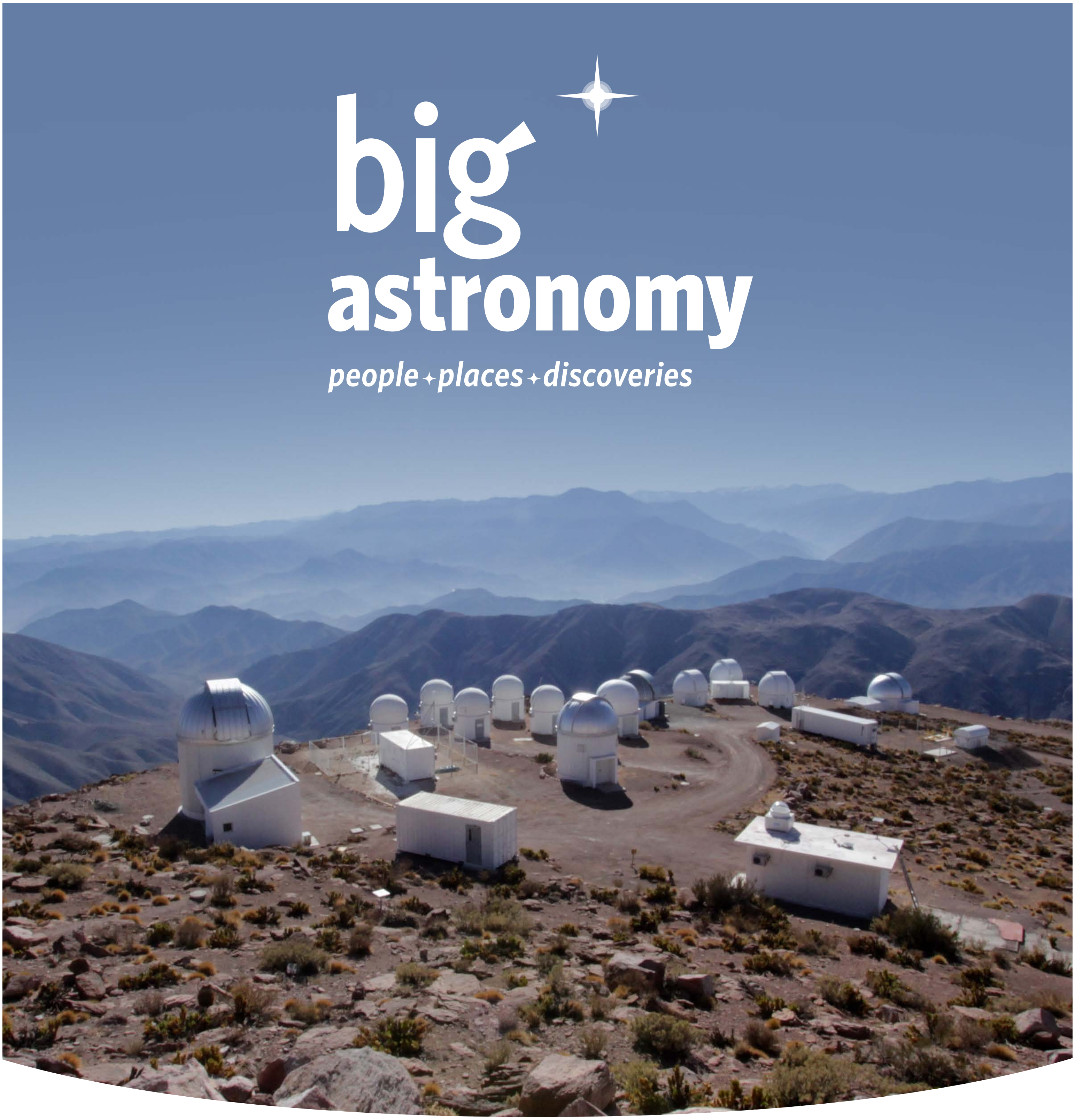

EDUCATOR GUIDE

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SHOW SUMMARY

Big Astronomy: People, Places, Discoveries explores three observatories located in Chile, at extreme and remote places. It gives examples of the multitude of STEM careers needed to keep the great observatories working. The show is narrated by **Barbara Rojas-Ayala**, a Chilean astronomer.

A great deal of astronomy is done in the nation of Chile, due to its special climate and location, which creates stable, dry air. With its high, dry, and dark sites, Chile is one of the best places in the world for observational astronomy. The show takes you to three of the many telescopes along Chile's mountains.

The first site we visit is the Cerro Tololo Inter-American Observatory (CTIO), which is home to many telescopes. The largest is the Victor M. Blanco Telescope, which has a 4-meter primary mirror. The Blanco Telescope's mirror focuses light onto a large lens, which is part of an instrument called the Dark Energy Camera. Here we meet **Marco Bonati**, who is an Electronics Detector Engineer. He is responsible for what happens inside the instrument. Marco tells us about this job, and needing to keep the instrument very clean. We also meet **Jacoline Seron**, who is a Night Assistant at CTIO. Her job is to take care of the instrument, calibrate the telescope, and operate the telescope at night. Finally, we meet **Kathy Vivas**, who is part of the support team for the Dark Energy Camera. She makes sure the camera is producing science-quality data.

The Dark Energy Camera was designed to peer into the farthest reaches of the Universe. But it has also been used to find thousands of small icy bodies far out in the Solar System, beyond Neptune, in the Kuiper Belt. These small icy worlds help us understand the history of our Solar System.

On Cerro Pachón, we visit another telescope called the Gemini South Observatory, which has an eight meter primary mirror. We meet **Vanessa Montes**, an Electronics Engineer who describes how well the teams work together at the telescopes. We also meet **Alysha Shugart**, Science Operations Specialist, who operates the telescope at night. An instrument on Gemini South called the Gemini Planet Imager helps us see planetary systems as they are just forming.

