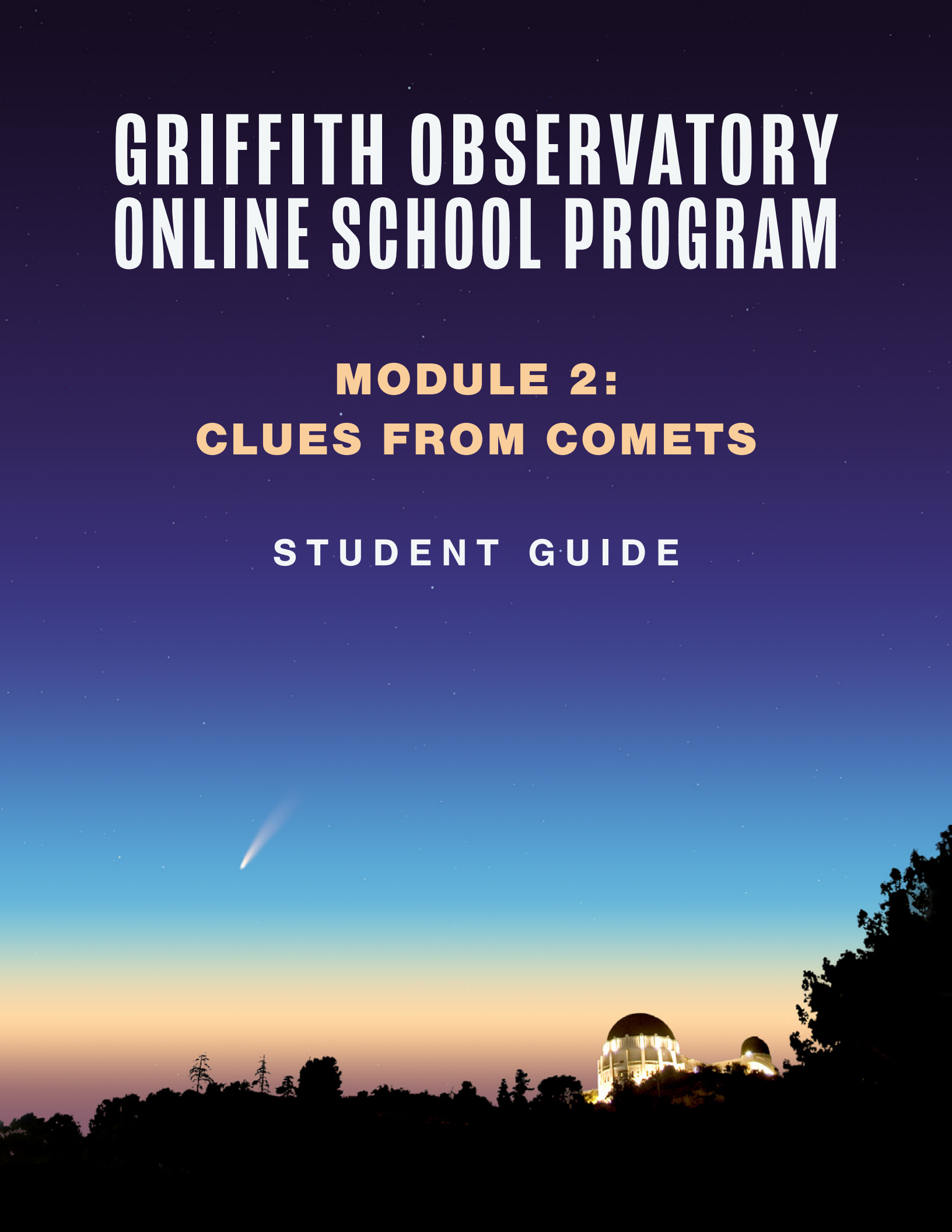
GRIFFITH OBSERVATORY ONLINE SCHOOL PROGRAM

MODULE 2: CLUES FROM COMETS

STUDENT GUIDE



Preparing for Your Virtual Visit

We are excited that your class will be participating in Module 2: Clues from Comets of Griffith Observatory's Online School Program. Together we shall join the tradition of observing. Here are some things you'll need to know before your virtual visit.

- You and your class will experience the entire live program in Zoom. Your teacher will send you the steps to follow to join the Zoom webinar session.
- Before joining the webinar, please set your Zoom name to contain your real first and last name.
- When you are admitted into the Zoom webinar, you will enter muted with your video off.
- You and your class will meet a Museum Guide from Griffith Observatory. The Guide will lead you through the live experience.
- During the program, you will be asked to participate in polls. After a question is asked, a poll will pop up on your screen. Select an answer, and remember to click "Submit!"
- You may use Zoom's chat function to communicate with Griffith Observatory staff if you are experiencing technical difficulties.
- You may submit to the Q&A box any questions about science you might have for Griffith Observatory staff. We shall hold a question-and-answer session at the end of the program and shall try to answer as many of your questions as we can.
- Remember to stay on your best behavior. We encourage you to answer the polls and ask any space or science-related questions you might have, especially those relevant to our discussion. Be polite. Any spamming behavior or inappropriate, rude, or harassing language sent to staff in the chat or Q&A is not tolerated and may result in being dropped from the Zoom session.
- We hope you have a wonderful time!

Pre-program Materials

To get the most out of Module 2: Clues from Comets, explore the following materials before your visit.

Module 2 Glossary

The glossary lists and defines important words used in Module 2: Clues from Comets.

Listen to the Module 2 Glossary

If listening helps you remember, this audio file will help you remember the words and definitions in the Module 2 Glossary.

Word Find

Are you a Module 2 Glossary Master? We challenge you to a word find.

