NASA'S UNIVERSE OF LEARNING

Activity Guide

Light & Color: Exploring Visible Light

Overview

This activity introduces learners to the visible-light spectrum and color mixing. Learners explore visible light by observing it with diffraction grating glasses to see how it can be broken up into its component colors (red, orange, yellow, green, blue, and violet).

Main Takeaways

- The primary colors of visible light are red, blue, and green. When all combined, these colors make white light.
- Combining red, blue, and green light in different ways, and with different intensities, produces different colors of light.
- Breaking light up into its component colors is called spectroscopy, an important tool for studying the universe.

Type of Activity

☑ Demonstration
☑ Facilitated activity
☐ Independent activity

Audience

- Families or other mixed-age groups
- Youth ages 12+

Prep. Time

~ 5 - 20 min.

Activity Time

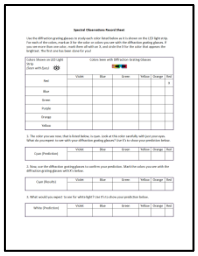
~ 10 - 45 min.

Supply Cost

~ $35 - $40 *(initial supply cost)*

Inside this Guide

Materials & Supplies

1 –		12v Flexible LED light strip (RGB) w/controller and power supply	Sample vendor: https://www.amazon.com/s?k=led+rgb+light+strip+with+remote
1 –		Roll of 1” masking tape	Sample vendor: https://www.staples.com/Highland-Masking-Tape-94-x-60-Yards/product_812041
1 set (about 25) –		Diffraction grating glasses	Sample vendor: https://www.rainbowsymphonystore.com/products/diffraction-grating-glasses-hand-held
Optional: Copies of Spectral Observations Record Sheet Copies of Take-Home Sheet			See the Printable Materials section

Note: It is important that LED lights are used for this activity - not incandescent lights. Incandescent lights emit a broad range of wavelengths/colors of light - even with color coating. They will not produce the desired effect that is achieved with LED lights. Also, incandescent lights produce more heat and can present a safety hazard.

Getting Ready

1. This activity is best done indoors and in a dimly lit room. However, by adjusting the brightness levels of the lights on the LED light strip with the remote control, it can also be done in brightly lit rooms and during outdoor events if there is access to electricity. Optimal group size is 6 to 25 participants.

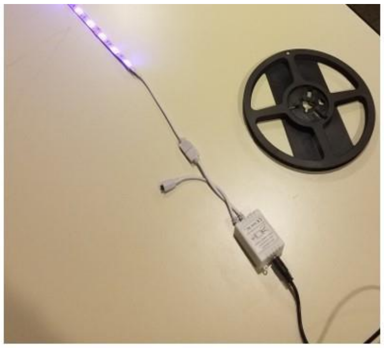
2. Locate a place in the activity area where the LED light strip will be near an electrical outlet and visible to the entire group of participants. The light strip can be displayed around the edge of a table for smaller groups, or displayed along a wall for larger groups.

3. Secure the LED light strip to the display area using small loops of masking tape. Be sure to use the tape along the back of the strip. Do not cover the LED lights with tape.

4. Connect the light strip to the RGB control box and power supply. Be sure the antenna on the RGB control box is unobstructed and can be detected by the remote control.

Power supply

Power supply connected to RGB control box



RGB control box connected to light strip

5. Plug the power supply cord into the nearest electrical outlet. Avoid the use of extension cords and power strips, and use the power cord in an area that won't experience foot traffic.

6. Using the remote control, turn on the light strip to be sure it is working correctly and that all of the LED lights clearly light up. Be sure to test the settings for all of the colors.

   If the LED light strip does not turn on, or is not responsive, try standing closer to the light strip/antenna. If this doesn't work, try the following: Check the power supply and power cord connections, check the connection to the RGB control box, be sure the antenna on the RGB control box is unobstructed, unplug and reattach the RGB control box.

7. Move around the activity area to test the remote control and distances for the activity. Also, test the brightness level of the LED lights. For small groups gathered around a table, or for close-up viewing, be sure to reduce the brightness level of the lights with the remote control. For larger groups, or in brightly lit rooms, be sure the LED lights are bright enough to be seen clearly by all participants.

8. Try it out! Using the remote control and a pair of diffraction grating glasses, stand a distance from the light strip and view the different colors with the glasses. This will provide a preview of what participants will experience.

