

# GRIFFITH OBSERVATORY ONLINE SCHOOL PROGRAM

## MODULE 2: CLUES FROM COMETS

### TEACHER GUIDE





## Dear Teacher,

Welcome to Griffith Observatory's Online School Program teacher resources!

It is our mission to inspire everyone to observe, ponder, and understand the sky. With this program, we intend to be your partner in education, providing you access to experts and unique activities that bring science to life in your classroom.

Our Fifth-grade Online School Program modules are

- Entirely free to participate
- Aligned with current fifth-grade education Next Generation Science Standards (NGSS)
- Interactive and presented live by Griffith Observatory's knowledgeable staff
- Intended to inspire students' curiosity for space exploration and S.T.E.M. (Science, Technology, Engineering, and Mathematics) subjects and to expose them to the latest astronomical science and technology

If we learn how to observe and do so carefully, we are rewarded with profound discoveries about the universe and ourselves. This is the unifying theme of our Online School Program modules and what we hope your students will take away from the program.

Thank you for teaching the next generation of critical thinkers and observers!





# Griffith Observatory Online School Program

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## Overview

Griffith Observatory's online school program is a live, interactive, virtual school program for fifth-grade students. The program offers live and prepared elements that feature Griffith Observatory's knowledgeable Museum Guides and Telescope Demonstrators. Like the in-person school program, this online program is offered to interested schools on a first-come, first-served basis, and we encourage participation by schools in communities that have limited access to special science-outreach initiatives. The online program enables students to have a meaningful, virtual Observatory experience without transportation and geographic barriers to participation. The operation of both programs is funded by Griffith Observatory and Griffith Observatory Foundation.

Griffith Observatory's online school program is hosted entirely through Zoom, is delivered live from Griffith Observatory, and meets current fifth-grade standards (NGSS 2015).

## Structure

The program is a series of modules that each address a different aspect of observation. Each module contains live, recorded, and animated elements, lasts about 30 minutes, and is followed immediately with a question-and-answer session. The modules are intended to be experienced in order, though not necessarily within a particular time-frame.

## Goals

The modules are designed to accomplish three goals:

- inspire students to be observers
- encourage students to appreciate their place in and relationship to the universe
- expose students to the latest astronomical science and technology



# The Modules

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## MODULE 1: EVERYONE IS AN OBSERVER

“Everyone Is an Observer” examines the observational skills everyone uses to navigate life. Through virtual daytime and night observation with Griffith Observatory’s historic coelostat and Zeiss telescope, participants learn how astronomers observe, use scientific instruments, and record data to expand their knowledge of the universe. How has systematic observation changed our understanding of objects in space, and how have our findings helped us understand Earth’s relationship to them?

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## MODULE 2: CLUES FROM COMETS

“Clues from Comets” investigates the process of using observations to understand cause-and-effect relationships between events, exemplified by our understanding of comets over time. Presented live from Griffith Observatory’s Leonard Nimoy Event Horizon theater, the program guides students through centuries of records kept on the appearances of comets as people gradually learned about their nature. Midway into the presentation, participants witness the manufacture of a life-ingredient-bearing comet from household supplies. Finally, participants embark on a journey to a real comet in space fashioned from actual photographs from the *Rosetta* mission. What can comets tell us about the solar system and about ourselves?

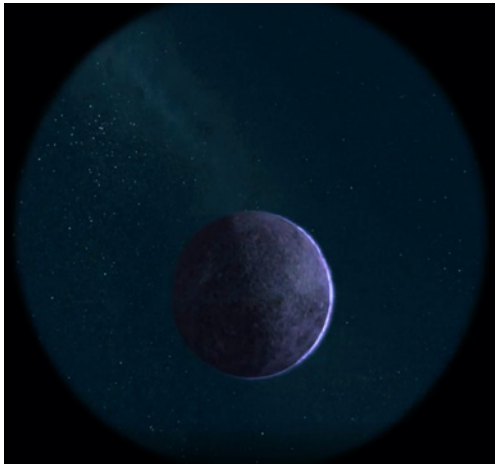
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## MODULE 3: THE SEARCH FOR WATER

“The Search for Water” emphasizes that liquid water is essential for life, looks inward at our own planet with thriving life forms, and then outward for other water-lush worlds. Griffith Observatory’s *Our Earth, Our Moon, Elements*, and *Solar System Worlds* exhibits are explored to identify conditions and materials present on our world versus others. The unique properties of water are examined with a variety of demonstrations, and the resilience of life is explored with footage from Earth’s extreme places. Students are then guided through the solar system in search of environments that sustain liquid water. The program includes animated elements from Griffith Observatory’s planetarium show *Water Is Life* that have been converted to 2-D and enhanced for on-line learning.

## Modules continued .....



### MODULE 4: EXOPLANETS ARE EVERYWHERE

“Exoplanets Are Everywhere” outlines the structure of our solar system and shows how a planet’s distance from its star, among other circumstances, is essential for making it a habitat for life. Students encounter exoplanet discoveries and what they mean. In this exhibit-based experience with interactive components, participants visit simulated alien worlds and solar systems in search of habitable planets. Students will visit The Gunther Depths of Space, experience the solar system models, see the current exoplanet count, take a tour of The Big Picture, see *Our Sun Is a Star*, and get acquainted with modern exoplanet-hunting technology.