Pieces of the Sky: What's the Difference?

This worksheet, inspired by Griffith Observatory's *Pieces of the Sky* exhibit, discusses the difference between asteroids, comets, meteors, meteoroids, and meteorites.

Comet in the Freezer

Here is a way to cook up your very own model comet from home. There's no dry ice needed – just a freezer and some common materials.

Sky Report

Griffith Observatory's Sky Report provides up-to-date information about what to see in the skies over Los Angeles and surrounding areas and even reports comets when they are visible.

Glossary

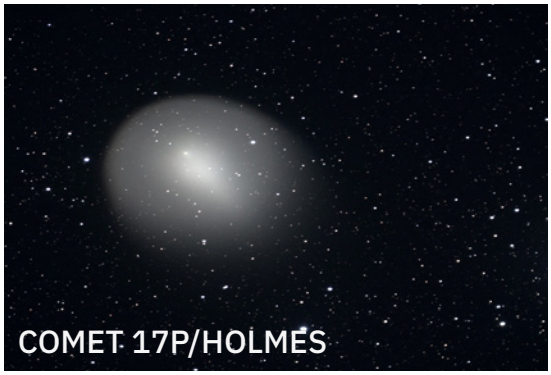
MODULE 2: CLUES FROM COMETS

atom – a basic unit of matter. An atom has a nucleus containing protons and neutrons and a cloud of electrons surrounding the nucleus.

carbon – the sixth element on the periodic table of elements. It is a versatile element that forms more compounds than all the other elements combined and is the chemical basis for life as we know it.

coma – the thin halo of gas and dust discarded from a comet nucleus as it is warmed by the Sun. In rare cases, comas can expand to enormous size as did comet Holmes in 2007.

comet – a small, icy object from the outer part of the solar system. Comets form tails as they approach the Sun and begin to warm up. The heat vaporizes the icy materials in comets to form tails of gas and dust that point away from the Sun. Comets also contain some of the essential ingredients for life, including carbon and water.


COMET 17P/HOLMES

comet tail – a stream of gas and dust that may extend hundreds of millions of kilometers away from a comet's coma. Most comets have two tails: A plasma tail made of electrically charged gas and a dust tail made of small solid particles. Comet tails point away from the Sun.

compound – a substance formed from atoms of different elements.

element – In chemistry, an element is a pure substance containing only one type of atom.

gravity – a fundamental force of nature in which all things with mass or energy — including planets, stars, galaxies, and even light — are brought toward one another.

hypothesis – an educated guess based on limited evidence and with no assumption that the guess is correct. An hypothesis is the starting point for scientific investigation and testing.

Kuiper Belt – the region in the solar system beyond the orbit of Neptune. It contains a large number of small, icy objects. Pluto is the most famous object in the Kuiper Belt. Comets also come from this region of space.

meteor – the streak of light produced when a small particle of space debris burns up as it collides with Earth's upper atmosphere at high speed. Meteors are commonly called "shooting stars," although they are not stars and are usually no larger than a grain of sand.


LEONID METEOR

meteor shower – an event in which a number of meteors appear to radiate from one point in the night sky. Meteors are debris that a comet left behind. We see meteor showers when Earth's orbit crosses the orbit of a comet.

orbit – a path followed by an object under the influence of gravitational force from another object. Earth orbits the Sun. The Moon and the International Space Station orbit Earth.

organic compound – An organic compound contains one or more carbon atoms that are linked to atoms of other elements. Certain organic compounds are chemically essential to life as we know it.


COMET 67P OUTGASSING

outgassing – a process by which a comet releases gases as it passes close to the Sun and warms up. Outgassing produces a visible coma and sometimes also a tail.

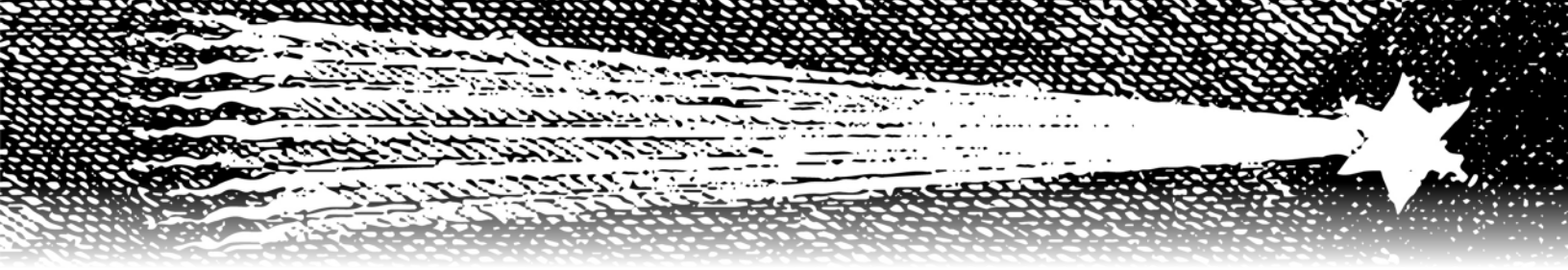
The Periodic Table – a system in which Earth's chemical elements are arranged in rows and columns. The Periodic Table helps us understand the elements and their properties.

probe – an unmanned spacecraft sent outside of Earth's orbit to gather information about distant planets and outer space.

spectroscope – a tool used by astronomers and physicists to determine the chemical make-up of an object by studying the light that object emits.

Tesla coil – a device originally designed by Nikola Tesla. It creates an invisible electric field within which devices may be powered wirelessly. Tesla coils produce a display of lightning-like sparks.

theory – a scientific explanation that is supported by overwhelming experimental evidence and widespread agreement within the scientific community.