We now travel farther north in Chile to the Atacama Desert, one of the driest places on Earth, to the Atacama Large Millimeter/submillimeter Array, or ALMA. People have observed the stars here for millennia. Here we meet **David Barrera**, president of the indigenous community of San Pedro de Atacama, which is near ALMA. He feels the cosmos walks with him. It is part of the community, part of their life. People and the cosmos make up a single unit. ALMA looks to unite scientific knowledge to indigenous knowledge.

ALMA is made of 66 radio antennas that work together, observing the sky in unprecedented detail, both night and day. The antenna array is located in an area known as the Chajnantor Plateau at an altitude of over 5000 meters. The extremely thin, dry air at Chajnantor is essential to successful observations at millimeter and submillimeter wavelengths. Each antenna dish weighs about 100 tons, and they needs to move from place to place to make different kinds of observations and receive maintenance. **Alfredo Elgueta** is one of only four people trusted to operate the transporter that moves the antennas. The antennas collect a huge amount of data. Because they work as a network, data from each antenna is compared to data from every other one. **Cella Verdugo**, an astronomer and data analyst, collects and studies these observations for astronomers around the world. ALMA has given us close up images of young planetary systems.

The show closes by previewing a new observatory that is being built in Chile, which will generate 20 terabytes of data every night. The data will be freely available to the world, enabling anybody to make the next great discovery.

All of the people we meet in the show come from different backgrounds, with many different talents and skills to contribute to Big Astronomy.

NATIONAL SCIENCE STANDARDS SUPPORTED BY THE BIG ASTRONOMY SHOW

MIDDLE SCHOOL, GRADES 6-8

MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system

- Planets form by coalescing out of discs of gas and dust surrounding young stars. Gravity causes small clumps of matter to attract more material from the disc, eventually forming entire planetary systems.

Crosscutting: Systems and System Models

- Models can be used to represent systems and their interactions.

MS-ESS2-5. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

- Chile's climate is special for many reasons. The Andes block rain clouds from the east, while currents in the Pacific Ocean bring cold waters north from the Antarctic. Along the Chilean coast, the air temperature drops, and as the cooled air sinks, it loses its moisture. These factors combine to create stable, dry air over Chile's coastal mountains, with few clouds.

MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system.

- Planets form in various sizes determined by a variety of factors. Rocky planets, gas giants, and small Kuiper Belt Objects are all discussed in this show.

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

- Both optical and radio telescopes collect electromagnetic waves on their curved primary mirrors, which focus the light on a secondary mirror or instrument, such as the Dark Energy Camera.

Crosscutting: Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

What is astronomy?

Astronomy is a natural science that studies the universe, celestial objects, and, broadly, everything that originates outside the Earth's atmosphere.

Who works in astronomy?

All sorts of people from all over the world, with different education levels and backgrounds, work in the field of astronomy. The most well-known profession in astronomy is an astronomer, who is a person who studies the universe. Astronomers need to use big observatories to take data. These observatories are supported by a large staff, with all sorts of areas of expertise. Some types of jobs that support astronomy include: engineers, mechanics, machinists, computer scientists, technicians, public relations managers, publicists, administrators, cooks, cleaning staff, educators, builders, health and safety personnel, and many more. Furthermore, indigenous peoples from all over the world have used astronomy in their daily lives for thousands of years, and continue to do so today. You can see a clip from the Big Astronomy show related to how teamwork is vital to astronomy and science here.

How does indigenous astronomy inform the practice of astronomy today?

Indigenous peoples from all over the world pay close attention to the night sky. The motions of the Moon, planets, and stars serve as a navigational aid, a calendar, and a reminder of stories that have been important in their culture for thousands of years. The native Andean peoples looked at the night sky and saw constellations in the dark lanes of the Milky Way. Today, ALMA, which is built on land owned by the people native to the Atacama Desert, is used to study objects within those same dark lanes of the Milky Way. Astronomers learn from the astronomy practices and cosmovision of native peoples. You can see a clip from the Big Astronomy show related to this question here.

Where is astronomy done?

Most big astronomy is done by taking observations with large telescopes. Some of these telescopes are in space, like the Hubble Space Telescope. Many telescopes are on Earth. Telescopes need to be built in areas with a likelihood of having clear skies. Chile is one of the best places in the world for optical astronomy. About 70% of the world's astronomy infrastructure is located on Chile's mountains. Many big observatories are built in remote locations away from light pollution, and at high elevations, to escape some of the interference of the Earth's atmosphere. Quite a few of these observatories are located on indigenous peoples' lands, including ALMA in Chile, and Kitt Peak and Mauna Kea in the United States.

You can see a clip from the Big Astronomy show related to how Chile's climate is uniquely suited for astronomy here.

