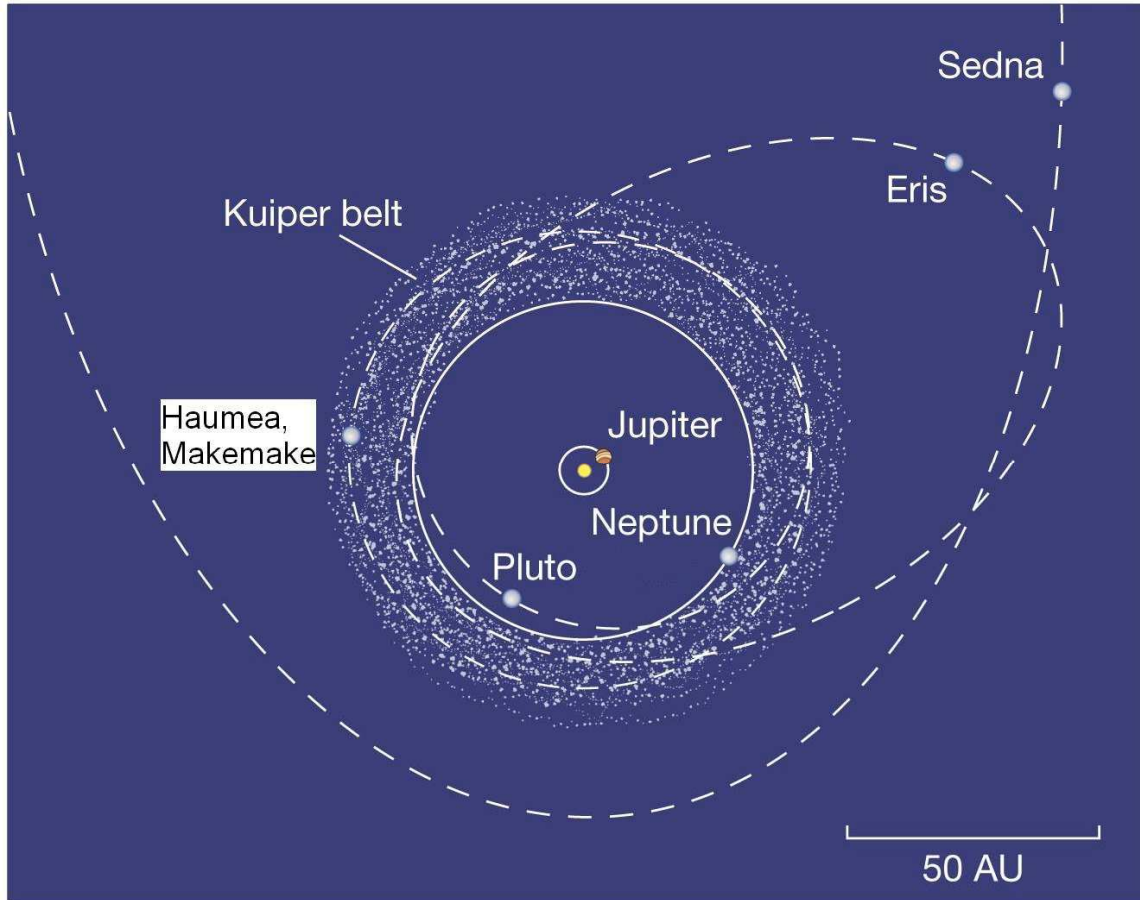


Uranus has no large moons, but five medium-sized moons:



Neptune has one large moon (Triton) and two medium-sized moons:





Observe all observable dwarf planets. If observable from CTIO, use PROMPT.

Note: If not observable this time of year, do not observe it!

Dwarf Planet*	Location	Filter	Exposure Duration (seconds)**
Ceres	Asteroid Belt	V	3
Pluto	Kuiper Belt	Open	80
Haumea	Kuiper Belt	Open	80
Makemake	Kuiper Belt	Open	80

* The dwarf planet Eris is too faint to observe with PROMPT in a single exposure.