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### MODULE 5: EARTH IS OUR HOME

“Earth Is Our Home” guides participants on an immersive, 13.8 billion-year journey through Griffith Observatory’s *Cosmic Connection* timeline. Environmental change can be caused by cosmic events or by living things. When ecosystems change, life also changes. Real-life stories demonstrate that studying Earth from an astronomical perspective sheds light on how people are changing Earth’s ecosystems. Two core messages are emphasized: The evolution of Earth and life are intertwined, and observation and scientific thinking are key for protecting Earth’s resources and environment.

# Program Rundown

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## Module 2 Strategies

- Connect students to the long, global history of observing by displaying historic art and records.
- Explain and show how tools, technology, and the scientific method have been applied over time to uncover information and answer global questions.
- Demystify comets by examining data, creating models, and showing the latest footage taken from orbit around comets.
- Supplement live and recorded content with documents and materials for the classroom and at home, to be used before and after participating in the module.

## Module 2 Breakdown



### PRE-PROGRAM WAITING ROOM

When logged on early, you encounter a waiting room animation indicating that the program has not yet begun.

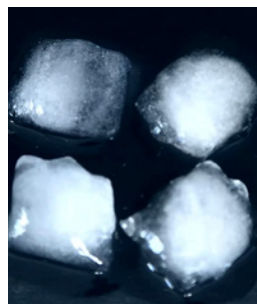
### ARRIVAL TO GRIFFITH OBSERVATORY ANIMATION

An animation designed and produced by Griffith Observatory's Satellite Studio brings you from the far reaches of the universe to Griffith Observatory.



### LIVE INTRODUCTION TO YOUR MUSEUM GUIDE

A Museum Guide joins you live from Griffith Observatory's Leonard Nimoy Event Horizon theater. The Guide shows historic images from around the world that illustrate changing perceptions of comets. We learn that occurrences that are uncommon or not understood can be unnerving and that people sometimes draw conclusions before enough observational evidence is collected.



### INTERACTIVE SECTION: CONNECTION VS. COINCIDENCE

The Museum Guide presents some examples of two events happening together, and students cast votes with Zoom's polling feature on whether they believe the events are connected or coincidental. We visit Griffith Observatory's Tesla coil and determine whether a special feature of the exhibit occurs through cause-and-effect or coincidence.



### EDMOND HALLEY'S HYPOTHESIS

A video shows how astronomer Edmond Halley combined centuries of global observations of comets with the modern understanding of gravity to create a testable hypothesis—later proven to be correct.



## Program Rundown continued.....



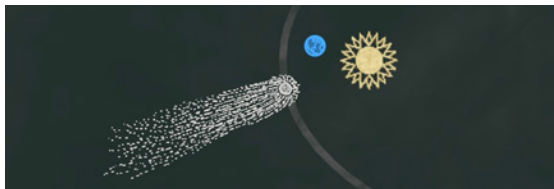
### MUSEUM GUIDE TRANSITION WITH PERIODIC TABLE AND SPECTROSCOPE TOUR

The live Museum Guide returns and recalls how Edmond Halley's research determined *how* and *why* comets move as they do. To find out *what* comets are made of, we take virtual tours of Griffith Observatory's spectroscope and *Elements* exhibit and learn how these tools can help us get to know comets.



### LIVE DEMONSTRATION: MAKE A COMET

We return to the live Museum Guide with knowledge about the ingredients that make up a comet. The Guide proceeds to build a model comet with these same ingredients. An overhead camera gives us a closer look at the process.



### A COMET'S LIFE ANIMATION

An animation plays. We learn how comets formed as members of the solar system. We are guided through a detailed model of how comets move in space and why we are able to witness parts of their journey from Earth.



### TRANSITION WITH LIVE MUSEUM GUIDE

We transition back to the live Museum Guide, who explains that we confirmed our observational evidence about comets by visiting them with spacecraft.



### ROSETTA MISSION VIDEO WITH FINAL REFLECTIONS

A video takes us along with ESA's *Rosetta* spacecraft on its 17-month observation of comet 67P/Churyumov-Gerasimenko. We see stop-motion animations of the comet in motion over time that were created with individual images captured by *Rosetta*. We witness the life-cycle of the comet and the spacecrafts' journeys through pictures taken by *Rosetta* and its lander *Philae*. The live Museum Guide returns with final thoughts.



### QUESTION-AND-ANSWER SESSION

We transition to a question-and-answer session with the live Museum Guide. The Guide answers science questions from students.