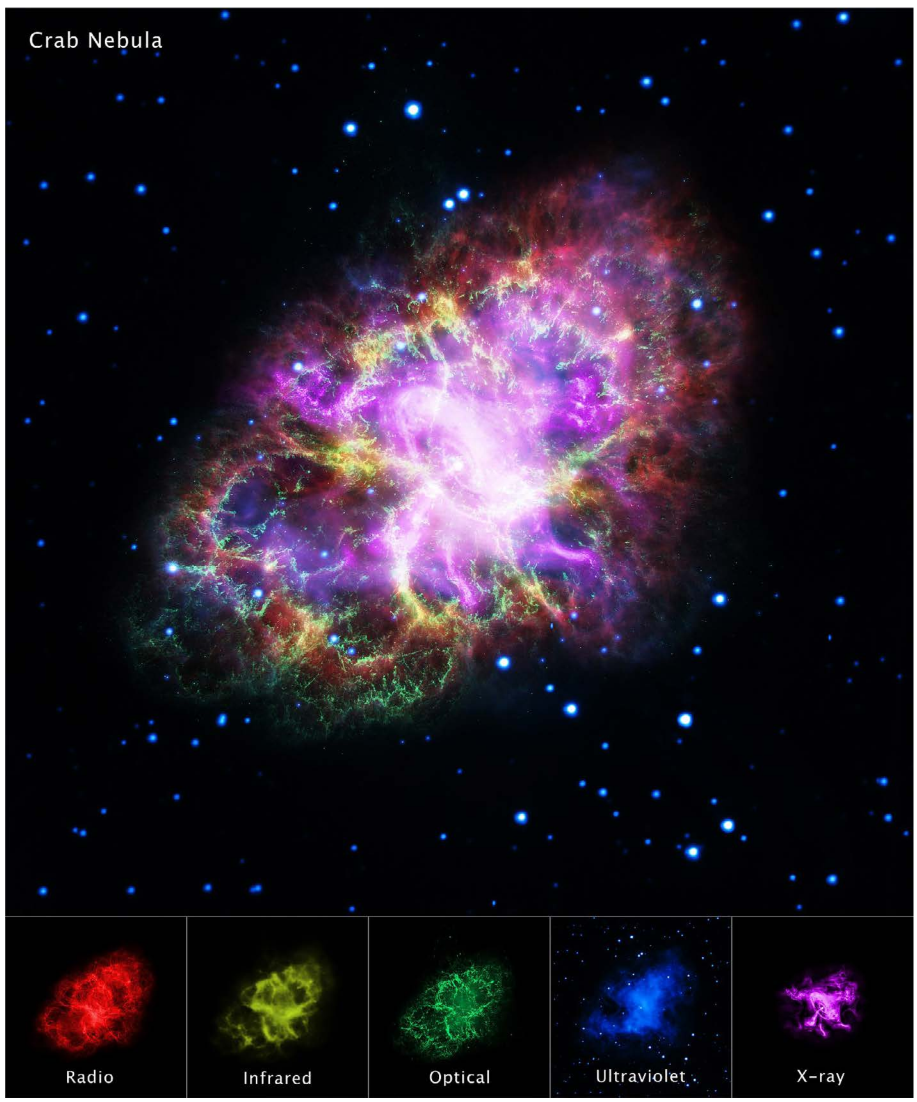
How do planets form?

Planets form out of the leftovers of star formation. Stars form when gravity causes a large cloud of gas and dust to collapse. Most of the collapsing mass collects in the center, forming the central star. The rest of the matter is flattened into a protoplanetary disk, out of which the planets, moons, asteroids, and other small bodies form. You can see a clip from the Big Astronomy show related to planetary formation here.

How does studying objects in different wavelengths improve astronomy?

Our universe contains objects that produce a vast range of radiation with wavelengths either too short or too long for our eyes to see. If we only studied the universe using the type of light we can see with our eyes (visible wavelengths) we would be very limited in what we could study. Some astronomical objects emit mostly infrared radiation, others mostly visible light, and still others mostly ultraviolet radiation. By building telescopes that can observe different parts of the electromagnetic spectrum, we can observe a more complete picture of an object.

You can see a clip from the Big Astronomy show related to observing in multiple wavelengths here.

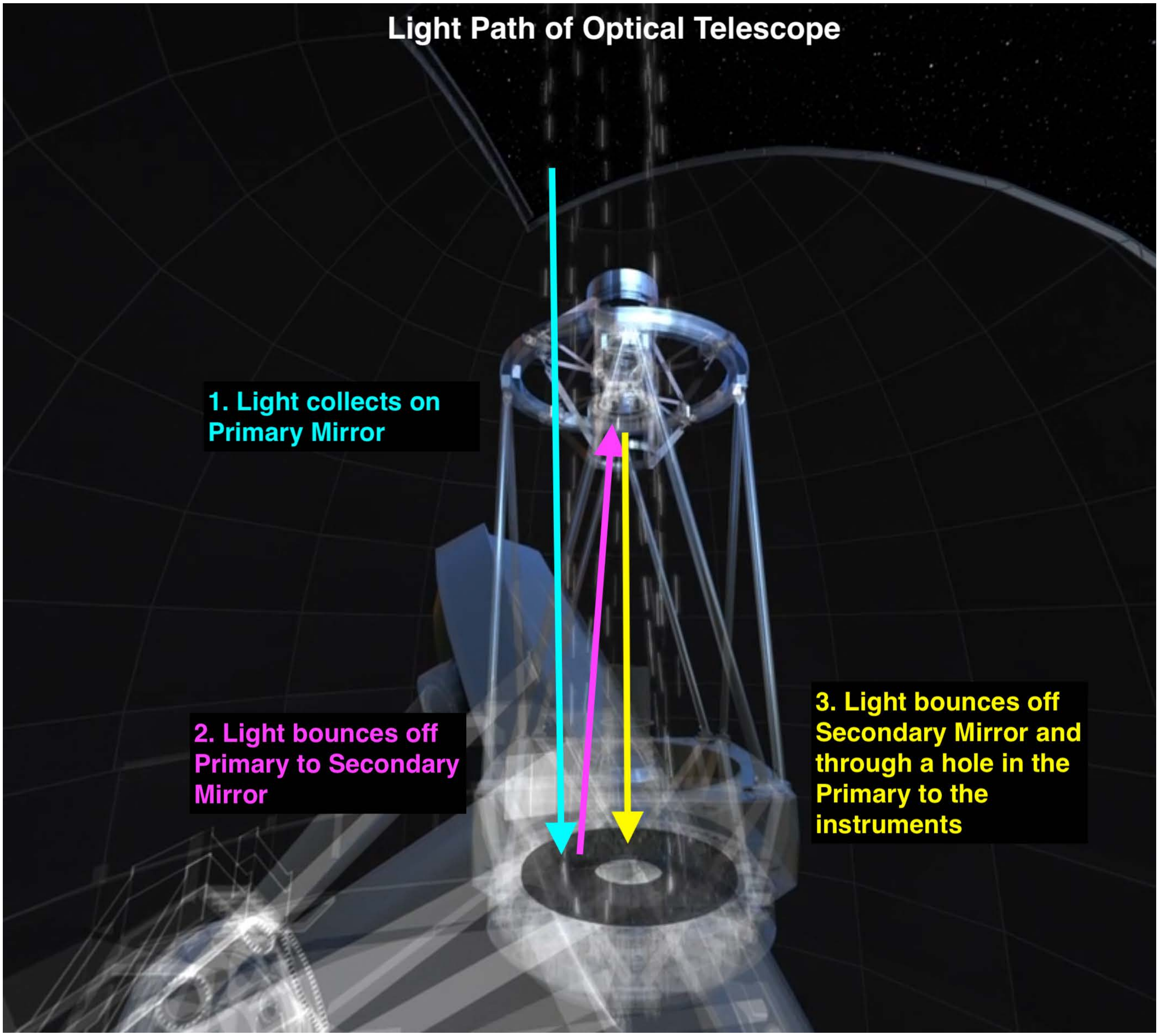


> Image By NASA, ESA, G. Dubner (IAFE, CONICET-University of Buenos Aires) et al.; A. Loll et al.; T. Temim et al.; F. Seward et al.; VLA/NRAO/AUI/NSF; Chandra/CXC; Spitzer/JPL-Caltech; XMM-Newton/ESA; and Hubble/STScI