** For PROMPT. Other telescopes might require longer exposures.

Observe one deep sky object from the following list of nebulae. If observable from CTIO, use PROMPT.

Note: If not observable this time of year, do not observe it!

Deep Sky Object	Object Type	Filter	Exposure Duration (seconds)*
Lagoon Nebula (M8)	Star Forming Region	Open	20
Orion Nebula (M42)	Star Forming Region	Open	20
Tarantula Nebula (NGC 2070)	Star Forming Region	Open	40
Trifid Nebula (M20)	Star Forming Region	Open	40
Crab Nebula (M1)	Supernova Remnant	Open	80
Eagle Nebula (M16)	Star Forming Region	Open	80

** For PROMPT. Other telescopes might require longer exposures.*

Observe one deep sky object from the following list of star clusters. If observable from CTIO, use PROMPT.

Note: If not observable this time of year, do not observe it!

Deep Sky Object	Object Type	Filter	Exposure Duration (seconds)*
47 Tucanae (NGC 104)	Globular Cluster	Open	20
M3	Globular Cluster	Open	40

** For PROMPT. Other telescopes might require longer exposures.*

Observe one deep sky object from the following list of galaxies. If observable from CTIO, use PROMPT.

Note: If not observable this time of year, do not observe it!

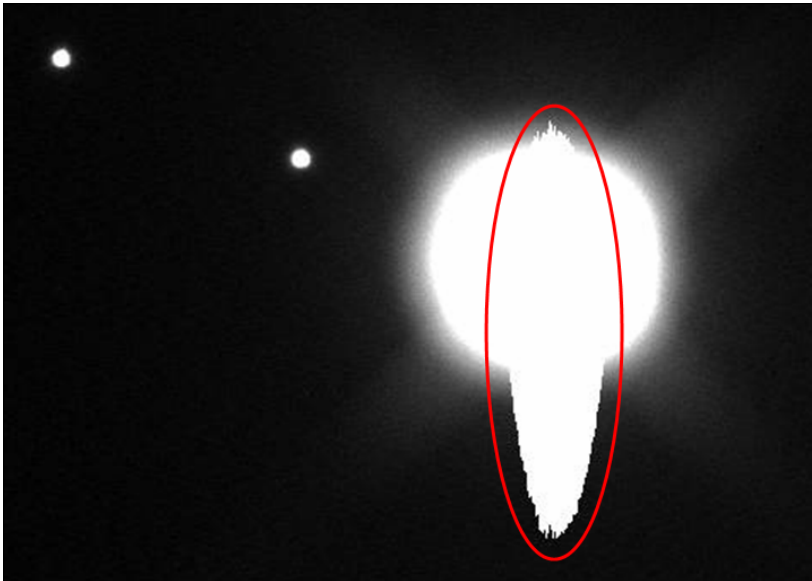
Deep Sky Object	Object Type	Filter	Exposure Duration (seconds)*
Centarus A (NGC 5128)	Elliptical Galaxy	Open	40
Sculptor Galaxy (NGC 253)	Spiral Galaxy	Open	40
Southern Pinwheel (M83)	Spiral Galaxy	Open	80
Spindle Galaxy (NGC 3115)	Spiral Galaxy	Open	80

** For PROMPT. Other telescopes might require longer exposures.*

Finally, you are welcome to use Skynet to observe any object that you are curious about this semester.

You are also welcome to re-observe these objects with different filters, exposure durations, and maximum airmasses.

The longer your exposure duration, the more detail that you may see. However, if you expose for too long, you may over-expose the bright parts of your images:



By lowering your maximum airmass (the default value is 3, the lowest value is 1), you are limiting how much atmosphere Skynet observes through. The less atmosphere that Skynet observes through, the higher quality that your images may be. However, if you lower the maximum airmass too much, fewer telescopes may be able to observe your object and those that can will have a shorter window of opportunity to do so. Consequently, you may have to wait longer to get your images.