Can you find the following words?

Cross out or circle the words when you find them.
They are hidden vertically, horizontally, and diagonally.

COMET
HALLEY
METEOR SHOWER
PERIODIC TABLE
ORBIT
KUIPER BELT
OORT CLOUD
ROSETTA
PHILAE
PERIHELION
HYPOTHESIS
THEORY
GRAVITY
ATOM
CARBON
NUCLEUS
COMA
TAIL
OUTGASSING
DUST

Q	E	R	Z	M	E	T	E	O	R	S	H	O	W	E	R
M	G	L	C	U	O	M	A	D	W	P	Y	J	T	I	B
E	P	E	R	I	H	E	L	I	O	N	V	Y	E	O	P
T	H	C	E	O	O	R	T	C	L	O	U	D	H	K	D
E	N	D	W	A	S	H	O	I	G	Y	S	P	X	U	K
O	A	U	M	H	L	E	U	X	C	I	Q	Y	N	I	U
R	G	S	C	A	K	B	T	I	O	Z	F	A	J	P	H
W	R	T	V	L	R	W	G	T	M	H	L	C	T	E	Y
Y	Q	B	N	L	E	F	A	X	A	B	J	E	S	R	P
C	S	F	C	E	K	U	S	G	T	Z	U	H	K	B	O
O	V	D	A	Y	E	M	S	A	P	H	I	L	A	E	T
M	P	E	R	I	O	D	I	C	T	A	B	L	E	L	H
E	F	X	B	N	T	V	N	Q	C	O	R	B	I	T	E
T	H	E	O	R	Y	J	G	N	K	A	M	E	L	Q	S
Z	B	G	N	D	A	Y	M	W	R	T	S	M	D	A	I
A	Z	U	P	F	O	C	G	R	A	V	I	T	Y	J	S

**Hint: The answer is hidden vertically.*

BONUS: Why did the scientist pick a shooting star over a burger for lunch?*

A burger is meaty, but a shooting star is a little ___ ___ ___ ___ ___ ___ !

Pieces of the Sky: What's the Difference?

ASTEROIDS – COMETS – METEORS – METEOROIDS – METEORITES

What's the difference? How can we keep track of all these space objects?

Let's start with meteors. What is a **meteor**? Another common name for a meteor is "shooting star," but a meteor is definitely not a star.

A meteor is a brief flash or streak of light that you might see crossing the night sky. A very bright meteor may even be visible in the daytime.

Leonid meteor

What makes the flash of light? A **meteoroid**! That's a grain of sand, a pebble, or a small rock traveling in space. If the meteoroid gets close enough to Earth, Earth's gravity pulls it toward us. Gravity speeds up the meteoroid until it is traveling very fast through the atmosphere.

How does the meteoroid light up the sky? **Ram pressure**.

When the meteoroid travels really fast, it "rams" into the air in front of it. The air can't get out of the way fast enough, and this causes it to heat up.

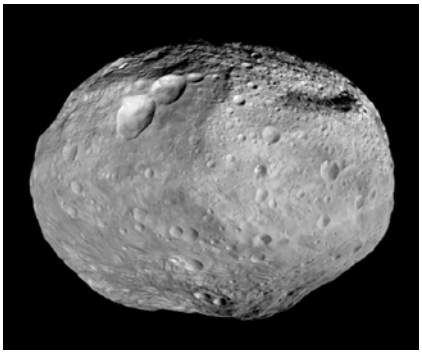
It's the super-heated air that makes the flash of light you see. That happens about 60 miles above the ground.

If the meteoroid is big enough, it doesn't fully burn up in the atmosphere. It might make it all the way to the ground, and if it does, it's a **meteorite**. First comes the meteoroid, then the meteor, and if the meteoroid hits Earth, it's a meteorite.

To review what we've learned so far, draw three lines connecting the term on the left with its description on the right:

meteorite	floats in space
meteoroid	flashes across the sky
meteor	found on Earth's surface

Many meteors that shoot across the sky come from **comets**. Others can come from **asteroids**. Both comets and asteroids are much larger than meteoroids. They both may be as big as a house, as big as a city, or even bigger. There's a famous asteroid named Vesta that is over three hundred miles across!



asteroid Vesta

Asteroids are made of rock and metal. Comets are made of ice and dust. One group formed closer to the Sun, and the other formed farther away. Think about what asteroids and comets are made of and then answer this question:

Which formed closer to the Sun? Comets or asteroids?

_____

Because comets are made of ice, they must form where it's very cold, farther from the Sun. Asteroids formed closer to the Sun. Asteroids sometimes crash into each other and break into smaller pieces that become meteoroids.

How do comets make meteoroids? Comets in our solar system orbit the Sun. When a comet approaches the Sun, the Sun's heat turns the comet's ice into water vapor.

The water vapor then rises from the nucleus along with some dust. The water molecules and dust turn into a **coma**, which is a mini-atmosphere around the comet's nucleus.

A comet tail is caused by the Sun. Particles shoot away from the Sun. Propelled by the intense heat, these particles are known as the **solar wind**. Solar-wind particles push the water molecules and dust particles in the comet's coma away from the nucleus to form a **tail**! A comet's tail always points away from the Sun.

comet NEOWISE

While a meteor is a quick flash of light across the sky, a comet is much farther away and seems to move very slowly through the sky. Some comets are bright enough to be seen without a telescope, and we can often observe them for many days in a row.

After the comet swings around the Sun and moves away from it, some of the icy, dusty tail particles, or meteoroids, stay behind in space. If Earth travels though those meteoroids much later, gravity takes over and pulls them into our atmosphere. When they move fast enough to heat up the air around them, they flash through the sky as meteors.