Activity Guidelines

REAL-WORLD CONNECTION… The universe is a VERY BIG place, and the objects in it are VERY FAR away. We depend on light (electromagnetic radiation) to carry information to us from objects in space. By collecting and studying this light with telescopes, we can learn something about the objects and their characteristics – such as their color, composition, location, and motion. One instrument used on telescopes is a spectrograph. Similar to prisms and diffraction gratings, spectrographs spread light into its component colors for detailed study.

Quick Start Guide

1. Ask, "What do you know about light?"

2. Participants share ideas.

3. Participants observe LED light strip with eyes and make observations.

4. Hand out diffraction grating glasses.

5. Participants make observations around the room with glasses.

Begin the activity by asking participants to share some things they know about light, or why light is important. Sample responses might include light is used to help us see, there are lights on in this room, light comes from the sun, etc.

Draw participants' attention to the light strip. Using the remote control, cycle through the colors on the light strip (red, orange, yellow, green, blue, purple, and white) one at a time. For each color, have participants name the color they see.

Next, turn the light strip off and provide each participant with a pair of diffraction grating glasses. Allow time for participants to explore with the glasses by observing the white lights in the room or activity area. Participants should make observations, make comparisons between what they see with and without the glasses, and/or describe what they see.

Safety Tip: Advise participants to **NOT** look at the sun if outside, or through windows if indoors. Also, participants should not stand close to light sources, but should observe them from a safe distance.

Participants should observe rainbow colors with the glasses, or a series of rainbows radiating out from light sources. Note: Results may vary depending on the type of lights used in the activity area.

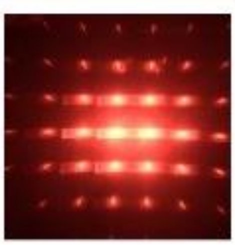
Activity Guidelines cont.

Ask participants what they see and why they think this is happening. Sample responses might include, “I see rainbows,” “I see different colors,” etc.

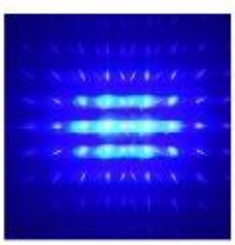
How this Works: Visible light includes any of the colors of the rainbow that the human eye can see (red, orange, yellow, green, blue, and violet). Whichever of these colors are present will combine to form the color your eye sees, white being a combination of all of these colors. The diffraction grating glasses have plastic lenses that are etched with very tiny lines that diffract light, or break it up into its component colors. This is similar to how a prism works.

Redirect participants back to the light strip. Say, “Now we’re going to see what happens when we use the diffraction grating glasses to observe specific colors of light. What do you think you would see if we looked at different colors of light? Do you think you will see a rainbow or a spectrum of colors? Let’s find out!”

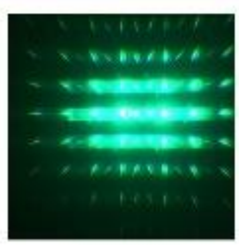
Starting with red, have participants view red, then blue, and then green on the light strip with the diffraction grating glasses. For each color, have participants share what they observe and/or record their findings on the Spectral Observations Record Sheet. For each of these colors, participants should mostly red, blue and green respectively, and not rainbow colors.



Results for red



Results for blue



Results for green

Note: Depending on the lighting used in the activity area, participants may also see some yellow and blue in the spectrum for green. However, they should mainly see green.

Quick Start Guide

6. Participants share out observations.

7. Participants make predictions about LED light strip.

8. Show red, blue and green on light strip, respectively.

9. Participants observe each color with diffraction grating glasses.

10. Participants see red, blue, and green spectrums.

Quick Start Guide

11. Show purple on light strip. Participants observe purple with glasses.

12. Participants make predictions about orange.

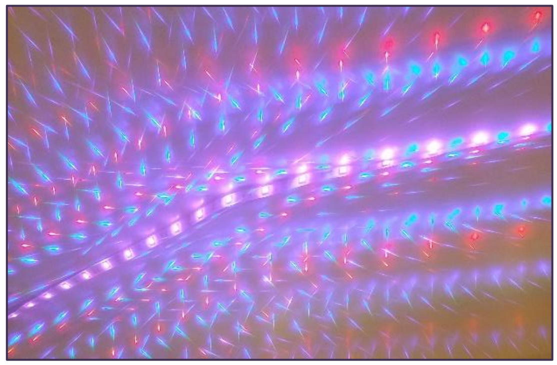
13. Show orange on the light strip. Participants observe orange with glasses.