image link here

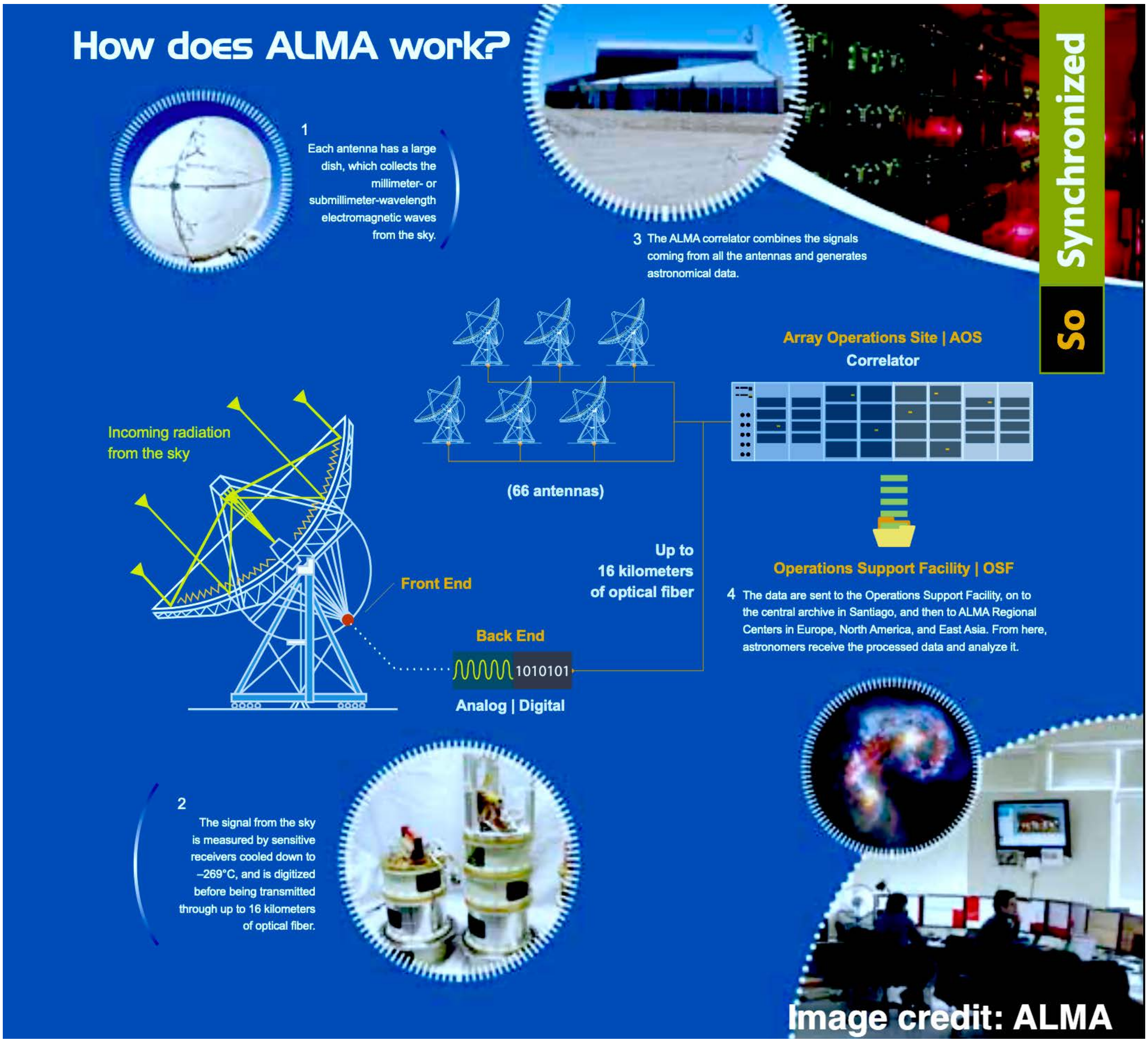
How do optical telescopes work?

Optical telescopes observe visible light, the type of light you can see. Light from the object astronomers are observing collects on a large mirror at the base of a telescope, called the primary mirror. The larger the mirror, the more light it can collect, so astronomers like to build the largest telescopes possible. The primary mirror is curved so that the light bounces off it and focuses on a secondary mirror. The light then bounces off the secondary mirror through a small hole in the primary mirror, to a suite of instruments. The instruments analyze the light in different ways, and the data is collected by the telescope operators. You can see a clip from the Big Astronomy show that shows how different telescopes work **here**.



How do radio telescopes work?

Radio telescopes work in much the same way optical telescopes do. However, they observe a type of electromagnetic energy that humans cannot see, radio waves. Stars, planets, galaxies, black hole accretion disks, pulsars, supernova remnants, and other celestial objects all emit radio waves. Radio telescopes observe these radio sources by collecting the radio waves on a primary mirror. The radio waves bounce off the primary mirror and focuses on a secondary mirror, which then directs the waves to the instruments that collect the radio signal. Most large radio telescopes, such as ALMA, work as an array—many antennas all working together as one big telescope. The radio signals collected by an individual antenna are correlated into one signal by a supercomputer. The signals can be interpreted as a spectrum graph, or an image. Radio telescopes allow astronomers to see very distant and very faint objects. They can also see objects whose visible light is obscured by dust. Radio telescopes can operate during both night and day and often make observations during the day when the sky is too bright for most optical astronomy.