As we pass through the debris from the long-gone comet, we see more meteors than usual, often for several days at a time. That is called a **meteor shower**. We can predict when a meteor shower will happen. It is a great time to scan the skies for the beautiful streaks of light we call meteors.

Comet in the Freezer

Cook up a Comet at Home!

Comets are small, icy bodies that orbit the Sun. They spend most of their time in the cold outer regions of our solar system as frozen relics of the material that formed the Sun and planets. Every once in a while, a comet comes near the Sun, heats up, and forms a tail of ice and dust that makes a spectacular show in the night sky. Comets give us clues about how Earth was formed and about the chemical activity at the time life originated. They play an ongoing role in the evolution of life on Earth.

Comets are sometimes called “dirty snowballs” and are made of interstellar ice, dust, and rock. The ices are frozen water (H_2O), ammonia (NH_3), and a number of organic compounds such as carbon monoxide (CO), carbon dioxide (CO_2), methane, (CH_4), ethane (C_2H_6), formaldehyde (CH_2O), alcohols (methanol and ethanol), long-chain hydrocarbons, and amino acids. Comets are held together by gravity.

Module 2: Clues from Comets and the live demonstration at Griffith Observatory teach a number of fundamental physical and chemical concepts that are aligned with the California State Standards.

MATERIALS AND COMET INGREDIENTS

- large mixing bowl
- large resealable bag
- water
- sand
- crushed charcoal (regular, not insta-light)
- glass cleaner (ammonia)
- corn syrup (optional)
- duct tape
- rubber bands
- paper towels for clean-up

PROCEDURE

1. Place an empty resealable bag in the empty mixing bowl. Add, in order, the following ingredients

    1 cup of water
    3 spoonfuls of sand
    3-4 spoonfuls of crushed charcoal
    3-5 squirts of glass cleaner (ammonia)
    a splash of corn syrup

PROCEDURE CONTINUED ON THE NEXT PAGE...

PROCEDURE CONTINUED...

2. Seal the bag tightly. To help your comet freeze into a round shape, loosely tie a rubber band around the middle of the resealable bag. Next, use duct tape to connect the bottom corners of the bag to the top of the bag, as pictured.

3. Allow your comet to freeze in the freezer for at least eight hours.

4. Tear the bag open. You've made a comet!

DISCUSSION

- Water is the primary ingredient of comets and is a necessary ingredient for life as we know it.
- The sand and charcoal represent the rock and dust in the comet. Comets are surprisingly dark—as dark as charcoal! This is contrary to our familiar experience with ice as something shiny and bright.
- The glass cleaner and corn syrup represent the ammonia and organic molecules that are also found in comets. These compounds are essential ingredients for life on Earth and perhaps elsewhere.

If you observe the comet over several hours, you'll notice it will melt back to liquid water. If you were to put your comet in space, however, the comet's ice would turn directly from solid to gas and release wisps of water vapor on its approach to the Sun.

Post-program Materials

We hope you enjoyed Module 2: Clues from Comets of Griffith Observatory's Online School Program. To continue your lifelong journey as observers, here are some activities and resources.

Periodic Comet Calculator

This worksheet explains what periodic comets are and shows you how to estimate when the next comets will appear in the sky!

How to Observe Comets

Want to observe an actual comet? Here are detailed instructions to let you prepare for the next comet sightings: What to research, where to go, what to bring, and how to spot comets.

Coloring the Cosmos

We have included a coloring book activity for a quiet moment.

Kerbal Space Program

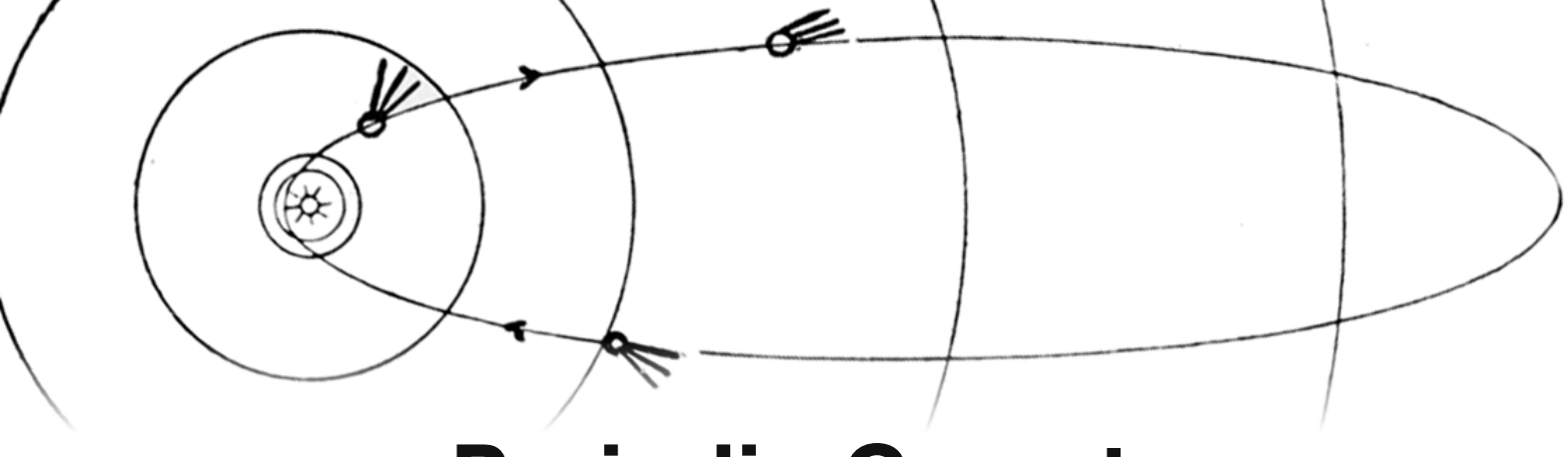
Are you up for a challenge? *Kerbal Space Program* (an advanced physics-based simulation video game) and the European Space Agency (ESA) teamed up to give players the ability to reenact ESA's *Rosetta* mission to comet 67P/Churyumov–Gerasimenko, from launch to landing!

