How many of you have seen an eclipse? (show of hands)
- Did it look like the one on the right or the left?

Eclipses happen all the time! There are an average of 2 solar eclipses (left image) and 2 lunar eclipses (right image) every year.

Solar and lunar eclipses both happen when the Sun, Moon, and Earth line up and a shadow is cast. They look very different and your chance of seeing them is very different. Let’s see why.

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Optional Activity:
*Have the audience create models of eclipses using the activity below before you go on to the next slide.*
The Yardstick Eclipse activity allows the audience to figure this out themselves.

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Lunar eclipse image credit: October 8, 2014 California Alfredo Garcia Jr
Solar eclipse credit: Tomruen - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=36349192
This is a very simplified diagram showing the difference between the two basic types of eclipses.

Let’s look at the solar eclipse on top. Here’s Earth. When are the people in the shadow seeing the eclipse? (daytime)
On Earth, we see the Moon pass in front of the Sun.
But does everyone on the daytime side see the eclipse? (no)

How about the lunar eclipse? What time is it for the people on Earth? What do we see? (point to Earth. Nighttime. Moon gets dark.)
Will all the people on the night side of Earth see the eclipse? (yes)
This makes lunar eclipses much more common because a whole half of the Earth can see each one (barring clouds!).

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Additional visualization of geometry: https://svs.gsfc.nasa.gov/4324
Shadow cone on US: http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4321

Find upcoming eclipses here: http://www.timeanddate.com/eclipse/

*Credit: NASA Space Place*
Pause for a moment to let the audience get this

Then <click the space bar/next> for the title to appear

An easy way to remember the difference between a lunar and a solar eclipse is in the name. The name tells you what gets darker when the eclipse happens. In a solar eclipse, the sun gets darker. In a lunar eclipse, the moon gets darker.

Great tweet by Dr. Katie Mack, astrophysicist and science writer
Why Don’t We Have an Eclipse Every Month?

Earth/Moon/Sun Orbital Relationships

(Demonstration of the moon’s tilted orbit using the Moon Phases Cart from Space Odyssey)
Kinesthetic astronomy activity done by Exploritorium to explain what we can show with the Moon Phases Cart. We will be doing this activity on the day of the eclipse (please click on link here or on the Galaxy Guide Portal)
A PARTIAL ECLIPSE occurs when the moon passes in front of the sun, off center and only a portion of the sun’s disk is obscured. Here, the observer is standing in the penumbral shadow of the moon.

AN ANNULAR ECLIPSE occurs when the moon passes dead center in front of the sun but, because the moon’s orbit is elliptical and so is sometimes closer and sometimes further from Earth, it appears too small to fully cover the disk of the sun.

A TOTAL ECLIPSE happens when the moon completely covers the sun. Here, the observer is standing under the umbral shadow of the moon. In a total solar eclipse, the sun’s outer atmosphere can be seen.
Cosmic Coincidence

The Sun’s diameter is 400x the Moon’s diameter, but the Sun is also 400x farther away from Earth!
A fun way to engage visitors with the idea that things appear smaller the further away they are is to have them take perspective photos (like the ones above) around the Museum. This concept is critical to astronomy but is often hard for visitors (especially kiddos) to grasp.
This cosmic coincidence of size and distance won’t always be true since the moon is moving away at 3.8 cm/yr and it’s apparent angular diameter is getting smaller. If interested, see the last two slides for the math.
Could Dinosaurs See a Total Solar Eclipses?
The Moon would have been closer to the Earth and thus appear larger and the Sun would have been very slightly smaller. Again, see equations on last two slides if interested in the math.
(See Portal for Video)
Video from NASA showing what the eclipse will look like from space (we are roughly at the perspective of the Sun when we start the video. The deep shadow of the moon is where the path of totality is, or where people will be able to see a total solar eclipse.
On Monday, August 21, 2017, the Moon will pass in front of the Sun, casting its shadow across all of North America. This will be the first total solar eclipse visible in the contiguous United States in 38 years.

The Moon's shadow can be divided into areas called the umbra and the penumbra. Within the penumbra, the Sun is only partially blocked, and observers experience a partial eclipse. The much smaller umbra lies at the very center of the shadow cone, and anyone there sees the Moon entirely cover the Sun in a total solar eclipse.

In the animation, the umbra is the small black oval. The red streak behind this oval is the path of totality. Anyone within this path will see a total eclipse when the umbra passes over them. The
much larger shaded bullseye pattern represents the penumbra. Steps in the shading denote different percentages of Sun coverage, at levels of 90%, 75%, 50% and 25%. The yellow and orange contours map the path of the penumbra. The outermost yellow contour is the edge of the penumbra path. Outside this limit, no part of the Sun is covered by the Moon.