Observation Name: RA: (H:M:S) : :

If interrupted... DEC: ° ' ''

Priority: Max Airmass: Group:

Max Sun Elevation: Don't start before (UTC):

[\[example time formats\]](#)

Select filters:

<input type="checkbox"/> U	<input type="checkbox"/> gprime	<input type="checkbox"/> Blue
<input type="checkbox"/> B	<input type="checkbox"/> rprime	<input type="checkbox"/> Rc
<input type="checkbox"/> V	<input type="checkbox"/> iprime	<input type="checkbox"/> Ic
<input type="checkbox"/> R	<input type="checkbox"/> zprime	<input type="checkbox"/> Clear
<input type="checkbox"/> I	<input type="checkbox"/> Open	<input type="checkbox"/> Halpha
<input type="checkbox"/> Lum	<input type="checkbox"/> Red	<input type="checkbox"/> OIII
<input type="checkbox"/> uprime	<input type="checkbox"/> Green	

B. ANALYZE YOUR IMAGES

EXERCISE 1

Go to:

<http://skynet.unc.edu/afterglow/>

In the following tutorial, you will learn how to view your images in **Afterglow** and how to adjust their brightness and contrast levels to bring out detail in them:

<http://skynet.unc.edu/ASTR101L/videos/afterglow/>

In the following tutorial, you will learn how to mark and label objects in your images, and how to save your adjusted, marked, and labeled images as jpeg files:

<http://skynet.unc.edu/ASTR101L/videos/markers/>

For the planets that you observed, and for the dwarf planet Ceres if you observed it, use Afterglow to adjust the brightness and contrast levels of your images to bring out as much detail in them as possible. Save your best image of each object as a jpeg file and include it in your lab report. Describe and discuss any detail that you see in the images.

EXERCISE 2

In the following tutorial you will learn how to view information about your image, including which telescope took it and the date and time that it did:

<http://skynet.unc.edu/ASTR101L/videos/information/>

For each final image from Exercise 1, use Afterglow to identify which telescope took it and the system (not universal) date and time that it did. Record this information in Table 1.

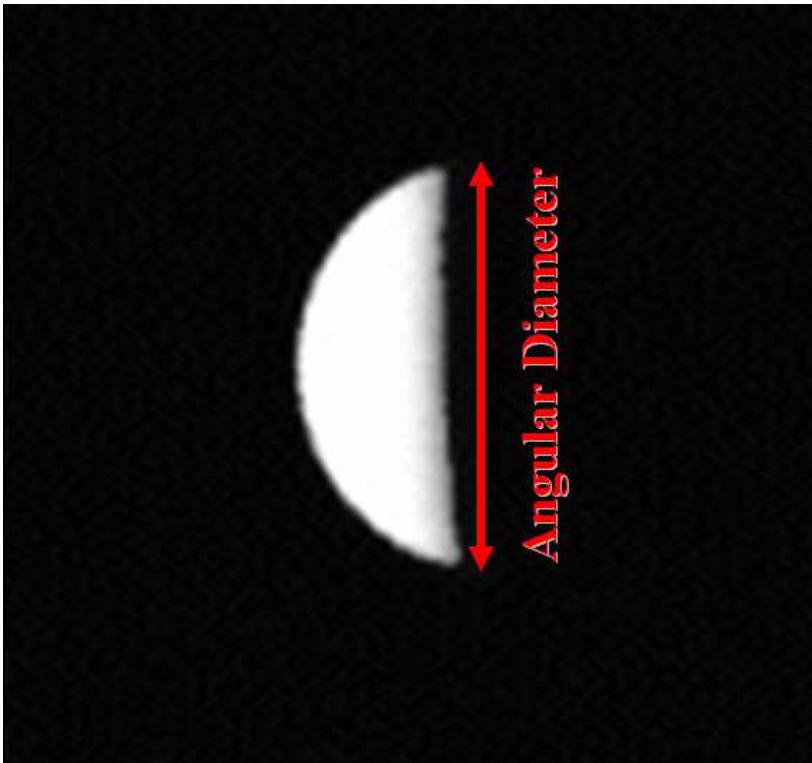
In the following tutorial, you will learn how to measure angles between and across objects in your images:

<http://skynet.unc.edu/ASTR101L/videos/angles/>

For each final image from Exercise 1, use Afterglow (1) to adjust the brightness and contrast levels such that the planet or dwarf planet is not washed out, and (2) to measure the planet's or dwarf planet's angular diameter to the nearest 0.1 arcseconds and record it in Table 1.

