

## + EQUIPMENT

Computer with Internet connection

## + BACKGROUND: A. PROMPT TELESCOPES - 1. PROMPT, CTIO, and SSO

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.

CTIO is one of the premier observatories in the world.



*Five of the eight PROMPT-Chile telescopes, with our Milky Way galaxy and the planet Venus in the background.*

Dr. Reichart and his students added a second PROMPT site in 2013, at the Siding Spring Observatory (SSO) in Australia.

It is night in Australia when it is day in the United States.

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

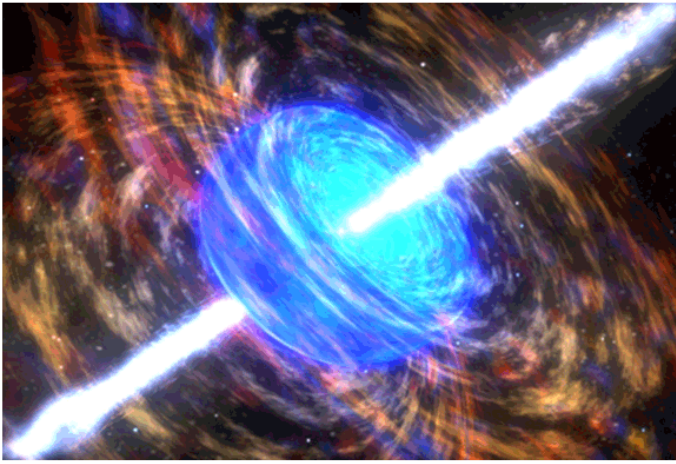
Each evening, the telescopes' [domes open](#) automatically and the telescopes prepare to take their first observations.

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

You can view [PROMPT-Chile and CTIO](#) interactively. You can view and listen to [individual PROMPT telescopes](#). (At night, both of these may appear dark, depending on the amount of moonlight.)

## + BACKGROUND: A. PROMPT TELESCOPES - 2. PROMPT and GRBs

Dr. Reichart's group built PROMPT 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*

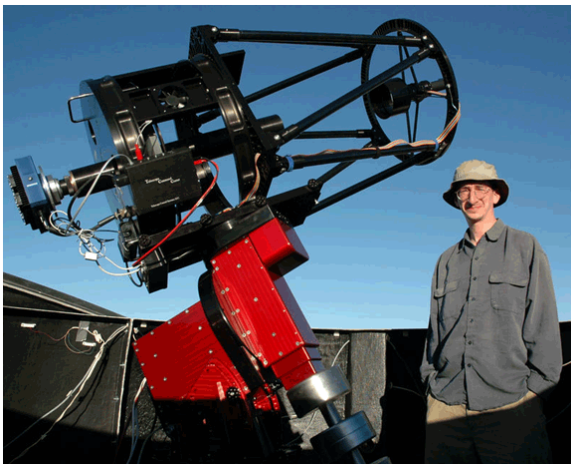
GRBs are the biggest bangs since the Big Bang. They are so luminous that they can be observed with relatively small telescopes, even if very far away. However, they fade quickly, often lasting only minutes. Consequently, PROMPT was built to be fast, not big.

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 12.9 billion light years away. Since the universe is only 13.8 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.