# 2015 Next Generation Science Standards Reflected in the Program

## Module 2: Clues from Comets

GRADE	STANDARD	NGSS DESCRIPTION	HOW THE STANDARD IS ADDRESSED
3-5	3-5-SEP-1	Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause-and-effect relationships.	Students determine whether multiple pairs of events are connected or coincidental with Zoom's interactive polling feature.
3-5	3-5-CCC-2	Cause-and-effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might not be a cause-and-effect relationship.	We explore global, historical perceptions of comets and compare them to modern ways of investigating comets with the scientific method. Observing routinely, keeping records, and testing hypotheses are key to revealing accurate information.
4	4-PS3-2	Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	Griffith Observatory's Tesla coil is explored in one of the interactive polls about connected versus coincidental events. It is revealed that the Tesla coil transfers invisible, wireless electricity to a nearby neon sign.
3-5	3-5-ETS1-2 ETS1.B	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	We share historical ideas about comets through records and stress that further observations were needed in order to obtain proof about their nature. Later, we show how astronomer Edmond Halley used records to form a testable hypothesis.
3-5	3-5-SEP1-8	(1) Asking Questions and Defining Problems, (2) Developing and Using Models, (3) Planning and Carrying Out Investigations, (4) Analyzing and Interpreting Data, (5) Using Mathematics and Computational Thinking, (6) Constructing Explanations (for science) and Designing Solutions (for engineering), (7) Engaging in Argument from Evidence, and (8) Obtaining, Evaluating, and Communicating Information	A video about astronomer Edmond Halley illustrates comprehensively the use of the scientific method. We witness how all of the strategies listed on the left are used to form a testable (and later proven) hypothesis about how and why comets move as they do.
3	3-PS2-2	Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.	We show that a certain comet was reported in historical records every 76 years and that this pattern was the basis of Edmond Halley's hypothesis: Comets are controlled by gravity, and therefore some may be predicted to return within measurable time periods.



## Standards continued.....

GRADE	STANDARD	NGSS DESCRIPTION	HOW THE STANDARD IS ADDRESSED
3-5	3-5-ETS1-3 ETS1.C	Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	We stress that while Edmond Halley's proven hypothesis revealed certain aspects about comets, it didn't reveal the full picture. More tools and methods were needed to study the nature of comets.
5	5-PS1-3	Make observations and measurements to identify materials based on their properties.	A video featuring two of Griffith Observatory's exhibits guides us through identification of a comet's materials with tools to observe the light coming from the comet.
5	5-PS1 PS1.A	Measurements of a variety of properties can be used to identify materials.	<i>Same as above</i>
5	5-PS1 PS1.B	When two or more different substances are mixed, a new substance with different properties may be formed	During the model comet-making portion of the show, the Museum Guide explains that ammonia (NH <sub>3</sub> ) is an independent chemical made from two elements that are essential for life: Nitrogen and hydrogen.
5	5-PS2-1	Support an argument that the gravitational force exerted by Earth on objects is directed down. [Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth.]	We use models to show, more broadly, how planets and comets are controlled by the Sun's gravity. The models simulate this motion and provide visual support for the argument of why comets return and appear the way they do from our vantage point on Earth.



# Connecting to the Program

## Overview

This section contains all of the information you and your students will need in order to join your online school program webinar session and ensure a successful virtual visit to Griffith Observatory. It is essential that you read and follow these instructions carefully.

Within 24 hours of completing the registration process for our program, you should have received a confirmation email from [online.sp@griffithmedia.org](mailto:online.sp@griffithmedia.org). The message includes a **Zoom webinar link**, the **date and time** of your session, and other important information and links. You are responsible for forwarding the necessary information, according to the instructions in the message, to your students and all included teachers. Shortly before your scheduled Griffith Observatory Online School Program webinar session, you will receive a reminder message.

## What You Need to Know

- Please be as punctual as possible. Your session includes a window for arrivals before the actual program begins, but the program will begin regardless of whether every registered classroom shows up or not.
- A Griffith Observatory staff member will be in the Zoom room to assist you if needed, relay some reminders, and will then act as your main point of contact for any questions you may have during the program. Use the chat feature to message the “Host and Panelists.”
- The school program now uses Zoom’s “webinar” model. Teachers and students are encouraged enter the webinar all at once. Although you will be muted with your video turned off, you may still use the chat function to message Griffith Observatory staff.
- Students that join the webinar from their individual devices are also not able to unmute themselves or share their video streams. They may not chat with each other. They may, however, use the chat feature to ask for help and use the Q&A feature to submit astronomical questions to staff. Questions submitted in the Q&A feature are not visible to everyone unless a staff member chooses to answer it live.
- You may also choose to project the program to your class. Note: This means you will need to answer the interactive polls and ask questions for the Q&A on behalf of your class.
- In the unlikely event that the Griffith Observatory video stream drops out of the webinar, please instruct your students to wait patiently and remain in the call.

## Connecting to the Program continued . . . . .

### Essential Information for Students

It is your responsibility to make sure your students receive and understand the following information. You may easily copy it and paste it into a message to your students. Make sure you insert your class's registered session **time, date**, and unique **Zoom webinar link** into the **orange** areas below. This information may be found in your confirmation email.

Dear Students,

Your class's Griffith Observatory Online School Program webinar time:  
[**INSERT YOUR REGISTERED WEBINAR TIME AND DATE**]

**Please log on at the time of your scheduled session. Make sure you set your "Zoom name" to contain your first and last name.**

Once you enter the webinar, you will be muted with your video off. You will see a video of Griffith Observatory against a sky that cycles between day and night, and you will hear music. If you do not see the video or hear the music, use this time to work with a grown-up to check your internet connection and sound. You may also use Zoom's chat feature to ask one of the Griffith Observatory hosts for help. Once everything is working perfectly, pay attention to the instructions, and have a great online visit to Griffith Observatory!