14. Show yellow on the light strip. Participants observe yellow with glasses.

15. Participants compare orange and yellow and look for differences in the spectrums.

Activity Guidelines cont.

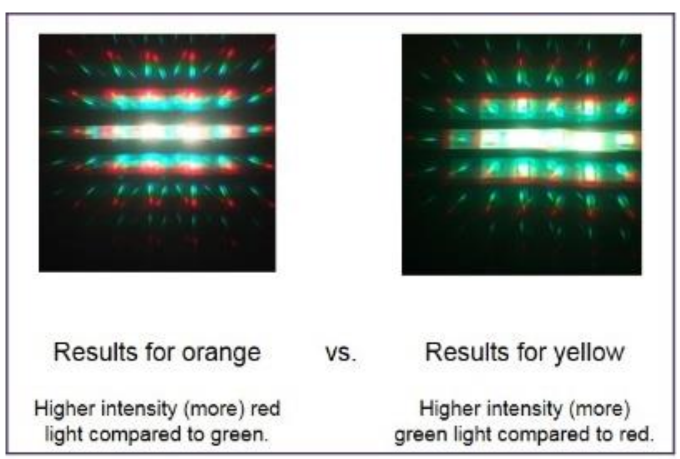
Say, "Have we seen any rainbows or different colors so far? Our next color is purple. Do you think we'll see something different this time?" If time allows, take some participant responses before proceeding. Then show purple on the light strip. Participants should now see mainly blue and red with the diffraction grating glasses. Ask participants if this is surprising, and why or why not.



Results for purple

Then ask, "So what would you expect to see if we change the lights on the light strip to orange?" Take some participant responses and then show orange. Participants should now see mainly red and green.

Ask, "If red and green make orange, and not red and yellow, what produces yellow?" Show yellow on the light strip. Participants should see red and green again with their diffraction grating glasses. Except this time, the green light in the spectrum should appear brighter/more prominent.



Activity Guidelines cont.

Challenge participants to identify the difference between orange and yellow light. Ask, “What is the difference between orange and yellow when they are both produced with red and green light?”

Participants can derive the solution by comparing orange and yellow light with the diffraction grating glasses. Use the remote control to change the light strip back and forth between orange and yellow. Participants can use the diffraction grating glasses and closely observe the changes in the respective light spectrums.

Finally, ask participants to identify the three main colors they have seen throughout the activity. Answer: red, blue, and green.

Ask, “What do you think we would see if we put red, blue, and green light all together?” Alternatively, you can have participants predict what the main colors are in the spectrum for white light. Show white on the light strip so that participants can observe it with their diffraction grating glasses.

Note: If the LED light strip is turned down to its lowest brightness setting, participants will be able to observe, upon close inspection, that each LED is made up of small red, blue and green lights.

If time permits, have participants observe cyan on the light strip. Participants should first observe the cyan-colored lights without the diffraction grating glasses and identify the color they see (cyan, aqua, blue-green).

Challenge participants to explain how this color of light can be made so that it looks different from blue. If necessary, remind participants that red light is added to blue light to make purple. Ask, “What would we have to add to blue light to get cyan?” Answer: green

Quick Start Guide

16. Participants identify the three main colors in the activity: red, blue, and green.

17. Participants predict what happens when you combine red, blue, and green light.

18. Show white on the light strip.

19. Participants make observations with glasses and confirm predictions.

20. If time permits, participants make predictions and observations for cyan.

Follow-up Activities & Resources

STEM Resources

NASA Wavelength – An online collections of NASA Earth and space science activities and resources for educators and learners. https://science.nasa.gov/learners/wavelength

STAR_net STEM Activity Clearinghouse – An online collection of STEM activities for libraries. http://clearinghouse.starnetlibraries.org/

Activities

Recoloring the Universe

http://chandra.harvard.edu/edu/pencilcode/

Recolor Activity - Try creating a color by stimulating your own red, green, and blue eye cells with an intensity between 0 and 255. http://event.pencilcode.net/edit/hoc2014/recolor#guide=http://event.pencilcode.net/home/hoc2014/video3.html

Observing with NASA

Control your own telescope and process your very own space images. https://mo-www.cfa.harvard.edu/OWN/