#### **+** BACKGROUND: A. PROMPT TELESCOPES - 3. How a PROMPT Telescope Works

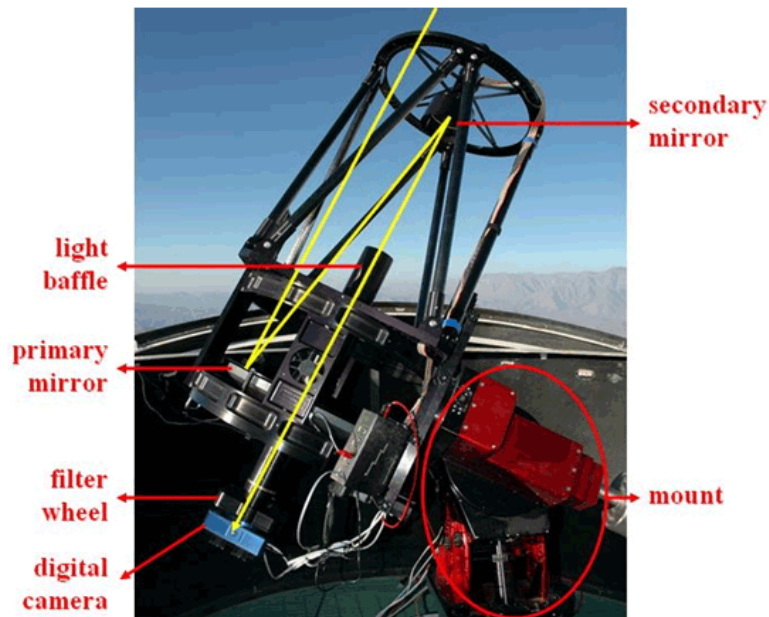
Here is one of the PROMPT telescopes up close, with Dr. Reichart next to it for scale.



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 and SSO, 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.)



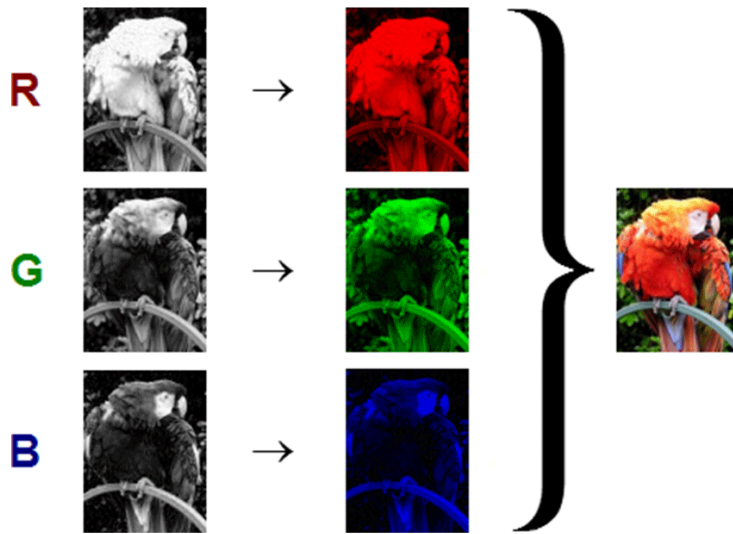
The secondary mirror redirects the light first through a tube called a **light baffle** and then through a hole in the center of the primary mirror. The light baffle helps to prevent stray light from contaminating images.

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.



*Notice how the parts of the photo with a lot of red in their color are brightest in the red filter, parts with a lot of green in their color are brightest in the green filter, and parts with a lot of blue in their color are brightest in the blue filter. White parts of the photo have equal amounts of red, green, and blue and consequently are bright in all three filters.*

#### BACKGROUND: A. PROMPT TELESCOPES - 4. PROMPT and Maintenance

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 or SSO 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 these sites 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.

#### BACKGROUND: 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. In 2013, 18 telescopes spanning three continents participated in UNC's Skynet Robotic Telescope Network.

Telescope	Site	Diameter	Availability	Owner
ARO-30	Astronomical Research Observatory, IL	30-inch	Poor	Astronomical Research Institute, Eastern Illinois University, Hands-On Universe
Dolomiti	Dolomites Astronomical Observatory, Italy	16-inch	Poor	Carlo Magno Zeledria Hotel
DSO-14	Dark Sky Observatory, NC	14-inch	Fair	Appalachian State University
DSO-17	Dark Sky Observatory, NC	17-inch	Poor	Appalachian State University
GORT	Hume Observatory, CA	14-inch	Poor	Sonoma State University
Guilford	Guilford Observatory, NC	16-inch	Poor	Guilford University
Morehead	Morehead Observatory, NC	24-inch	Poor	UNC
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
PROMPT-SSO-1	SSO, Australia	17-inch	Good	UNC
PROMPT-SSO-2	SSO, Australia	17-inch	Good	UNC
PROMPT-SSO-3	SSO, Australia	17-inch	Good	UNC
PROMPT-SSO-4	SSO, Australia	17-inch	Good	UNC
R-COP	Perth Observatory, Australia	14-inch	Excellent	Perth Observatory
Yerkes-41	Yerkes Observatory, WI	40-inch	Poor	University of Chicago

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.