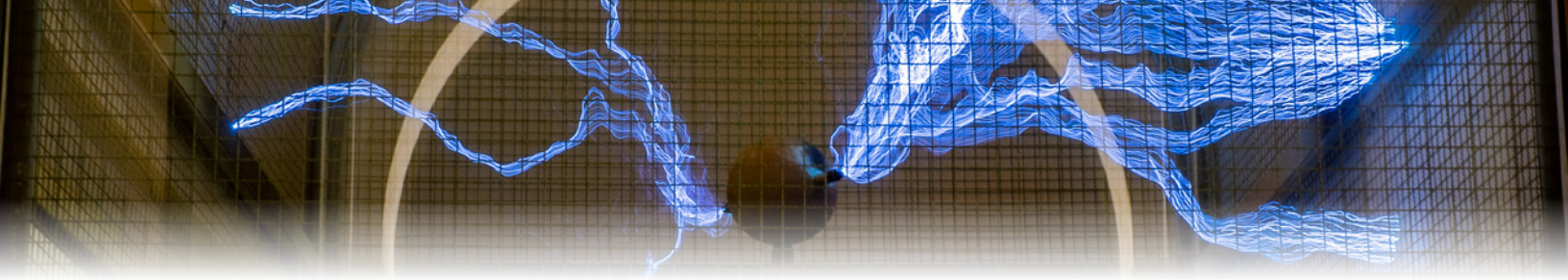
Click the link below or copy and paste it into an Internet browser to join the meeting.

YOUR CLASS'S ZOOM WEBINAR LINK:  
[**INSERT YOUR GRIFFITH OBSERVATORY ZOOM WEBINAR LINK**]

**THIS WEBINAR LINK IS YOURS AND YOURS ONLY. DO NOT SHARE IT WITH ANYONE NOT PART OF YOUR CLASS.**

Before the program, please make sure you have reviewed your **Student Guide**.





## Frequently Asked Questions

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### **How safe are the online school program's meeting rooms?**

Your meeting room has a unique **Zoom webinar link** that will only be issued to the teacher/adult contact(s) you indicated during the registration process and to other teachers and students that have registered for that particular session. The email message with the Zoom webinar link also contains necessary information to relay to your students. This information includes a prohibition on sharing the Zoom webinar link, as keeping the webinar session link private guarantees security. At the beginning of the program, staff will state that any inappropriate, rude, or harassing language or spam sent to staff in the chat or Q&A is not tolerated and may result in being dropped from the Zoom session.

### **Do my students and I need to download the Zoom app to view the program?**

No. You may click the Zoom webinar link or copy and paste it into an internet browser. If you do not have the Zoom app, your browser will present you with an option to “join from your browser.” If you do have the Zoom app, you will be redirected to the webinar in your Zoom app after searching the link in your internet browser.

### **Can I access my registration form to make changes?**

There is a link in your confirmation email to make any registration corrections or to reschedule.

### **What happens if a participant has poor connection, loses connection, or needs help?**

Students will be told early in the Zoom webinar what they should do if they need help or if a connection issue occurs. They may use Zoom's chat feature to talk to Griffith Observatory staff members to report or receive help with technical issues. If a participant's call fails, the participant will be able to use the same Zoom webinar link to rejoin the session.

### **May I or my students record the program?**

No. Like the Observatory's in-person school program, the live webinar is designed and intended to be experienced in the moment. We also need to safeguard the program content, quality, and integrity. In the future, we may consider producing recorded versions of the program, but they would be optimized for that format (vs. a live program.)

## Contact

For any concerns or questions, contact [online.sp@griffithmedia.org](mailto:online.sp@griffithmedia.org).



## Pre-program Materials

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

### Module 2 Glossary

The glossary identifies and defines important words that are useful for students before they attend “Clues from Comets.”

#### [Listen to the Module 2 Glossary](#)

This helps students become familiar with the terms we shall use in the program. This is recommended as an accessibility resource for students with physical and/or language-related challenges. The audio file includes pronunciations and definitions of important terms used in our program (same as in the Glossary above).

### Word Find and Grading Version

This activity helps students become accustomed to glossary terms by searching for them in a word find.

### Pieces of the Sky: What’s the Difference?

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

### Cook Up a Comet

Here is the “recipe” for the model-comet demonstration performed in “Clues from Comets” that you can do in the classroom.

### Comet in the Freezer

Here is an alternative way to cook up a comet. Students may safely try this one from home.

#### [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 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.

**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.

**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	KUIPER BELT	HYPOTHESIS	NUCLEUS
HALLEY	OORT CLOUD	THEORY	COMA
METEOR SHOWER	ROSETTA	GRAVITY	TAIL
PERIODIC TABLE	PHILAE	ATOM	OUTGASSING
ORBIT	PERIHELION	CARBON	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 \_\_\_\_\_!