ELECTROMAGNETIC SPECTRUM	The entire range of wavelengths or frequencies of electromagnetic radiation extending from gamma rays at short wavelengths to radio waves at long wavelengths.
ELECTROMAGNETIC WAVES	Any one of the types of waves that are propagated by simultaneous periodic variations of electric and magnetic field intensity and that include radio waves, infrared, visible light, ultraviolet, X-rays, and gamma rays.
EXTRASOLAR PLANET	A planet orbiting a star other than our Sun; a planet outside of the Solar System.
GALAXY	A system of millions or billions of stars, together with gas and dust, held together by gravitational attraction.
KUPIER BELT	A large belt of asteroids that extend out beyond the orbit of Neptune. Unlike the asteroids in the Main Asteroid Belt, these asteroids are made mostly of ice.
MULTIMESSENGER ASTRONOMY	Astronomy based on the coordinated observation and interpretation of disparate “messenger” signals. The signals included in multimessenger astronomy are electromagnetic radiation, gravitational waves, neutrinos, and cosmic rays. They are created by different astrophysical processes, and thus reveal different information about their sources.
OPTICAL TELESCOPE	An instrument that gathers and focuses light, mainly from the visible part of the electromagnetic spectrum, to create a magnified image for direct viewing, or to make a photograph, or to collect data through electronic image sensors.
PLANETARY SYSTEM	A star together with all the celestial bodies that are held by its gravitational attraction and revolve around it, including planets, moons, asteroids, comets, and more.
RADIO TELESCOPE	A specialized antenna and radio receiver used to receive radio waves from astronomical radio sources in the sky. Radio telescopes are used to study the radio frequency portion of the electromagnetic spectrum emitted by astronomical objects.
TELESCOPE	An instrument designed to make distant objects appear nearer, containing an arrangement of lenses, or of curved mirrors and lenses, by which rays of light are collected and focused and the resulting image magnified.

These educational activities relate to the topics addressed in ***Big Astronomy: People, Places, Discoveries.*** Teachers could incorporate them into pre-visit lessons, or post-visit activities.

Sorting the Solar System

Appropriate for: 3rd Grade - 5th Grade
Prep Time: 5 minutes
Activity Time: 30 minutes

The objects in our solar system are not limited to planets; rather, they range in size from microscopic dust all the way up to the Sun. In this sorting activity, students will practice sorting the objects in the solar system by characteristics used by scientists.

OBJECTIVES

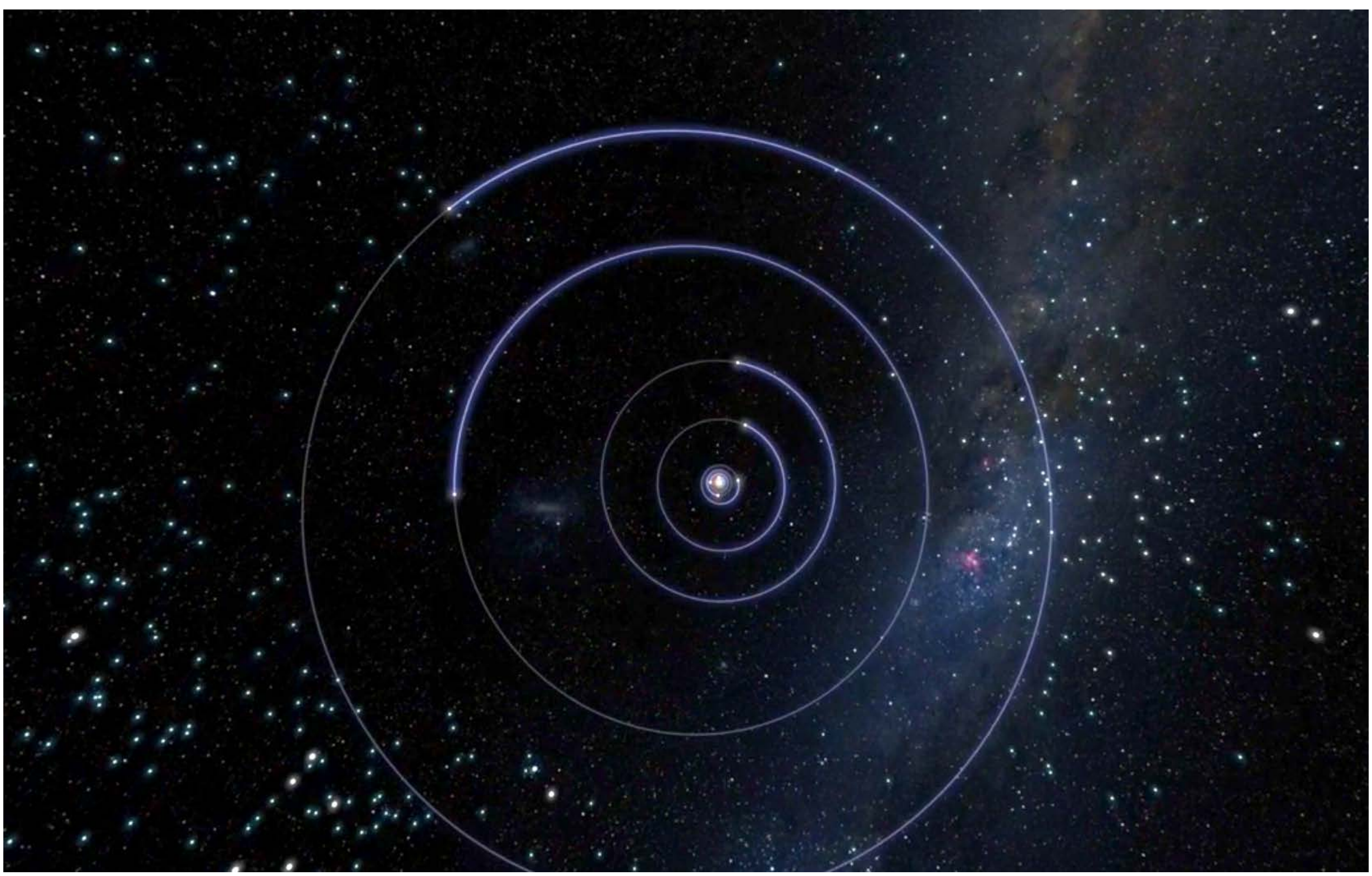
In this activity students will:

1. Review and categorize the diversity of objects in the Solar System.
2. Explore how scientists use common characteristics to classify objects.