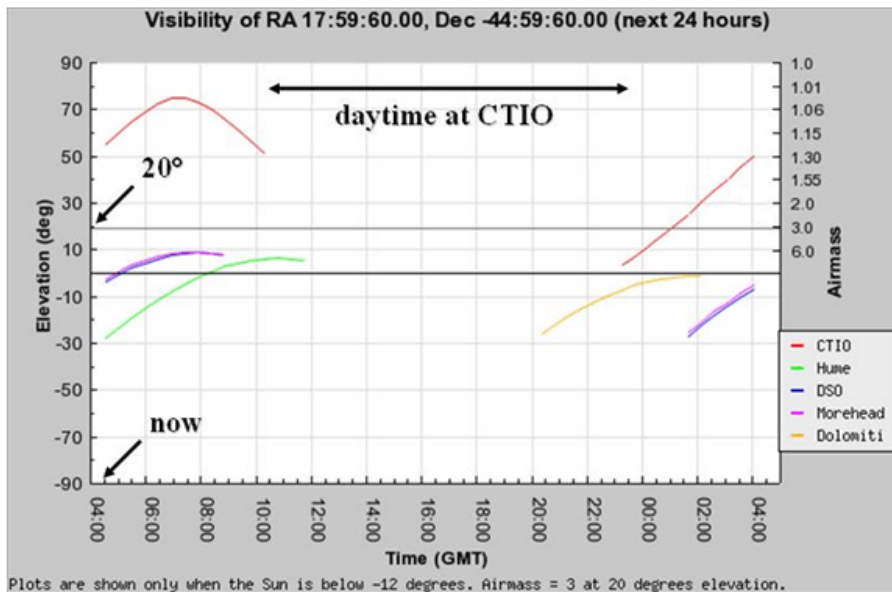
**You are welcome to observe with any of the Skynet telescopes.** Availability and image quality are usually best with the PROMPT telescopes. However, PROMPT is in the southern hemisphere and consequently cannot image all northern sky objects.

**PROCEDURE: A. OBSERVE WITH SKYNET - 1. How to Observe with Skynet**

To observe with Skynet, go to this [website](#). Your instructor will provide you with a username and password.

Next, watch this [tutorial video](#).

**Remember:** For an object to be observable, it must be greater than 20° above the horizon for at least part of the night on 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

Finally, also remember: 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)

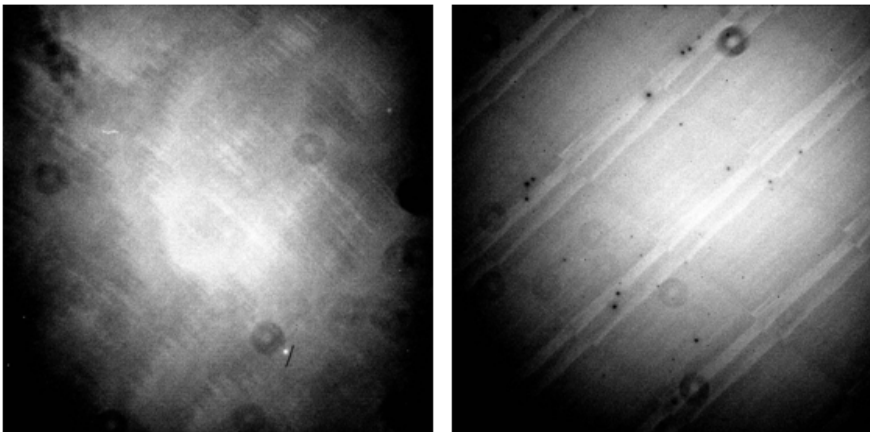
Repeat these exposures  time(s) with  minutes  between groups of exposures.

**+** PROCEDURE: A. OBSERVE WITH SKYNET - 2. How to Check Your Images

In this [tutorial](#), you will learn how to check your images once they have been taken.