Stop for Science: Somewhere over the Rainbow Activity Resources

http://chandra.harvard.edu/edu/stop/

Poster - http://chandra.harvard.edu/edu/stop/rainbow_poster.pdf
Interactive - http://chandra.harvard.edu/edu/stop/explore/rainbow.html
Facilitator's Guide - http://chandra.harvard.edu/edu/stop/rainbow_guide.pdf
Question Poster - http://chandra.harvard.edu/edu/stop/rainbow_quest.pdf
Question & Answer Sheets - http://chandra.harvard.edu/edu/stop/rainbow_answer.pdf

National Informal Education STEM Network

Exploring the Universe: Filtered Light – this toolkit demonstrates how scientists can use telescopes and other tools to capture and filter different energies of light to study the universe. http://nisenet.org/catalog/exploring-universe-filtered-light-2018

Multimedia

ViewSpace
https://viewspace.org/

NOTGLaDOS: Electromagnetic Spectrum the Musical
https://www.youtube.com/watch?v=OYK7G6r0Pec

PBS Learning Media: Making Rainbows
https://mpt.pbslearningmedia.org/resource/buac18-k2-sci-ps-makerainbows/making-rainbows

Family Connections

Families can explore light and color together by creating color wheels or using everyday objects to create rainbows at home. Learners can also continue the fun at home by trying some online activities. See the Take-Home Sheet in the Printable Materials section for details.

Science Background Resources

Tour of the Electromagnetic Spectrum
https://science.nasa.gov/ems

Stop for Science: Listening to Light Video Podcast
http://chandra.harvard.edu/resources/podcasts/media/pod110412_hd.m4v

Cosmic Concepts: Electromagnetic Spectrum
https://www.youtube.com/watch?v=0g4vLkKNZ7Y

Chandra Sketches: Our Connection with Light
http://chandra.harvard.edu/resources/podcasts/media/pod110915_hd.m4v

Chandra Sketches: Highlights of Light
http://chandra.harvard.edu/resources/podcasts/media/pod240915_hd.m4v

Space Scoop: At the End of the Rainbow
https://www.youtube.com/watch?v=WMQl5_li4h0&list=UUcvatGFnbYUCgXRapk1dMvw

Primary Colors of Light and Pigments
http://learn.leighcotnoir.com/wp-content/uploads/2011/07/primaries.pdf

How do Space Telescopes Break down Light?
https://webbtelescope.org/contents/media/videos/2018/10/1181-Video?itemsPerPage=100&filterUUID=21409408-9414-41eb-a027-a6b3abfe7af5

Prism Animation
https://media.stsci.edu/uploads/video_file/video_attachment/3589/STScI-H-v0811e-1280x720.mp4

FAQs

1. What is color?

Color is the characteristic of human visual perception described through categories such as red, orange, yellow, green, blue, or purple. The perception of color is the result of stimulation of photoreceptors in the human eye by visible light. The color of objects is determined by the color or wavelength of the light that is reflected from them. This reflection is governed by the object's physical properties such as light absorption, emission spectra, etc.

2. How is color seen?

Light is either emitted or reflected to our eyes. The inner surfaces of human eyes contain photoreceptors—specialized cells that are sensitive to light and relay messages to your brain. There are two types of photoreceptors: cones (which are sensitive to color) and rods (which are more sensitive to intensity). You are able to “see” an object when light from the object enters your eyes and strikes these photoreceptors.

Humans can only see visible light. Different wavelengths of visible light are perceived as different colors. For example, light with a wavelength of about 400 nm is seen as violet, and light with a wavelength of about 700 nm is seen as red. However, this experience may vary across individuals and not everyone sees colors in exactly the same way.

3. What is light (electromagnetic radiation)?

Light, or electromagnetic radiation, is a form of energy. It refers to the waves (or photons) of the electromagnetic spectrum carrying electromagnetic radiant energy. The electromagnetic spectrum is a continuum – there is no limit to how big or small wavelengths can be. It consists of all the different wavelengths of electromagnetic radiation, including microwaves, radio waves, infrared, visible light, ultraviolet, X-rays, and gamma rays. All electromagnetic radiation is light, but we can only see a small portion of this radiation—the portion we call visible light.