Stellarium Guide

This guide includes instructions to help you learn how to use Stellarium, free planetarium software that shows a realistic simulation of the sky in real time.

Internet Resources

The internet may be helpful. This resource lists a variety of websites that will help you expand your astronomical knowledge and have fun doing it.



Periodic Comets

Periodic comets orbit the Sun in a certain length of time, or period.

When a periodic comet reaches its closest point to the Sun, the comet is at **perihelion**. *Peri* means "near," and *helion* means "Sun." One **orbital period** is the difference in time from one perihelion to the next perihelion.

Short-period comets have orbits that bring them back to perihelion every 200 years or less. Long-period comets have orbits that bring them back to perihelion in more than 200 years.

How do we know when to expect a comet to return? You might have heard of Halley's Comet. (Halley is pronounced like "rally.") It returns to the Sun about every 75 to 76 years. It reached perihelion on April 20, 1910, and again on February 9, 1986.

The time between those two dates is 75 years, 9 months, and 20 days. We may then expect Halley's Comet to return again on November 1, 2061. Astronomers who study comet Halley closely, however, expect it to reach its next perihelion sooner than that, on July 28, 2061. How old will you be on that day?

Why would Halley's Comet have a shorter orbital period this time? Can you think of things that it might encounter that could slightly alter its orbital period? How would that happen?

We may still calculate roughly when comets will return, however. If we find the two latest perihelion dates for a comet, subtract the earlier date from the most recent date, and then add that number to the most recent perihelion date, we may get an estimate for that comet's return.

On the next page you will see a list of some periodic comets and their two most recent perihelions. Can you figure out when they should return next?

All it takes is a little arithmetic and a calendar. Let's try it!

Comet Return Calculator

EXAMPLE:

Comet Name: 12P/Pons–Brooks
Most recent perihelion year: 1954
Prior perihelion year: 1884
Time difference (Period): **70 years**

As astronomers predicted, this comet reached perihelion on April 21, 2024!

Add this time difference to the most recent perihelion. 1954 + **70 years**
Next estimated perihelion year: **2024**

1) Comet Name: 1P/Halley
Most recent perihelion year: 1986
Prior perihelion year: 1910
Time difference (Period): _____
Next estimated perihelion year: _____

2) Comet Name: 67P/Churyumov-Gerasimenko
Most recent perihelion year: 2021
Prior perihelion year: 2015
Time difference (Period): _____
Next estimated perihelion year: _____

3) Comet Name: 36P/Whipple
Most recent perihelion year: 2020
Prior perihelion year: 2011
Time difference (Period): _____
Next estimated perihelion year: _____

4) Comet Name: 27P/Crommelin
Most recent perihelion year: 2011
Prior perihelion year: 1984
Time difference (Period): _____
Next estimated perihelion year: _____

5) Which comet can we expect to observe first?

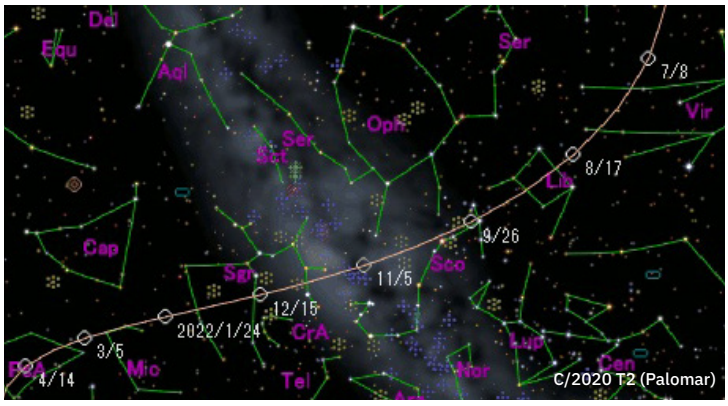
_____

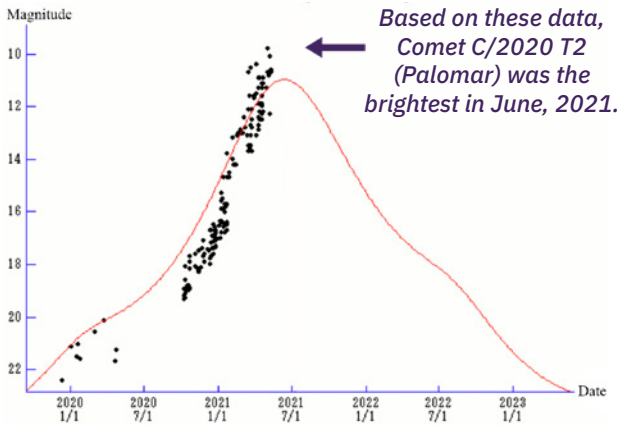
How to Observe Comets

Comets are among the oldest objects in the solar system. Composed of rock, dust, and ice, they generally go around the Sun in long, narrow orbits which may stretch well beyond the orbit of dwarf-planet Pluto.