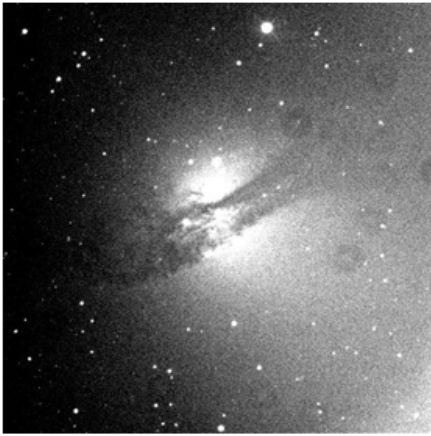
**If any of your images are of poor quality for any reason, re-observe them!**

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):



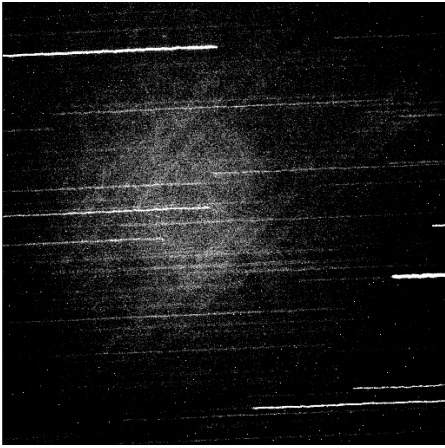
Due to wind or mount misbehavior distorting or streaking the images:



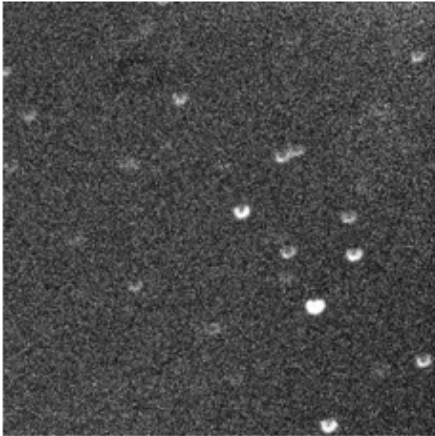
Due to mount misbehavior off-centering the images:



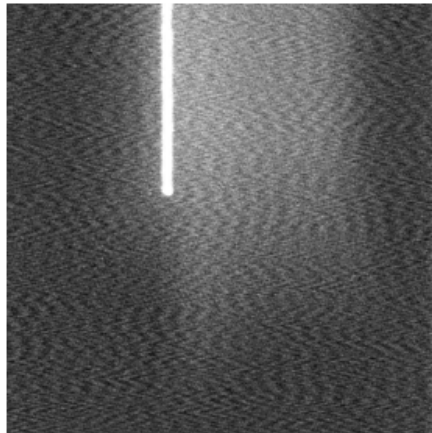
Due to mount not tracking Earth's rotation:



Due to focus misbehavior:

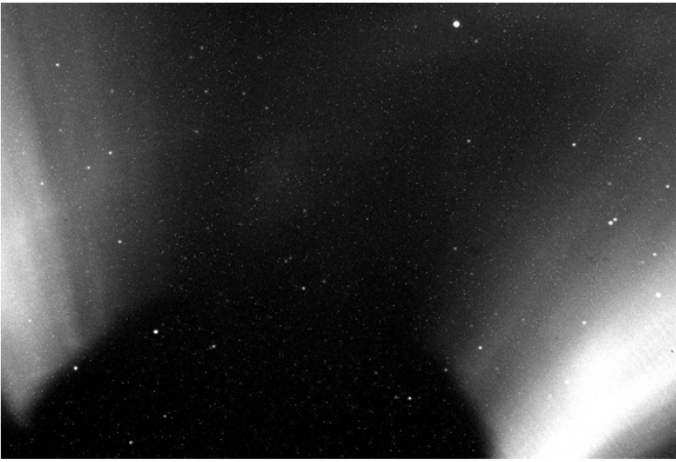


Due to camera shutter sticking:



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

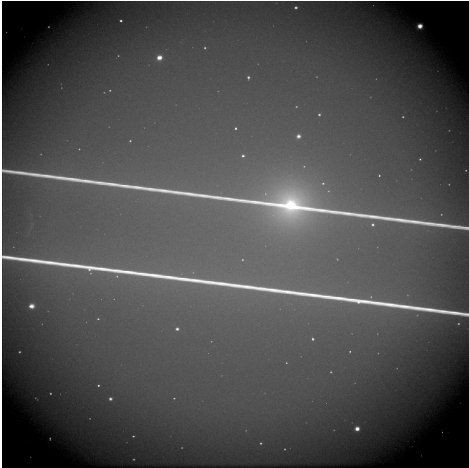




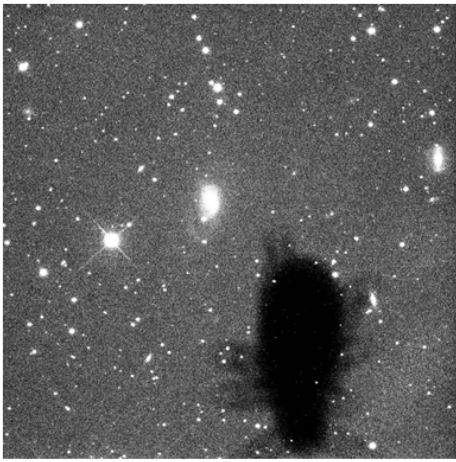
Due to a satellite moving through that part of the sky during the exposure:



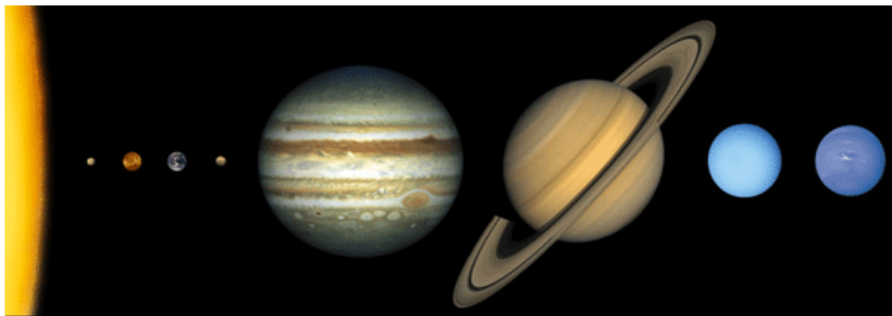
Due to an airplane moving through that part of the sky during the exposure:



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



**PROCEDURE: A. OBSERVE WITH SKYNET - 3. Observe Planets**



*The sun and the solar system's eight planets (left to right: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune).*

**Observe all currently observable planets:** If the observability chart indicates that a planet is not currently observable, do not request an observation of it! If observable from CTIO or SSO, use PROMPT and the following filters and exposure durations.

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

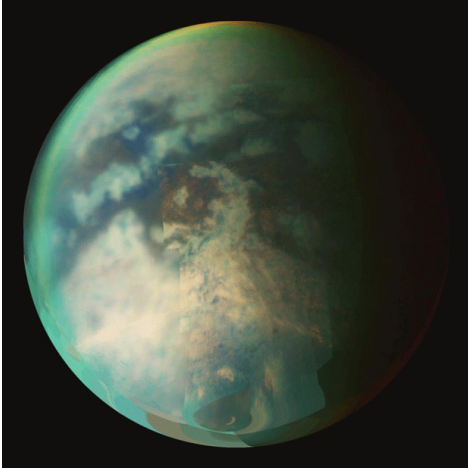
**Check your images:** If any of your images are of poor quality for any reason, re-observe them.