The numbers in the lower left corner give the latitude and longitude of the center of the umbra as it moves eastward, along with the altitude of the Sun above the horizon at that point. Also shown is the duration of totality: for anyone standing at the center point, this is how long the total solar eclipse will last. Note that the duration varies from just 2 minutes on the West Coast to 2 minutes 40 seconds east of the Mississippi River.
The reason this eclipse is such a big deal is that everyone in the US will be able to see the eclipse – either partial or total.

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Here is the progression of what you would see if you were on the path of totality. The phase before the total eclipse in this image is called the “diamond ring” and the phase right after “Baily’s Beads.” These phases are created by light passing through valleys and craters on the Moon.
Denver will see the Sun 92% covered
The eclipse magamove project has 2 parts: a simulator and the megamovie. The simulator (linked above) will show you what the eclipse will look like from any location. This is really interesting to play around with to see the stark difference between what we will see in Denver and totality. The megamovie takes advantage of the fact that this solar eclipse will likely be the most photographed celestial phenomena to date due to easy access to cameras and solar film. They will stitch together movies and photos of the eclipse that people take to make a 90 min “megamovie” of the eclipse.
During a partial eclipse, Do Not Look Directly At The Sun. The only time it is safe to look at the Sun without eclipse glasses or protection is during totality, which we will not see here in Denver. There are many ways to view a partial eclipse. Even those on the path of totality will observe a partial eclipse for all but a few minutes, so this applies to everyone. We’re going to talk about 3 different ways to view a solar eclipse here.
Warning! The next movie shows what happens to a pig’s eye when exposed to light from an unfiltered telescope. It is graphic. Start at about 40 seconds. In training we skipped the end dissection because it was graphic. This is why you never look at the sun without proper protection!
Pinhole projection can be done anywhere by making a small hole in a piece of cardboard or tinfoil and looking at the light that shines through it to a flat place a few feet away.

You might not know this, but the round lights you see everyday on the ground, between the leaves of trees are actually projections of the Sun!
You can use any number of small holes like the spaces between leaves, a colander, or even your hands.

Get creative and try it out before the eclipse. You can try different shaped holes, different sizes. See what works best.

Activity suggestion:
As you walk in the evening, you can try this at night with street lights through the leaves. Some lights are actually made up of many smaller LEDs and you will see those in the projections.
There are ways to observe the eclipse directly, but it requires special filters.
Use approved eclipse glasses – not sunglasses!
Also welders glass #14 is safe for viewing. Don’t combine two #7 glasses. That is not safe.
Telescopes and binoculars equipped with special solar filters are also useful if you have access.

Use only special-purpose solar filters on your precious optics! These are usually made of metalized glass or special Mylar, not from a balloon.

Make sure that the filters go on the front of your telescope or binoculars! Solar filters that screw into your eyepiece are EXTREMELY dangerous. You are concentrating all of the heat and light up to that point and asking a small filter to do much more work than the front filter would need to. These have a tendency to crack. Naomi knows someone that has a zig-zag pattern on their cornea because a filter like this cracked while they were observing the sun.

Get these filters as far in advance as possible. Manufactures have already started running out of filters as of May.
Image credit: Rick Feinberg
Another method of projection involves binoculars or a small telescope. 

**Emphasize**: This is not viewing the Sun directly! You never want to look through binoculars at the Sun. *

By carefully covering all but one lens, you can project an image of the Sun onto a flat surface. This set-up needs careful monitoring so that no one accidentally looks through the eyepiece. You will go blind.

Please note that this type of equipment is not designed to be used this way and may get hot. Keep an eye on the equipment to make sure that there is no internal grease melting or that the equipment is not getting too hot.
What is DMNS Doing for the Day of the Eclipse?

• Safe Solar Viewing on Boettcher Plaza
  • Telescopes, binoculars, pinhole viewers, eclipse glasses
• Eclipse Activities
• Face Painter with special eclipse design
• Space Odyssey Exploration Stations and Shows
• View Live Streams of the Eclipse
Congress appropriated $8,000 to fund eclipse expeditions – given to US Naval Observatory to fund multiple eclipse expeditions in Rocky Mountains

Maria Mitchell – all female eclipse expedition to Denver

Thomas Edison Observed from Wyoming

Asaph Hall, just discovered the moons of Mars in 1877, expedition to La Junta.

The Georgetown Courier later reported: “Monday morning the sun rose ... in a cloudless sky, and every sign bespoke a genuine Colorado summer day for the great event astronomers had promised.”