Most of the time comets are too faint and too small to be seen, but that changes as they approach the Sun. Some comets appear on predictable schedules (like Halley's Comet), while others show up for the first time. When comets appear, Griffith Observatory provides viewing guidance (**Sky Report**) and shares spectacular imagery. The **Observatory's public telescopes** always highlight comets when they are in view.

For information on comets that may be visible now, visit **Weekly Information on Bright Comets**. If you click on the name of a comet and then scroll down, you will see a "Finding Chart" and a "Magnitude Graph."





A Finding Chart (left) maps the constellations through which a comet travels (from our perspective on Earth) and when. A Magnitude Graph (right) shows when a comet will appear brightest and will therefore be easiest to spot.

Objects that have a lower-number magnitude, like +8, are brighter than objects with a higher magnitude, like +15. The *lower* the magnitude number, the greater an object's brightness. Comet NEOWISE, which was visible to the unaided eye, reached a visual magnitude between +1 and +3 in July, 2020. The Sun's magnitude is -26.72.

Constellations are imagined patterns of stars in the sky. If you become familiar with the constellations, you may have an easier time searching the sky for comets. Refer to the "Stellarium Guide" included in this packet to download free programs that may help.

Now that you know the part of the sky and the best time to look for your chosen comet, here is what you will need.

YOU WILL NEED

1. Good weather
2. Little or no Moon (The Moon is a huge nightlight.)
3. Dark skies (away from cities)
4. A clear horizon (from an open field or a high place)
5. A small telescope or binoculars

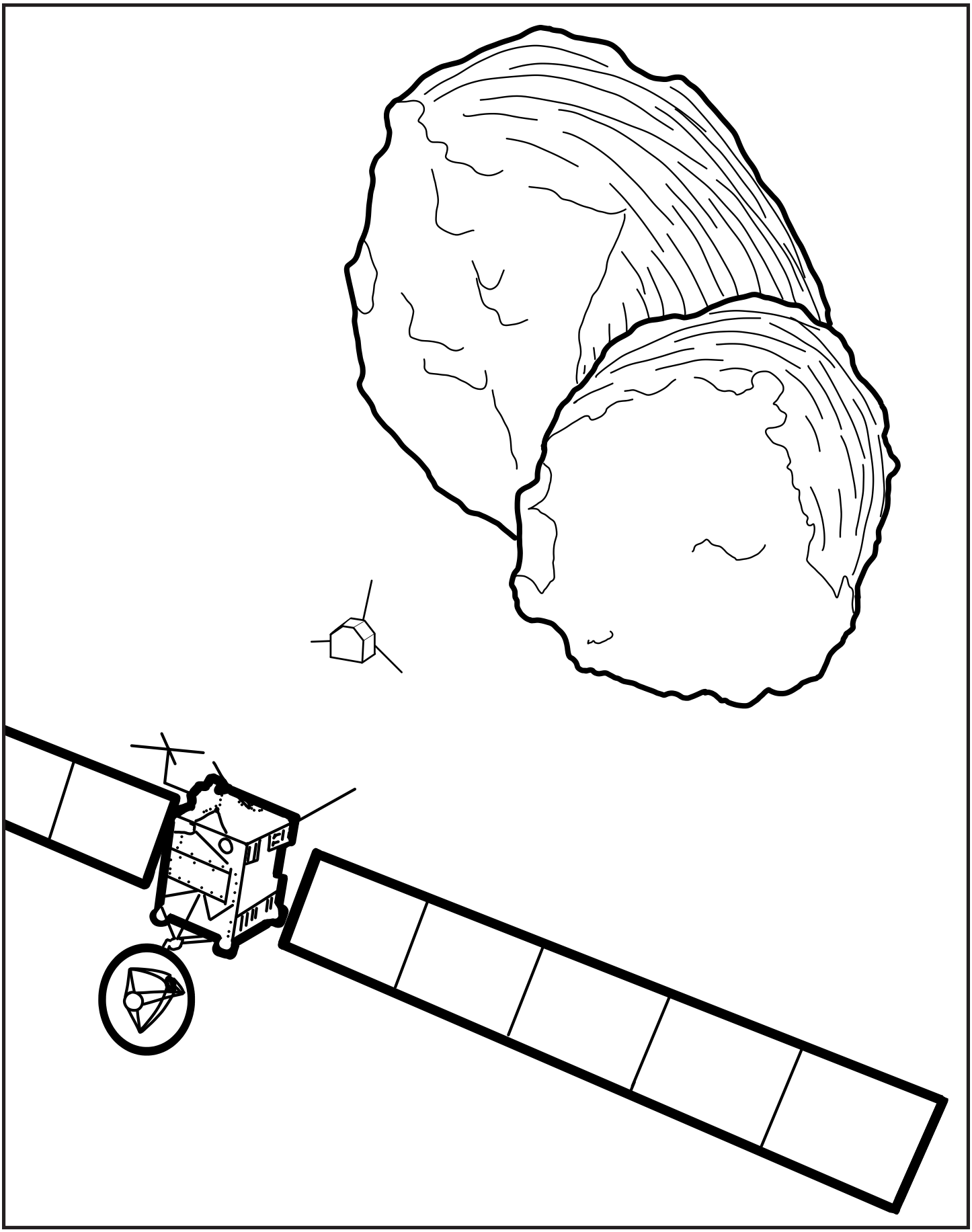
STEPS

Remember that it will be easiest to find a comet if you have researched which constellation it currently occupies. Use **Stellarium** or a sky-touring app like **Night Sky** or **Stellarium Mobile** to determine whether the comet's current constellation will be visible in the sky *right before sunrise* or *right after sunset*. Comets glow brightly when they are close to the Sun, and so here on Earth we may observe comets when the Sun is right below the horizon.