**PROCEDURE: A. OBSERVE WITH SKYNET - 4. Observe Moons**

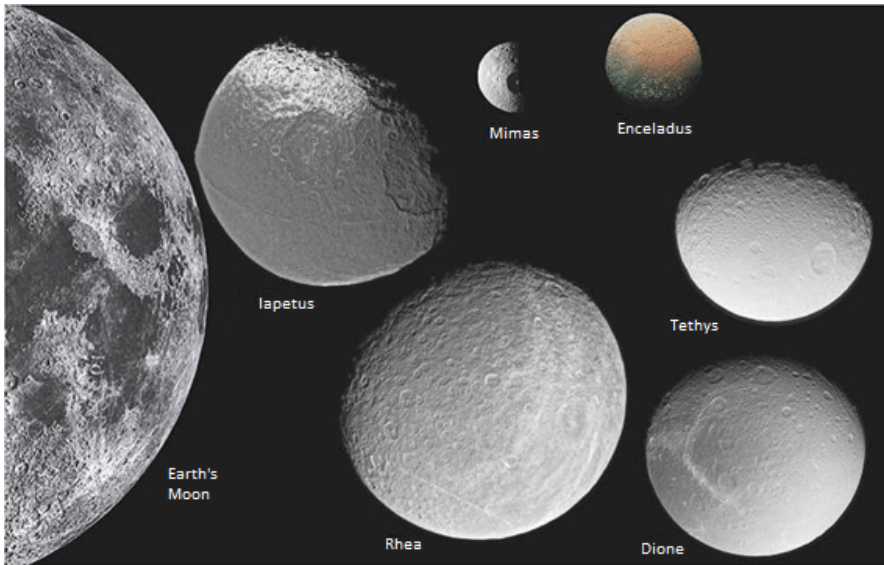
Aside from Earth's moon, all of the solar system's large and medium-sized moons orbit Jupiter, Saturn, Uranus, or Neptune. Jupiter has four large moons (left to right: Io, Europa, Ganymede, and Callisto), but no medium-sized moons.



Saturn has one large moon (Titan)



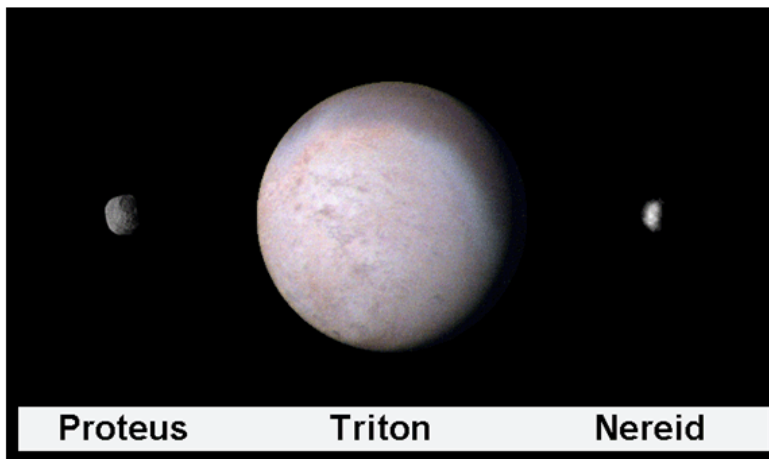
and six medium-sized moons.



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



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



The filters and exposure durations that you used in the previous section to observe Jupiter, Saturn, Uranus, and Neptune are not ideal for observing their moons, which are significantly fainter. However, different filters and exposure durations can be used to better observe and to observe more of these moons. (The trade-off is that the planets will be over-exposed in these images.)

**Observe large and medium-sized moons around all currently observable planets:** To observe a planet's moons, observe the planet, not the moons! The moons should be in the image. If the observability chart indicates that a planet is not currently observable, do not request an observation of it. If observable from CTIO or SSO, use PROMPT and the following filters and exposure durations.

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

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

✚ PROCEDURE: A. OBSERVE WITH SKYNET - 5. Observe Dwarf Planets



Earth and its moon and the five dwarf planets and their moons.

**Observe all currently observable dwarf planets:** If the observability chart indicates that a dwarf planet is not currently observable, do not request an observation of it. If observable from CTIO or SSO, use PROMPT and the following filters and exposure durations.

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
Eris	Kuiper Belt	Open	160

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

**PROCEDURE: A. OBSERVE WITH SKYNET - 6. Observe Deep Sky Objects**

**Observe one deep sky object from the following list of nebulae:** If the observability chart indicates that a nebula is not currently observable, do not request an observation of it. If observable from CTIO or SSO, use PROMPT and the following filters and exposure durations.