MATERIALS & TEACHER PREP

Print the **Solar System cards** in color, one-sided, on card stock or thick paper. (Printing each complete set on different color stock will make it easier to collect the cards later). Cut each page into three strips so that the image and corresponding description stay together. Fold each strip in half to make two-sided cards. Paste closed or tape around the edges, or laminate to make permanent cards.

This activity works well as a small group activity, so create enough sets of Solar System cards to allow one set for each group of students.



SCIENTIFIC TERMS FOR STUDENTS

- **ASTEROID** A rocky space object that can be a few feet wide to several hundred miles wide. Most asteroids in our solar system orbit in a belt between Mars and Jupiter.
- **COMET** Frozen masses of gas and dust which have a definite orbit through the solar system.
- **CRATER** A hole caused by an object hitting the surface of a planet or moon.
- **DWARF PLANET** A non-satellite body that fulfills only the first two of the three criteria for planet (see below).
- **METEOR** An object from space that becomes glowing hot when it passes into Earth's atmosphere.
- **METEORITE** A piece of stone or metal from space that falls to Earth's surface.
- **MOON** A natural satellite that orbits a larger object.
- **PLANET** A celestial body that (1) is in orbit around the Sun, (2) has sufficient mass to assume hydrostatic equilibrium (a nearly round shape), and (3) has "cleared the neighborhood" around its orbit (International Astronomical Union, 2006).
- **STAR** A giant ball of hot gas that emits light and energy created through nuclear fusion at its core.

INTRODUCTION

Ask the class to list the kinds of things that are found in the Solar System. Explore their ideas on what makes each different from the others, how many of each there are, and if there is more than one star in the Solar System. Include discussions of why the Sun appears so much brighter than other stars, how the Sun's mass compares to the other objects in the Solar System, and how the Sun's gravity affects those objects.

Show the students one of the cards and explain that they have images of various Solar System objects on one side, and information about the object on the back.

PROCEDURE

1 Break the class into small groups (three students each) and give each group a set of cards.

2 Explain that scientists sort things by their characteristics – size, composition, and position are examples of how things can be categorized.

3 Ask each group to work together as scientists to sort the objects into categories based on their characteristics. It's up to them to determine what categories to create.

4 When the groups have completed sorting the objects, select one card and ask each group to describe how they categorized it. What characteristics does it share with the others in that category? Could the object fit into more than one category they have created?

5 Different groups will categorize the same object differently. Discuss the differences between the groups' categories.

6 Explain how scientists carefully observe new discoveries and apply their knowledge of existing objects to help understand and describe what they have found.

EXTENSIONS

Give each student a card and ask them to sort themselves by size, distance from the Sun, common materials, alphabetically, or shape. There may be more than one way to sort. All reasonable attempts should be accepted.

Ask each group to sort their objects based on a given characteristic such as size. The first group to sort them correctly wins. Allow each group to finish and hold their hand up when they're done. Once they raise their hand, they can't change their order. If the first group has anything out of order, go to the second, and so forth.

Pick an object and have students take turns asking yes/no questions until they guess the object. The person who guesses correctly gets to pick the next object. Give time during games and between rounds for students to look at the backs of the cards.

BACKGROUND FOR EDUCATORS

The objects that make up our Solar System range in size from microscopic specks of dust all the way up to the massive star at its center. Yet it is common for us to think of the Solar System as consisting of the Sun and the planets—a misconception reinforced by the typical depiction of the Solar System as planetary orbits circling the Sun. Other common misconceptions are that there is more than one star in the Solar System, or that objects in the Solar System fall into specific, predetermined categories, distinct from each other. This activity allows students to explore the variety of objects found in the Solar System, and to create their own logical categories for them based on observation of the object's characteristics.

You can watch a clip related to how planetary systems form **here**.

This activity was adapted from a classroom activity originally developed by Anna Hurst Schmitt for the Teacher's Newsletter Universe in the Classroom. It may be found **here**.

How Telescopes Work—It's All Done with Mirrors

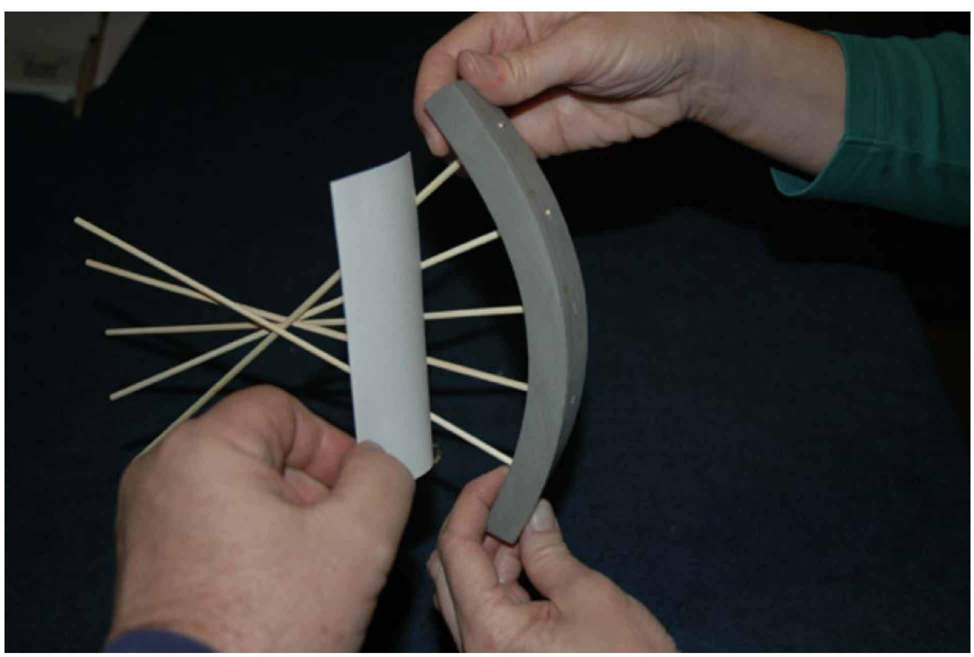
These simple demonstrations are a great way to illustrate the path of light as it reflects off of mirrors and how this is used in telescopes.