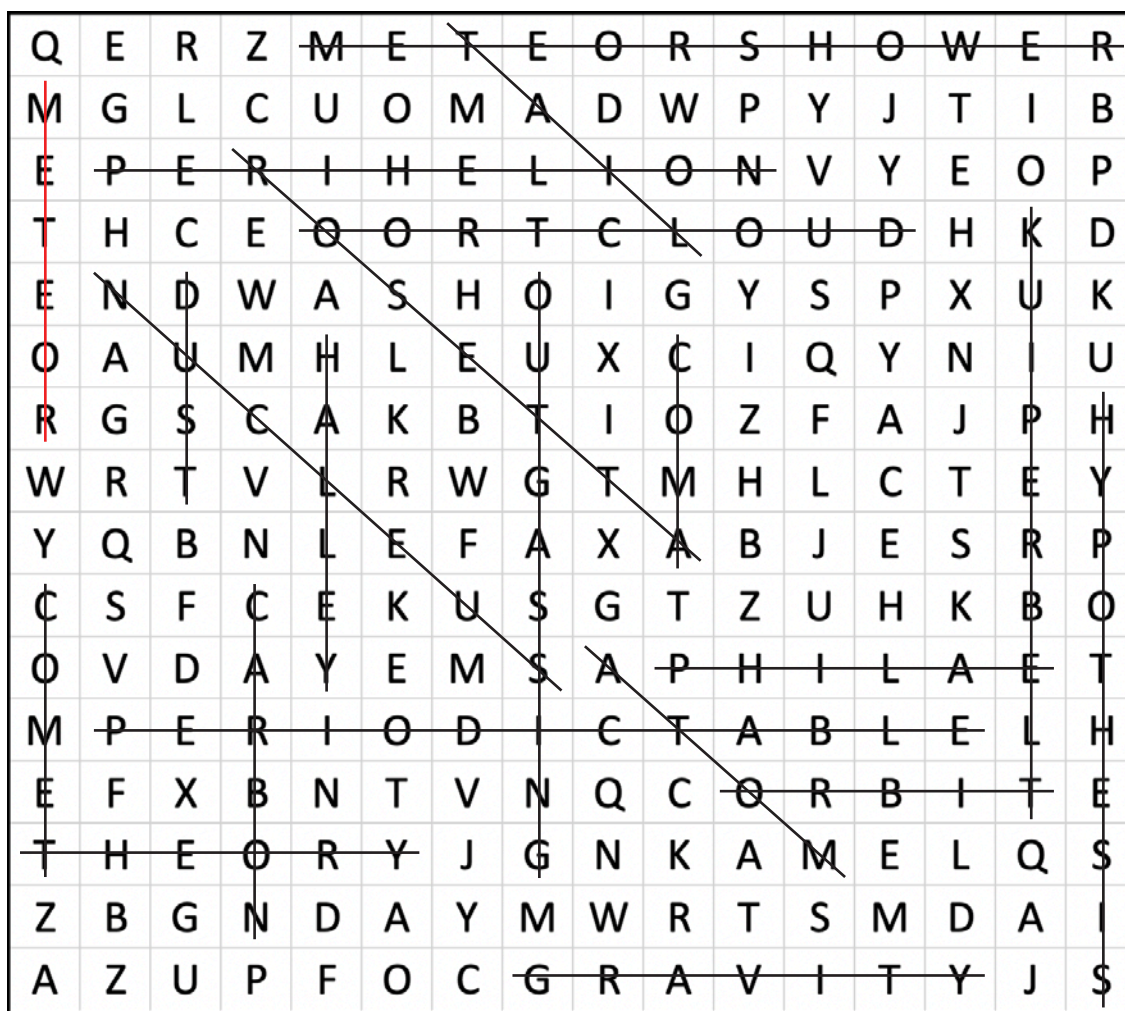




## Can you find the following words?

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

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



\*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 M E T E O R !



# 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.

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.



Leonid meteor

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

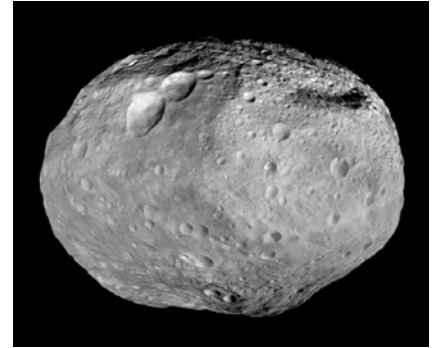
found on Earth's surface

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!

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?

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asteroid Vesta

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 through 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.

# Cook Up a Comet



## Classroom Demonstration Instructions for Teachers

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 states of water ( $\text{H}_2\text{O}$ ), ammonia ( $\text{NH}_3$ ), and a number of organic compounds such as carbon monoxide ( $\text{CO}$ ), carbon dioxide ( $\text{CO}_2$ ), methane, ( $\text{CH}_4$ ), ethane ( $\text{C}_2\text{H}_6$ ), formaldehyde ( $\text{CH}_2\text{O}$ ), 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.

**WARNING: Dry ice is  $-79^\circ\text{C}$ . ( $-110^\circ\text{F}$ .) and can cause frostbite or burns if brought in contact with the skin. Thick, thermally insulating gloves should be worn at all times when handling dry ice. This is an adult demonstration only. Children should not handle dry ice and must be supervised at all times in its presence.**

## MATERIALS AND COMET INGREDIENTS

- sturdy ice chest
- 2 large mixing bowls
- large mixing spoon
- large resealable bags
- cold-resistant/chemical-resistant gloves
- safety goggles
- mallet (at least three pounds)
- crushed charcoal (regular, not insta-light)
- towel
- paper towels for clean-up
- sand
- glass cleaner (ammonia)
- water
- dry ice (at least five pounds)
- corn syrup (optional)

## PREPARATION

Dry ice may be purchased from any ice store. Purchase enough (at least five pounds) to try the demonstration at least once before classroom use. Be aware that you will lose some ice over time due to sublimation in the cooler. It is wise to purchase more than you think you will need, especially if the demonstration is more than a day away.



## PREPARATION CONTINUED...

Wearing the gloves and safety goggles, wrap the dry ice in the towel and crush it with the mallet. Allow the dry ice to sit in the ice chest for a few hours. Fresh dry ice tends to crush to a coarse texture rather than to the powdery consistency that you want. Put the dry ice in one of the mixing bowls, and cover with the towel.