4. What is the difference between colors of light and colors of pigments?
The primary colors of white light are red, blue, and green. The colors of lights are additive and can be combined in different proportions to make all other colors. For example, red light and green light added together are seen as yellow light. This additive color system is used by light sources, such as televisions and computer monitors, to create a wide range of colors. When different proportions of red, blue, and green light enter your eye, your brain is able to interpret the different combinations as different colors.

However, the primary colors of pigment (also known as subtractive primaries) are used when producing colors from reflected light. For example, when mixing paint or using a color printer. The primary colors of pigment are magenta, yellow, and cyan (commonly simplified as red, yellow, and blue).

Pigments are chemicals that absorb certain wavelengths of lights and prevent them from being transmitted or reflected. Because paints contain pigments, when white light (which is composed of red, green, and blue light) shines on colored paint, only some of the wavelengths of light are reflected. For example, cyan paint absorbs red light but reflects blue and green light; yellow paint absorbs blue light but reflects red and green light. If cyan paint is mixed with yellow paint, you see green paint because both red and blue light are absorbed and only green light is reflected.

5. Why do red and green light produce orange (or yellow) light?
Participants may think that red and yellow produce orange. While this is the case for paints and pigments, this is not the case for light. Light mixes additively. As you add more light, the colors become lighter and lighter. So orange (or yellow), a relatively light color, is made with red and green, two relatively dark colors. [Yellow is produced by adding less/lower intensity red light with more green. Orange is produced by adding more red light and less green.] Eventually, when you've added all three primary colors of visible light (red, blue, green) together, you end up with white light.

6. Why do I see orange, yellow and purple light when I look at white light through a diffraction grating, but I don't see these colors when looking at orange, yellow or purple?
This is because of the way that LEDs work. Different elements emit different colors of light, and LEDs work by using elements that emit particular colors. In this activity, we want to understand how we (humans) see colors. Red, green, and blue are the primary colors of white light only because those are what the receptors in our eyes are attuned to. For example, when something looks red, it's because the "red" cones in our eyes are stimulated, but when something looks yellow, it's because both the "red" and "green" cones are stimulated.

7. What information can light reveal about objects in space?
Electromagnetic radiation, or light, is a form of energy. By measuring the wavelength or frequency of light coming from objects in space, we can learn something about their nature, such as their temperature, composition, and velocity. Since we are not able to travel to a star or take samples from a galaxy, we must depend on electromagnetic radiation to carry information to us.

8. How does light travel and what can cause it to change direction?
Light travels in straight lines unless something causes it to change direction. When light encounters matter, it can change its direction through a process of reflection, refraction, or diffraction. Telescopes operate on the principals of either reflection or refraction.

9. What is dispersion?
The separation of light into its component colors is known as dispersion. For example, visible light is made up of different colors. Each color bends by a different amount when refracted. That's why visible light is split, or dispersed, into a rainbow when it passes through a lens, prism or diffraction grating. Shorter wavelengths, like violet and blue light, bend the most. Longer wavelengths, like red and orange light, bend the least.

10. What is spectroscopy?
Spectroscopy is the study and interpretation of an object's electromagnetic spectrum using instruments such as spectrographs or spectrometers. Similar to a prism, spectrographs and spectrometers spread electromagnetic radiation into its component frequencies and wavelengths for detailed study.

11. What is a diffraction grating?
A diffraction grating is a device that splits light into its component parts or spectrum. It often consists of a mirror with thousands of closely spaced parallel lines, which spread light out into parallel bands of colors, or distinct fine lines or bars.

Printable Materials

Spectral Observations Record Sheet

Use the diffraction grating glasses to study each color listed below as it is shown on the LED light strip. For each of the colors, **mark an X** for the color or colors you see with the diffraction grating glasses. If you see more than one color, **mark them all with an X**, and circle the X for the color that appears the brightest. The first one has been done for you!

Colors Shown on LED Light Strip *(Seen with Eyes)* 	Colors Seen with Diffraction Grating Glasses 					
	Red	Blue	Green	Purple	Orange	Yellow
Red	X					
Blue						
Green						
Purple						
Orange						
Yellow						

1. What would you expect to see with the diffraction grating glasses for white light? **Use X's to show your prediction below**.

	Red	Blue	Green	Purple	Orange	Yellow
White (Prediction)						

2. Now, use the diffraction grating glasses to confirm your prediction. **Mark the colors you see with the diffraction grating glasses with X's below**. Circle the X's for the strongest or most visible colors.