Therefore, a comet usually will be most visible toward the east about 30 minutes before sunrise or to the west about 20 minutes after sunset. Sweep that part of sky slowly for a small fuzzy object.

Finding a comet takes patience. Comet hunters who are trying to find *new* comets spend hundreds of hours observing. Comets are named after their discoverers, and so many people think it is worth the effort.

ESA's *Rosetta* Mission to Comet 67P/Churyumov–Gerasimenko



By Sarah Vincent

Stellarium Guide

Here are two free apps to help you tour the sky.

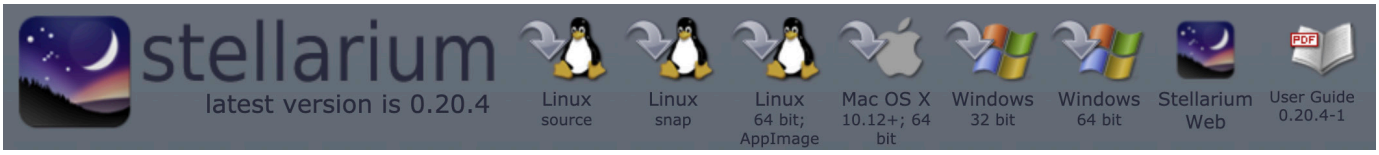
Night Sky

Stellarium Mobile

If you are interested in a more accurate sky and advanced controls, Stellarium is for you.

Downloading and Installing Stellarium

With the help of an adult, visit **https://stellarium.org** to download Stellarium to your device. The top of the web page will look like the image below. Be sure to choose the correct version for your computer.



Once you download the file, find it in your “Downloads” folder. To install Stellarium, double-click on the installation file, and follow the installation instructions.

Launching Stellarium

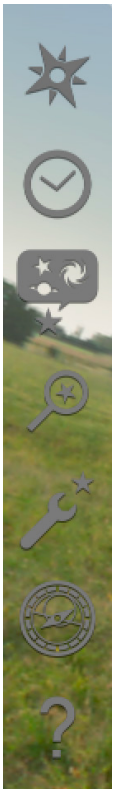
Once installed, double-click on the Stellarium icon to launch the program and begin your stellar exploration. When you start Stellarium, you may see something like the scene below.

You may change your view either by left-clicking and dragging your mouse or by using the arrow keys.

Using Stellarium

Note the small bar at the bottom of the screen. It is possible that the simulated sky represents the sky from a city that is not the same as yours.

To change the location and time of your sky observation, move your cursor down to the lower left side of the screen to make a menu appear. The top four settings are especially useful for exploring the night sky.



Location window [F6]

Date/time window [F5]

Sky and viewing options window [F4]

Search window [F3]

Configuration window [F2]

Astronomical calculations window [F10]

Help window [F1]

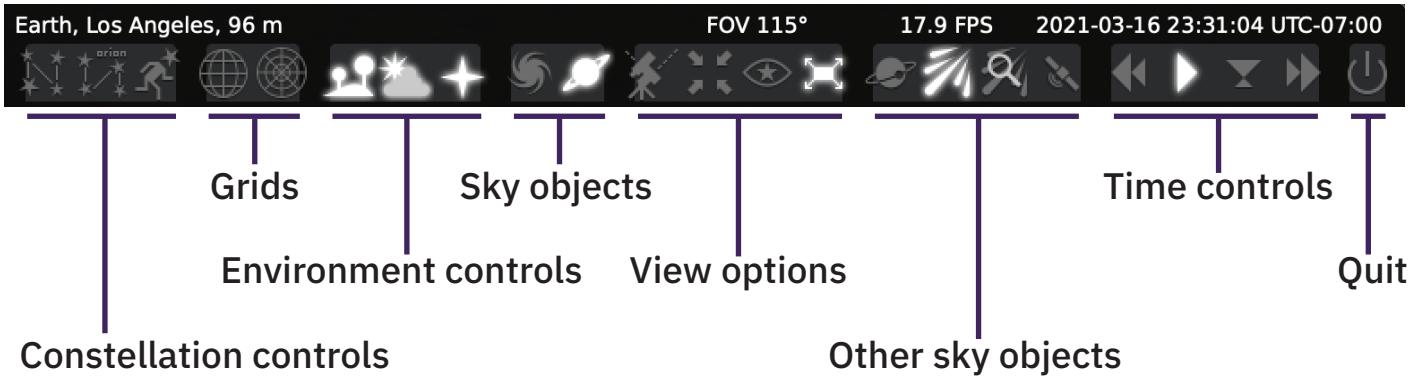
If you click on the **Location window**, you may see what the sky looks like from any place on Earth. You may even move yourself to another planet or moon!

Changing your location will not change the landscape, but you may do that by selecting the **Sky and viewing options window** and clicking on the **Landscape** tab to choose from a list of landscapes.

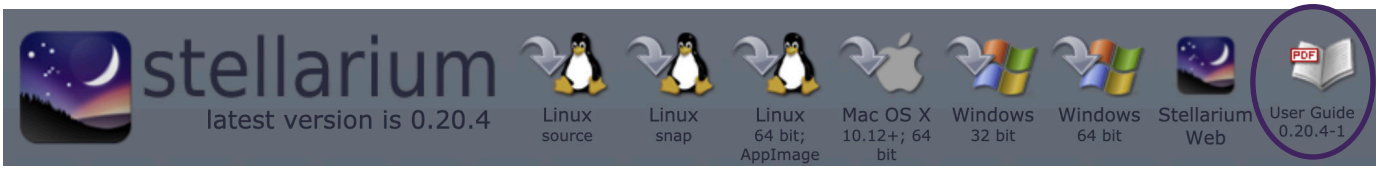
If you click on the **Date/time window**, you may change the date and time to anything you want. If you choose a time after the Sun sets, you will see the night sky. You may also view the sky thousands of years in the past or future!