## 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
2. Add 1½ cups of dry ice, and mix vigorously for about 30 seconds.
3. Wearing protective gloves, lift up the mixture, and squeeze it together to allow any run-off to spill into the mixing bowl. Hold the comet and allow it to freeze, for about 20-30 seconds.
4. Tear the bag open. You've made a comet!



## DISCUSSION

In order to mix the comet, liquid water is used. After the ingredients are mixed, the liquid is flash-frozen with dry ice to replicate the comet's true icy disposition.

- 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 the familiar experience of 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.

Observing the comet over several hours may be quite enlightening. Over the course of about 3-4 hours, the comet will sublime and release wisps of carbon dioxide. Before it melts completely to a sludgy residue, it becomes a crater-filled mass. The formation of a comet tail may be simulated by using a hair dryer on a low setting to pass warm air over the comet.

# 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.

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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

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

### Periodic Comet Calculator and Grading Version

This worksheet explains what periodic comets are and guides students through the process of estimating when actual comets are going to reach perihelion (their closest points to the Sun).

### How to Observe Comets

This resource will help 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 provided a coloring-book-style activity for students.

### [Kerbal Space Program](#)

Do you have any space-obsessed students that play video games? This advanced physics-based simulation game teamed up with the European Space Agency (ESA) to give players the ability to reenact ESA's *Rosetta* mission to comet 67P/Churyumov–Gerasimenko, from launch to landing!

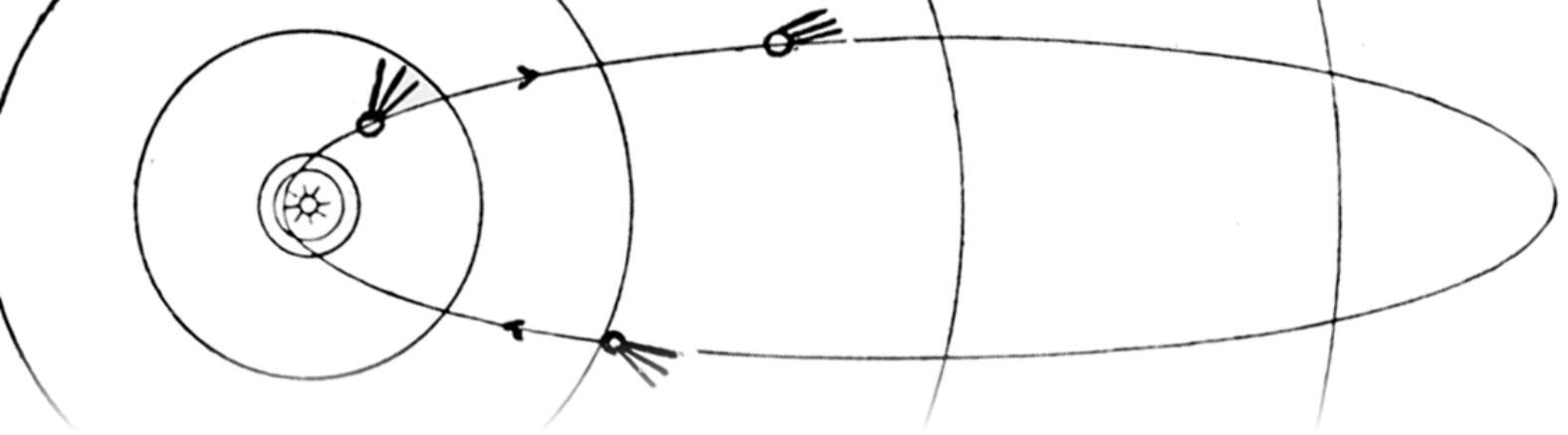
### Stellarium Guide

This guide includes instructions to help students 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 variety of websites will help students expand their 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**

*Add this time difference to the most recent perihelion. 1954 + 70 years*

Next estimated perihelion year: \_\_\_\_\_ **2024**

*As astronomers predicted,  
this comet reached perihelion  
on April 21, 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?**

\_\_\_\_\_

# Comet Return Calculator

## EXAMPLE:

**Comet Name:** 12P/Pons–Brooks

Most recent perihelion year: 1954

Prior perihelion year: 1884

Time difference (Period): 70 years

Add this time difference to the most recent perihelion. 1954 + 70 years

Next estimated perihelion year: 2024

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

**1) Comet Name:** 1P/Halley

Most recent perihelion year: 1986

Prior perihelion year: 1910

Time difference (Period): 76 years

Next estimated perihelion year: 2062 (Astronomers say July 28, 2061)

**2) Comet Name:** 67P/Churyumov-Gerasimenko

Most recent perihelion year: 2021

Prior perihelion year: 2015

Time difference (Period): 6 years

Next estimated perihelion year: 2027 (Astronomers say April 9, 2028)

**3) Comet Name:** 36P/Whipple

Most recent perihelion year: 2020

Prior perihelion year: 2011

Time difference (Period): 9 years

Next estimated perihelion year: 2029 (Astronomers say November 4, 2028)

**4) Comet Name:** 27P/Crommelin

Most recent perihelion year: 2011

Prior perihelion year: 1984

Time difference (Period): 27 years

Next estimated perihelion year: 2039 (Astronomers say May 27, 2039)