TOPICS COVERED

- How does a telescope work?
- Why is the image upside down?
- How do mirrors focus and concentrate light?

Find the full activity write up and **video explanation here**.

Find a video clip showing how different telescopes work **here**.



Picture an Astronomer

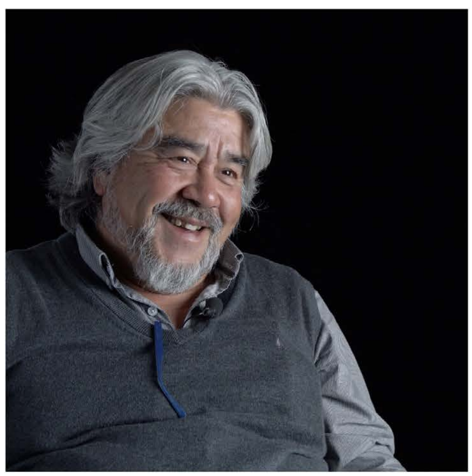
Appropriate for: all ages
Prep Time: 5 minutes
Activity Time: open ended

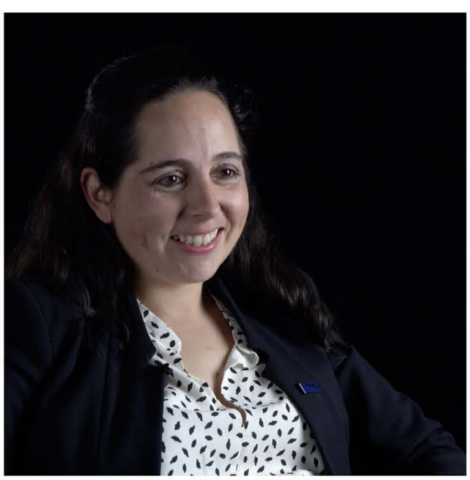
GOALS

This activity is intended to help students look at their assumptions and stereotypes about who might be an astronomer, and encourage class discussion about who works in science in general. This activity is best to do before viewing the planetarium show or flat screen film.









THE ACTIVITY

Ask students to picture what an astronomer, or someone who works at an observatory, looks like, and then discuss their assumptions. You can begin by reading this paragraph:

Close your eyes and picture this scene. It is the end of a long night at the observatory and the astronomer is closing up as the first rays of dawn are seen on the horizon. The astronomer is tired and ready for a good day's sleep. Now focus on the astronomer, coming toward you on the road that comes from the observatory. Get a good close look at the astronomer, rubbing tired eyes. Draw a picture (or for older students—get a clear mental image) of what the astronomer looks like.

Note that this paragraph carefully omits any hint about the gender, age, or race of the astronomer. After students have made their own picture (as elaborately or as simply as time allows), have them compare and discuss the different pictures they came up with. In the past, there has been a tendency for participants of all ages to draw scientists as middle-aged white men. If your students also show such a tendency, this gives you an opportunity to discuss who became an astronomer in the past, and how the opportunities have expanded today and some (but by no means all) of the societal barriers have fallen.

EXTENSIONS

1. Have students discuss the images of astronomers (or scientists in general) in the media. What gender, race, or age are astronomers they may have seen in the movies, on TV? Have any of them seen astronomers in the newspaper or on the TV news? What kind of news or stories about astronomy have the students read or seen recently? If students don't remember seeing astronomers in the media in particular, you can broaden the question to scientists in general.