Click on the **Search window** and search any sky object to inspect it. Get a closer look at what you have selected by zooming in.

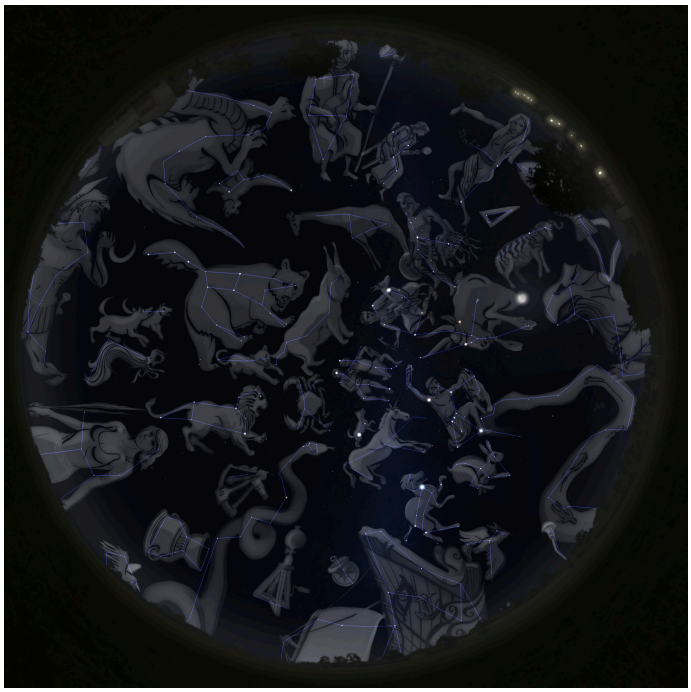
Move your cursor down to the lower side of the screen to access additional settings. These are useful for controlling the movement of the sky and selecting what you want to see in the sky.



For more thorough information including how to use Stellarium's more advanced functions, visit **https://stellarium.org** and download the official User Guide.



The wonder of space is yours to discover.



Internet Resources

Not all websites are equally accurate. The world wide web, while convenient, can frequently provide incorrect and incomplete information. Below is a list of some of the best space science websites recommended by Griffith Observatory educators.

GRIFFITH OBSERVATORY

The most-visited public observatory in the world.

https://griffithobservatory.org

ASTRONOMY CLUBS

Find an astronomy club near you! Amateur (and some professional) astronomers are happy to share their telescopes, their enthusiasm, and their knowledge. A list of local clubs and more information may be found on our website:

https://obs.la/astronomyresources

CITIZEN SCIENCE PROJECTS

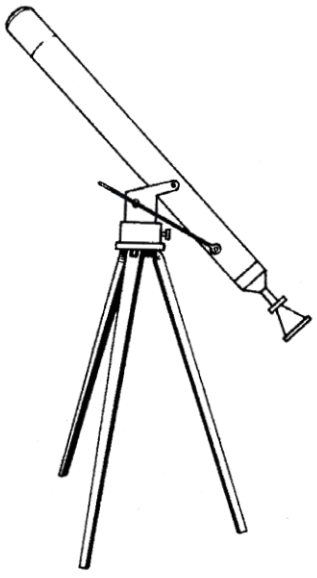
You may make a real contribution to astronomy by participating in these scientific projects.

Help scientists with their research into stars, Mars, Earth, galaxies, astronautics, the Sun, and black holes! Multiple projects are listed at this website:

https://science.nasa.gov/citizen-science

Another useful site that lists multiple Citizen Science projects:

https://zooniverse.org



NASA WEBSITES FOR SPACE FANS

Check out games and projects for budding space scientists:

https://spaceplace.nasa.gov/menu/play

Explore space with NASA's remarkable app, "NASA's Eyes:"

https://science.nasa.gov/eyes

Visit websites dedicated to learning for grades 5 through 8:

https://nasa.gov/learning-resources/for-students-grades-5-8

Watch NASA's live and original programming for free:

https://plus.nasa.gov

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INTERNET RESOURCES CONTINUED...

RESOURCES FOR TEACHERS

Free lesson plans and activities for K-12 from Jet Propulsion Laboratory:
https://jpl.nasa.gov/edu/

Find Next Gen STEM learning opportunities for students in multiple settings:
https://nasa.gov/learning-resources/for-educators

Search NASA's educational activities and resources by subject, type, and grade level:
https://science.nasa.gov/learn/catalog

YOUTUBE CHANNELS

Griffith Observatory

European Space Agency

PBS Space Time

MORE WEB LINKS

California Science Center: Astronomy education programs, workshops, lesson plans, and resources. https://californiasciencecenter.org

The Lunar and Planetary Institute: Astronomy education programs, workshops, and resources. https://lpi.usra.edu/education

StarDate: The public education and outreach arm of the McDonald Observatory, Texas.
https://stardate.org

WorldWide Telescope: This website turns your computer into a telescope and brings together data and imagery from telescopes around the world.
https://worldwidetelescope.org

Astronomical Society of the Pacific: Organization of professional and amateur astronomers with astronomy education conferences, education programs, and resources, including professional development opportunities for teachers. https://astrosociety.org

Planetary Society: Open membership organization that sponsors planetary events and programs. Its "Space for Kids" page lists many at-home activities.
https://planetary.org/kids

Exploratorium: A resource for at-home experimentation and projects.
https://exploratorium.edu/explore

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