Note: For Saturn, measure the angular diameter of its rings.

Note: If the planet's phase is not full, it will not appear circular. If so, measure its angular diameter along its longer axis:



EXERCISE 3

Download a free copy of **Stellarium**:

<http://www.stellarium.org/>

In the following tutorial, you will learn how to use Stellarium to simulate how planets, their moons, and dwarf planets appeared in the sky when Skynet observed them:

<http://skynet.unc.edu/ASTR101L/videos/stellarium/>

Remember, for any of your images that you simulate with Stellarium, you must first change Stellarium's location to a city that is near to the telescope that took the image:

Telescope	Nearby Location
Dolomiti	Trento, Italy
DSO-14	Asheville, United States
HSC	Lynchburg, United States
GORT	Santa Rosa, United States
Morehead	Chapel Hill, United States
PARI-16	North Canton, United States
PROMPT-1	La Serena, Chile
PROMPT-2	La Serena, Chile
PROMPT-3	La Serena, Chile
PROMPT-4	La Serena, Chile
PROMPT-5	La Serena, Chile
TTT	Fort Collins, United States

Also remember to change Stellarium's date and time to the system (not universal) date and time that Skynet took the image.

For each final image from Exercise 1, use Stellarium to find the planet's or dwarf planet's true angular diameter when Skynet took the image and record it to the nearest 0.1 arcseconds in Table 1.

Note: For Saturn, Stellarium gives the true angular diameter of its rings.

Calculate the percent error for each of your angular diameter measurements and record it in Table 1:

$$\text{percent error} = \frac{|\text{measured value} - \text{true value}|}{\text{true value}} \times 100\%$$

Note: The vertical lines in this equation mean “absolute value of” or “positive value of”. For example: $|-1138| = 1138$.

In your lab report, include Table 1, a sample percent error calculation, and discuss sources of error. In particular, discuss why objects with smaller angular diameters tend to have larger percent errors.