Goals: observe the solar corona, find if there is a planet “Vulcan” between the Sun and Mercury (and only observable during eclipse)

Many tourists from Midwest, many to Garden of the Gods

In Denver, banks shut down, stores closed, and the streets filled with awestruck observers

Discovery: discovery of “streamers,” giant solar rays extending out from the sun’s corona – out to distance 10-12 times solar diameter. Most accurately captured by Samuel P. Langley from the summit of Pikes Peak, where the
atmosphere was crystal clear.
"If you do a worldwide survey of eclipse lore, the theme that constantly appears, with few exceptions, is it's always a disruption of the established order," said E. C. Krupp, director of the Griffith Observatory in Los Angeles, California, as quoted in National Geographic.

Chinese mythology refers to a dog or dragon that eats the Sun. People would bang pots to get it to go away. Importance to emperor – power in predicting eclipses and being able to scare off the dragon. Astronomer beheaded because the failed to predict one eclipse.

"The Vikings saw a pair of sky wolves chasing the sun or the moon," said the Griffith Observatory astronomer. When one of the wolves caught either of the shining orbs, an eclipse would result. If they completely ate the Sun or the Moon, that was a sign of the beginning of Ragnarock but they have only taken bites out of it (eclipses).
The Mayans were skilled observers and closely monitored celestial events. The Astronomer Priests were closely tied to the rulers and celestial were often tied to political events or used for political purposes. Image from Dresden Codex (right). The Maya were able to predict the 1991 eclipse in Mexico within 1 day of when it happened!
This is being called the Great American Solar Eclipse because so many people will be able to observe it. All of the National Parks will have a view of the eclipse and are planning eclipse viewing activities.
There are other ways to get involved with the eclipse in addition to watching it. NASA is encouraging people to incorporate STEAM (Science Technology Engineering Art and Mathematics). They have several art projects that you can get involved with.
How Can You Share Information About the Eclipse with Guests Now?

- Solar Telescopes
- Science on a Sphere Eclipse Datasets
- Moon Phases Cart
- The Gift Shop – resources and fun t-shirts and posters!
- Sun., Aug. 6th Free Day Celebrating the Eclipse
Don’t worry – if you miss this one there are many more to come, including one south of Denver in 2045!
Resources

Earth and Space Science Activity Kit: www.nisenet.org

Free Eclipse Online Course: https://www.coursera.org/learn/eclipse

Solar Eclipse Mythology:
http://www.native-languages.org/legends-eclipse.htm

Eclipse Activity Kit: Eclipsekit.com

Live Streams of Eclipse:
https://eclipse2017.nasa.gov/eclipse-live-stream
https://www.exploratorium.edu/eclipse

Eclipse Glasses:
http://www.thousandaksoptical.com/eclipse.html
Solar Eclipse Math

When Will the Last Total Solar Eclipse on Earth Happen?

\[
A(\text{arcsec}) = 206265\frac{\pi}{180}
\]

\[
\begin{align*}
D_{\text{sun}} &= 149,000,000 \text{ km} \\
D_{\text{moon}} &= 1,392,000 \text{ km} \\
\rho &= 3,474 \text{ km}
\end{align*}
\]

1. Find angular diameter of the Sun.
   
   \[A = 1930 \text{ arcseconds or } \sim 0.5^\circ\]

2. The diameter of the Sun is changing due to nuclear fusion. Verify equation for \(T=4.5\) (today)
   
   \[d_{\text{sun}} = 1392000 \times (0.0073T^2 - 0.026T + 0.90)\]

3. Convert the above equation to angular diameter
   
   \[A_{\text{sun}} = \frac{1392000 \times (0.0073T^2 - 0.026T + 0.90)}{d_{\text{sun}}}\]

4. \(D_{\text{moon}} = 356,400 \text{ km at perigee but is moving away at 3.8 cm/yr.}\)
   
   Create an equation to describe the diameter of the moon at time \(T\).
   
   Rate moving away in km/billion years:
   
   38,000 km/billion yrs

   What was \(D_{\text{moon}}\) at \(T=0\) (4.5 billion yrs ago)?
   
   \[D_{\text{moon}} = 356,400 - (38000 \times 4.5) = 185,400 \text{ km}\]

   Final equation
   
   \[D_{\text{moon}} = 38000T + 185,400\]

6. Convert that equation to angular diameter
   
   \[A_{\text{moon}} = \frac{38000T + 185,400}{1392000}\]

Solar Eclipse Math
When Will the Last Total Solar Eclipse on Earth Happen?

The last eclipse will occur when Earth is 4.75 billion years old.
Or about 250 million years from now!

https://eclipse2017.nasa.gov/challenge-13-4f2e80%3a-last-total-solar-eclipse-earth