**5) Which comet can we expect to observe first?**

Comet 67P/Churyumov-Gerasimenko

GRADING VERSION



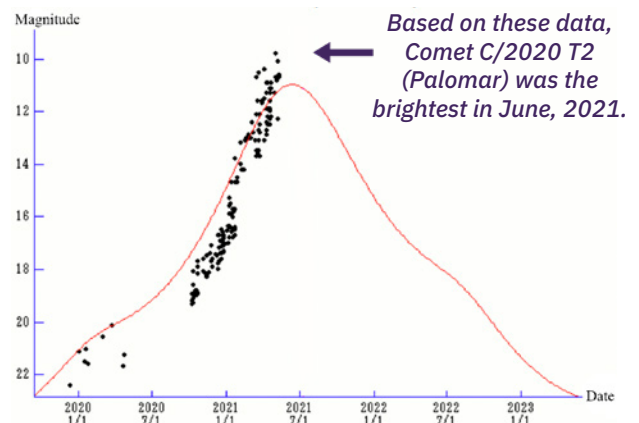
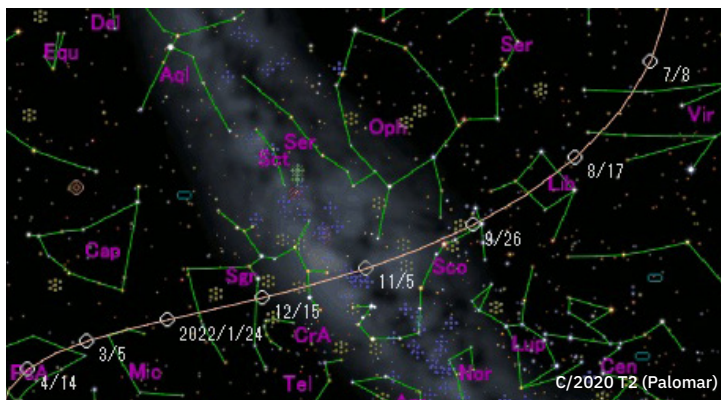


# How to Observe Comets

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

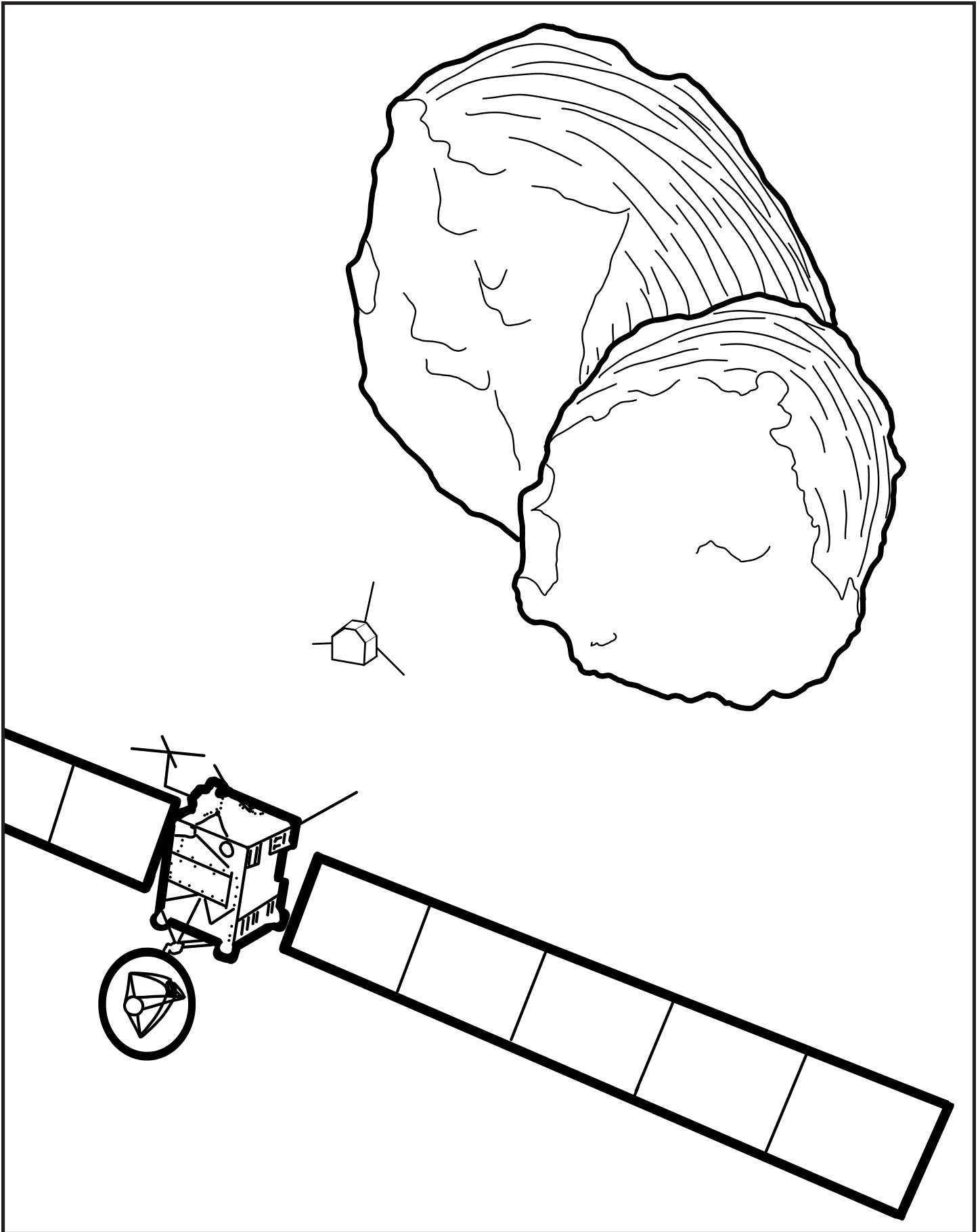
Remember that it will be easiest to find a comet if you have researched which constellation it currently occupies. Use Stellarium or a sky-touring app like Night Sky or Stellarium Mobile to determine whether the comet's current constellation will be visible in the sky *right before sunrise* or *right 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