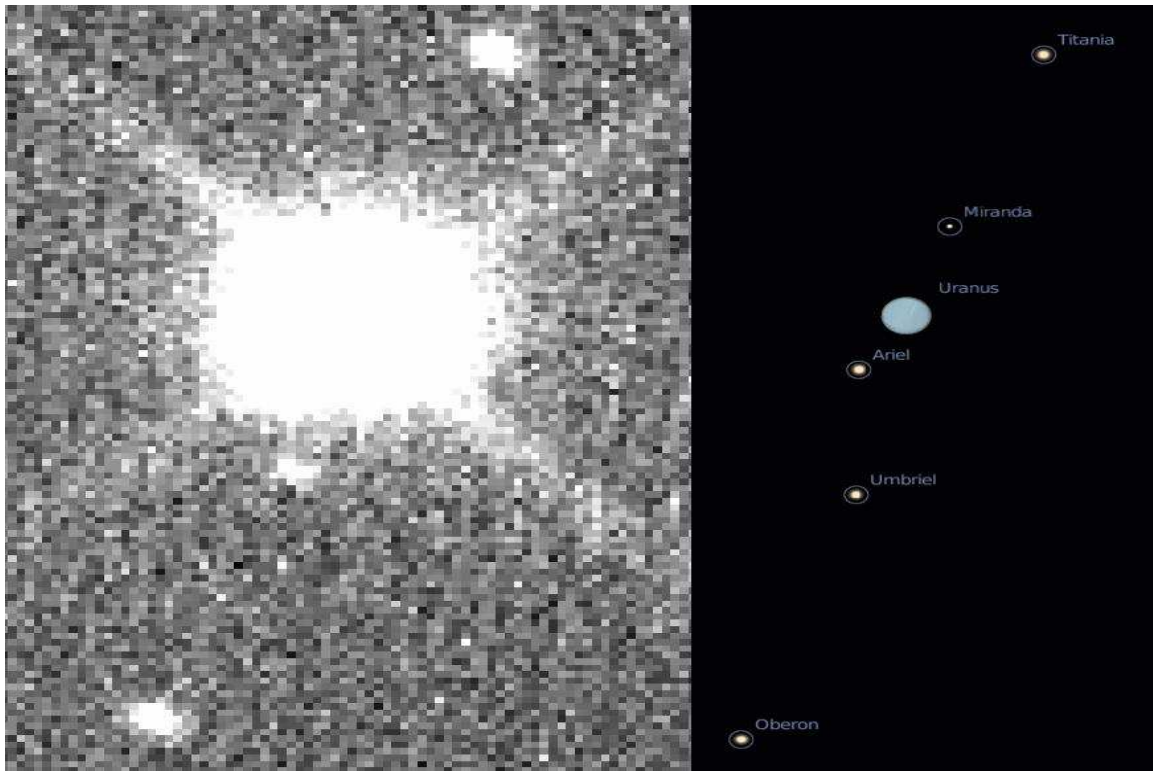
EXERCISE 4

For the large and medium-sized moons that you observed, use Afterglow to adjust the brightness and contrast levels of your images to bring out as many moons as possible. (It is okay if you wash out the planets.)

In the following tutorial, you will learn how to compare your images to Stellarium's simulations of them to identify the moons in your images:

<http://skynet.unc.edu/ASTR101L/videos/moons/>

Remember to set Stellarium's location, date, and time to those of your image. After zooming in to the planet in Stellarium, remember to view it equatorially, and then zoom out far enough to match as many of the objects in your image as possible to Stellarium's simulation of them. Keep in mind that moons or other objects that are close to the planet in Stellarium might be lost in the washing out of the planet in your image:



In the image (left), the moons Oberon, Umbriel, and Titania can be identified using Stellarium (right). However, the moons Ariel and Miranda are too close to Uranus, which is washed out in the image, to be identified.

If you do not see any moons when you think you should, it is possible that thin clouds blocked enough of the incoming light that you cannot see the moons but you can still see the planet, in which case you should re-observe.

Note: Neptune's moons do not appear in the most recent version of Stellarium. However, you should be able to see Triton, Neptune's largest moon, close to Neptune in your image.

For your best image of each planetary system, use Stellarium to identify as many moons as possible. Use Afterglow to label them and save the labeled image as a jpeg file. Include it in your lab report. Google each moon that you identified to learn more about it and include one fact about each of these moons in your lab report.

EXERCISE 5

In the following tutorial, you will learn how to compare your images to archival **Digitized Sky Survey (DSS)** images to find objects that are moving through that part of the sky:

<http://skynet.unc.edu/ASTR101L/videos/dss/>

For the dwarf planets in the Kuiper Belt that you observed, use Afterglow and the DSS to find the dwarf planets.

Next, use Afterglow to adjust the brightness and contrast levels of your images to bring out the dwarf planets. For your best image of each dwarf planet, label the dwarf planet and save the labeled image as a jpeg file. Include it in your lab report. Google each dwarf planet that you observed to learn more about it and include one fact about each of these dwarf planets in your lab report.

EXERCISE 6

Of the deep sky objects that you observed, select your favorite nebula, star cluster, and galaxy. For your selected objects, use Afterglow to adjust the brightness and contrast levels of your images to bring out as much detail in them as possible. Save your best image of each object as a jpeg file and include it in your lab report. Google each object and include a brief description of it in your lab report.

DATA TABLE 1: ANGULAR DIAMETERS

Object	Observable?	Telescope	System Date	System Time
Mercury				
Venus				
Mars				
Ceres				
Jupiter				
Saturn				
Uranus				
Neptune				

Object	Measured Angular Diameter (arcsec)	True Angular Diameter (arcsec)	Percent Error
Mercury			
Venus			
Mars			
Ceres			
Jupiter			
Saturn			
Uranus			
Neptune			