Deep Sky Object	Object Type	Filter	Exposure Duration (seconds)†
<a href="#">Carina Nebula (NGC 3372)</a>	Star Forming Region	Open	20
<a href="#">Lagoon Nebula (M8)</a>	Star Forming Region	Open	20
<a href="#">Orion Nebula (M42)</a>	Star Forming Region	Open	20
<a href="#">Tarantula Nebula (NGC 2070)</a>	Star Forming Region	Open	40
<a href="#">Trifid Nebula (M20)</a>	Star Forming Region	Open	40
<a href="#">Crab Nebula (M1)</a>	Supernova Remnant	Open	80
<a href="#">Eagle Nebula (M16)</a>	Star Forming Region	Open	80

**Observe one deep sky object from the following list of star clusters:** If the observability chart indicates that a star cluster is not currently observable, do not request an observation of it. If observable from CTIO or SSO, use PROMPT and the following filters and exposure durations.

Deep Sky Object	Object Type	Filter	Exposure Duration (seconds)†
<a href="#">47 Tucanae (NGC 104)</a>	Globular Cluster	Open	20
<a href="#">M3</a>	Globular Cluster	Open	40

**Observe one deep sky object from the following list of galaxies:** If the observability chart indicates that a galaxy is not currently

observable, do not request an observation of it. If observable from CTIO or SSO, use PROMPT and the following filters and exposure durations.

Deep Sky Object	Object Type	Filter	Exposure Duration (seconds)†
<a href="#">Centaurus A (NGC 5128)</a>	Elliptical Galaxy	Open	40
<a href="#">NGC 253</a>	Spiral Galaxy	Open	40
<a href="#">Sombrero Galaxy (M104)</a>	Spiral Galaxy	Open	40
<a href="#">NGC 2997</a>	Spiral Galaxy	Open	80
<a href="#">NGC 6744</a>	Spiral Galaxy	Open	80
<a href="#">Southern Pinwheel (M83)</a>	Spiral Galaxy	Open	80
<a href="#">Spindle Galaxy (NGC 3115)</a>	Spiral Galaxy	Open	80

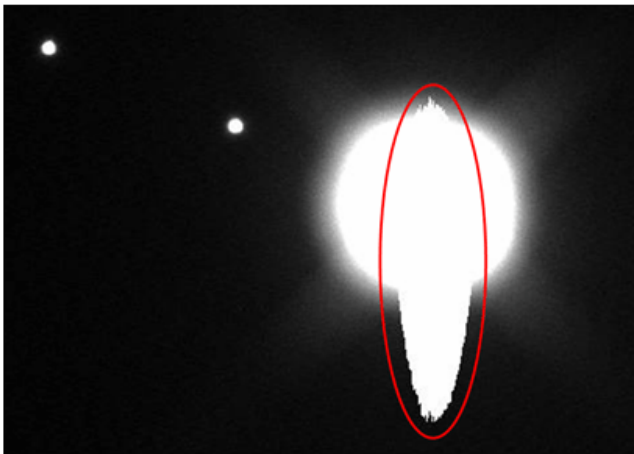
**PROCEDURE: A. OBSERVE WITH SKYNET - 7. Beyond the Labs**

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 U, u', H $\alpha$ , OIII, and SII filters let the least light through. They are useful for bright objects. The Luminance, Open, and Clear filters let the most light through. They are useful for dim objects. U/B/V/R/I, u'/g'/r'/i'/z', and Blue/Green/Red span the visible colors from near-ultraviolet to near-infrared. The first two are scientific filter sets. The third is designed to mimic the response of the human eye. Not all telescopes are equipped with the same filters.

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: (HMS)  :  :

If interrupted...  DEC:  °  '  ''

Priority:  Max Airmass:  Group:

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

Select filters:

U  gprime  Blue  
 B  rprime  Rc  
 V  iprime  Ic  
 R  zprime  Clear  
 I  Open  Halpha  
 Lum  Red  OIII  
 uprime  Green