# Stellarium Guide



Night Sky

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

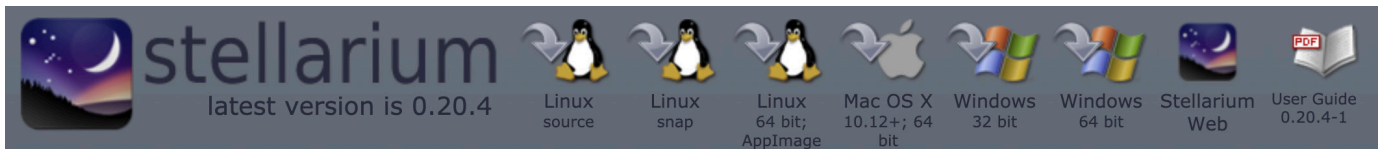


Stellarium Mobile

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]**

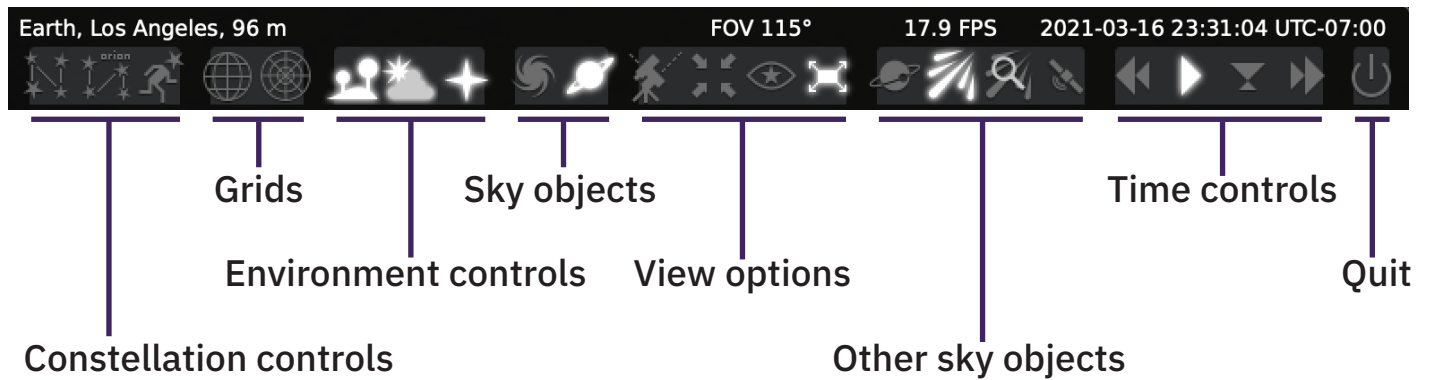
If you click on the **Location window**, you may see what the sky looks like from any place on Earth. You may even move yourself to another planet or moon!

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.

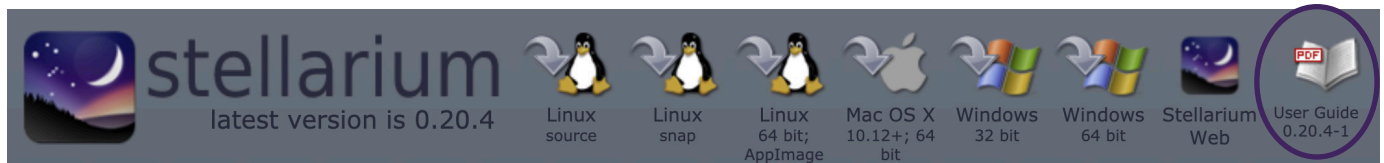
If you click on the **Date/time window**, you may change the date and time to anything you want. If you choose a time after the Sun sets, you will see the night sky. You may also view the sky thousands of years in the past or future!

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:"

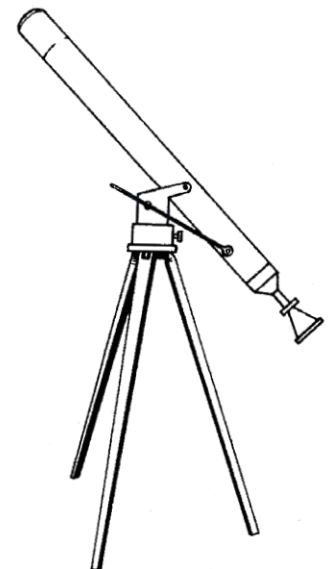
<https://science.nasa.gov/eyes>

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>



## 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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Griffith Observatory is owned and operated as a public service by the City of Los Angeles, Department of Recreation and Parks. The work of the Department is overseen by the Board of Recreation and Park Commissioners, appointed by the Mayor of Los Angeles with confirmation by the Los Angeles City Council.

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