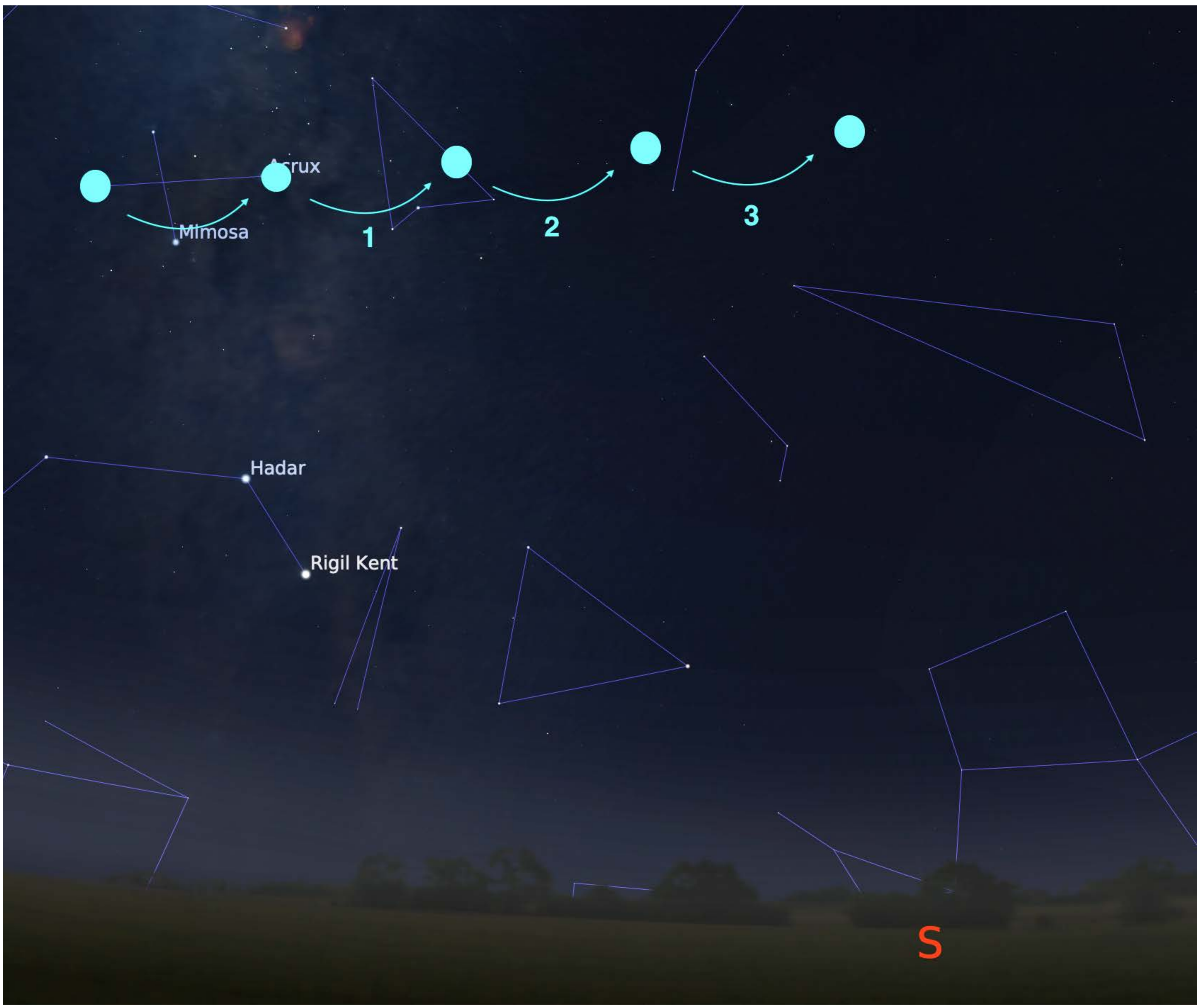
2. Visit **www.bigastronomy.org** to view videos of people who work at major observatories. Take note of various types of jobs it takes to keep the big observatories in operation - much more than just astronomers! Note that people from different countries, different educational backgrounds, and of different genders are represented.

Activity based on "***Picturing an Astronomer***" by Astronomical Society of the Pacific: **astrosociety.org**

Andean Constellations

There are 88 constellations currently recognized by the International Astronomical Union and taught in the United States, but they are only one perspective on the night sky. Constellations are formed by human imagination making familiar, recognizable patterns from the brighter stars in the sky. Throughout history, cultures devised their own constellations. People all over the world have used the stars and what they can see in the sky as a tool. If you can recognize star patterns that come and go with the seasons, you can use these patterns to predict when to plant crops, or when the seasons will change. People from around the world also used the star patterns to navigate. To help them remember the important patterns in the sky, many cultures took myths and legends that were already important to their culture and assigned them to the stars, or in the case of the Andean people, to the dark lanes in the bright Milky Way. The information below was reported by Juan Fernandez, an expert on Andean star lore.

The Andean peoples used both the stars and the shadows of the Milky Way as constellations. One very important grouping of stars in the southern hemisphere is the chakana, or Southern Cross. The chakana represents balance and symmetry. The Sky



and Earth, Sun and Moon, Day and Night, Men and Women. You can use the Southern Cross to find the south celestial pole and find your cardinal directions. To do this, take the distance between the longer part of the cross and multiply it by three, and you will have found due south.

The glow of the Milky Way is especially bright in the Southern Hemisphere. This band of light is the combined luminosities of hundreds of billions of stars in our galaxy. Along the band of light, there are dark patches, where the light from the stars is blocked out by clouds of dust, far away in our galaxy. The Andean people used the dark patches as constellations. The dark patches represent animals, and telling stories about those animals passed down important information from generation to generation.

This black spot (***see picture below***) in the Milky Way was called the **Frog**. Today, it is also called the coal sack.

To the Andean peoples, this large dark lane represents the Big Llama, the **Yacana**. In the beginning of time, the father of everything was looking at the emptiness of the Earth. Feeling sad over the lack of beauty, he sent one of his most beautiful daughters to the Earth, the Yacana. He gave her the mission to create beauty. She created the water and the winds, but she felt alone. She went back to the sky and asked her father for help. He sent the **Fox**, a smart spirit. The Fox called the Frog for help. The Frog called the rain, which brought fertility to the land.

Finally, the **Snake** came to help. The snake, whose eye is marked by the brightest star in the Southern Cross, brought knowledge to the Earth.

Just as people all over the world use constellations as tools to track the passage of time and to navigate, so do the Andean people. In the summer, in the high Andes, the llamas are moved to the mountains to feed on the grasses. People knew when to move the llamas because this is when the Baby Llama is touching the Andes right before sunrise. This is also the time of year when the Frog is upside down, a signal that the rains will come. Telling these stories about the sky, understanding the patterns in the stars, allowed the Andean people to track the changing seasons, and know when to move their herds. These traditions continue today.

Additional Resources

ALMA Educational Website:
http://kids.alma.cl/

Gemini Educational Website:
https://www.gemini.edu/pio/#education_outreach

Citizen Science Project about Light Pollution:
https://www.globeatnight.org/

Citizen Science on Exoplanet Hunting:
https://www.zooniverse.org/projects/ianc2/exoplanet-explorers

Citizen Science on Planet Nine Hunting:
https://www.zooniverse.org/projects/marckuchner/backyard-worlds-planet-9

Figures In the Sky - How Cultures Across the World have seen the Sky:
http://bit.ly/33hYkbl

Native SkyWatchers - North American Indigenous Astronomy:
https://www.nativeskywatchers.com/

Night Sky Network
https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=664

EDUCATIONAL VIDEOS

Chilean Geography
https://youtu.be/JBKeprzd8tE02

Planet Families
https://youtu.be/--4aGYHEqNo

Astronomy at Many Wavelengths
https://youtu.be/v_436qhaLbc

Teamwork
https://youtu.be/iMOjmN-VF1s

Indigenous Understanding of Astronomy
https://youtu.be/d9H-V73px1I

Credits

Award Number:
NSF-AISL 181143