White (Results)	Red	Blue	Green	Purple	Orange	Yellow

3. What colors have appeared the most frequently during this activity?

4. What conclusion can you make about these colors and how different colors of light are made?

Spectral Observations Record Sheet – Answer Key

Use the diffraction grating glasses to study each color listed below as it is shown on the LED light strip. For each of the colors, **mark an X** for the color or colors you see with the diffraction grating glasses. If you see more than one color, **mark them all with an X**, and circle the X for the color that appears the brightest. The first one has been done for you!

Colors Shown on LED Light Strip *(Seen with Eyes)*	Colors Seen with Diffraction Grating Glasses					
	Red	Blue	Green	Purple	Orange	Yellow
Red	X					
Blue		X				
Green			(X)			X
Purple *(The brighter color, red or blue, will depend on the shade of purple shown.)*		X				X
Orange	(X)		X			
Yellow	X		(X)			

1. What would you expect to see with the diffraction grating glasses for white light? **Use X's to show your prediction below**.

	Red	Blue	Green	Purple	Orange	Yellow
White (Prediction)						

2. Now, use the diffraction grating glasses to confirm your prediction. **Mark the colors you see with the diffraction grating glasses with X's below**. Circle the X's for the strongest or most visible colors.

	Red	Blue	Green	Purple	Orange	Yellow
White (Results)	(X)	(X)	(X)	X	X	X

3. What colors have appeared the most frequently during this activity?

Red, blue, and green

4. What conclusion can you make about these colors and how different colors of light are made?

Red, green, and blue are the main colors of white light. When you put them all together, you get white light. If you use different combinations of them, you will get other colors. For example, red and blue light make purple, and red and green can make either orange or yellow.

Take-Home Sheet:

ACTIVITIES TO TRY AT HOME!

Color Wheels

Materials: pencil, ruler, scissors, markers or crayons (red, orange, yellow, green, blue and purple), uncoated white paper plate (dessert or lunch size)

Directions:

1. Get a grown-up to help.
2. Trim the edge off the paper plate to create a flat white circle.
3. Divide the circle into 6 equal sections, using the ruler and a pencil.
4. Color each section a different color (red, orange, yellow, green, blue and purple).
5. Use the pencil point to carefully poke a hole through the circle's center.
6. Push the pencil through the circle with the color side of the circle facing up and the pencil point facing down.
7. Using the top half of the pencil as a handle, spin the circle on a hard surface like a top. What change do you notice in the circle's colors?

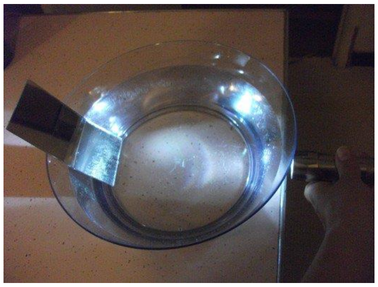
Making Rainbows

Materials: a flashlight or a sunny day, a mirror (at least 5″ by 5″), a large bowl of water, a CD, a piece of plain white paper

Directions:

1. Make rainbows by just holding a CD up to some sunlight – or shine a flashlight on one in a darkened room – and you will see a rainbow on the CD. Go a little further, and try to catch the reflection of the CD's rainbows on some white paper!

2. Fill a large, clear bowl or dish halfway with water and prop up a mirror inside it so that part of the mirror is under the water and part is out. Place the bowl near a sunny window with direct light coming in so that it hits the mirror (early morning or early evening light works best). Hold a piece of white piece of paper above the bowl to "catch" the rainbow. You might have to move a bit until you find it.



Note: Adult supervision required.

Explore More… *with online activities*

Recoloring the Universe

http://chandra.harvard.edu/edu/pencilcode/

Recolor Activity - Try creating a color by stimulating your own red, green, and blue eye cells with an intensity between 0 and 255. http://event.pencilcode.net/edit/hoc2014/recolor#guide=http://event.pencilcode.net/home/hoc2014/video3.html

Observing with NASA

https://mo-www.cfa.harvard.edu/OWN/

Control your own telescope using the MicroObservatory Robotic Telescope Network! Process your very own space images.

NASA's Universe of Learning materials are based upon work supported by NASA under award number NNX16AC65A to the Space Telescope Science Institute, working in partnership with Caltech/IPAC, Jet Propulsion Laboratory, Smithsonian Astrophysical Observatory, and Sonoma State University. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.