


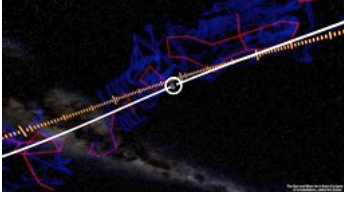
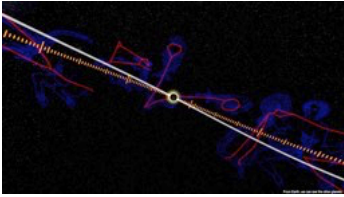

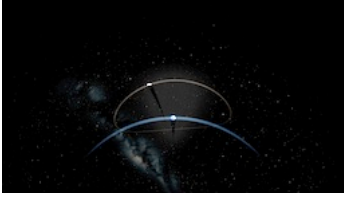



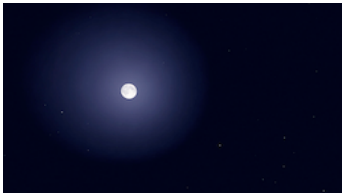
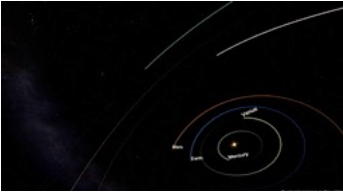
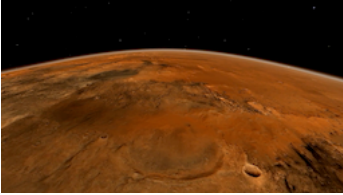

TOTALITY!





VERSION 3.1 : APRIL 4, 2023







REVISED: MAY 17, 2023



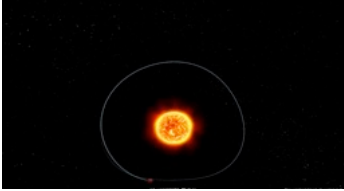
SCENE	TIME	SCRIPT
SCENE 1		
	00:03	<p>On July 11th, 1991, Monte Alban was plunged into darkness for almost 7 minutes as the Moon’s shadow crossed central Mexico.</p> <p>The crowded citadel grew strangely quiet as the Moon covered more and more of the Sun. Gradually darkness descended on the mountaintop. At totality, horns and drums were required to frighten away the celestial jaguar, who ate the Sun, and caused the eclipse.</p> <p>Soon the Sun returned to the mountaintop. But the jaguar is still here, etched in this stone façade. It’s ready to pounce, waiting for the next eclipse that threatens this sacred place.</p> <p>On April 8, 2024, the jaguar may awaken again, as the Moon casts its shadow over Mexico.</p>
DISCUSSION		<p><i>Other cultures imagined different creatures taking a bite out of the Sun during an eclipse. Ask students to imagine a Chinese dragon and suggest other creatures.</i></p>
SCENE 2		TITLES
	01:00	TOTALITY!
SCENE 3		
	01:17	<p>Solar eclipses are very rare for any location on Earth. The alignment of the Sun, Moon, and Earth must be exact. The Moon’s shadow must be in the right place and of the right length. The smallest change – the Moon slightly below or above the Sun– results in a shadow that misses your location or perhaps Earth, entirely.</p> <p>The Moon is a small world orbiting close to Earth, while the Sun is a star 400 times larger than the Moon, but 400 times farther away. These two bodies are no bigger in the sky than a finger on your outstretched hand. They must align exactly for the Moon’s shadow to cover you, causing a rare total solar eclipse.</p>
SCENE 4		

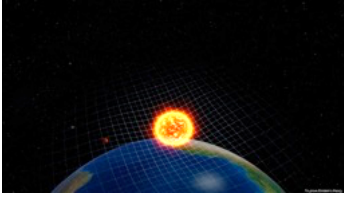

	02:11	<p>The Sun and Moon lie in front of a band of constellations, called the Zodiac. The Moon's path is shown in white. The Sun's in yellow with hash marks. Their paths cross twice a month as the Moon goes through its phases. If the Sun is at a crossing node, then the Moon can pass exactly in front of it. When that happens, the dark New Moon will cover some or all of the Sun's photosphere. The Moon's shadow will reach a small part of the Earth, causing a solar eclipse.</p>
DISCUSSION		<p><i>Try blocking the Moon with just your little finger, just to see how small the Sun and Moon are in the sky. Are they really the same size?</i></p>
SCENE 4.5		
	02:47	<p>From Earth, we can see the other planets.</p> <p>Jupiter and Uranus are in Aries.</p> <p>Mercury lies close by in Pisces.</p> <p>Venus and Neptune are also in Pisces.</p> <p>Saturn, and Mars lie beyond in Aquarius.</p> <p>The bright Jupiter and Venus will be easy to see during totality when the Moon covers the Sun and the sky is dark.</p>
DISCUSSION		<p><i>Planets are always found in front of Zodiac constellations, never in front of other patterns.</i></p>
SCENE 5		
	03:15	<p>Every 223 months, alignments of the Sun, Moon, and Earth repeat in a pattern called a Saros Cycle. The solar eclipse over Monte Alban in 1991 returned 223 months later in 2009, bringing over 6 minutes of totality to China. In 2027, this saros cycle will cause an eclipse to shadow Egypt, passing over Luxor, site of the Karnak Temple Complex. On Aug 12, 2045, this cycle returns to North America, causing the Moon's shadow to cross the US.</p>
SCENE 6		
	04:07	<p>A Saros cycle also predicts lunar eclipses because they often occur two weeks before or two weeks after a solar eclipse. The geometry is straightforward, although we must shrink the enormous distance scale to fit on our dome. In a solar eclipse, the Moon casts a shadow on the Earth, but only on a small part of our planet. Two weeks later the Moon's path crosses the Sun's path at full moon. At this time the Earth casts its shadow on the Moon.</p> <p>People living on the side of the Earth facing the Moon will see it moving through Earth's shadow. When the Moon lies completely within the shadow, it turns red and is often called a blood moon. The color comes from red light scattered into Earth's shadow by its atmosphere. The shade of red is affected by Earth's clouds and dust.</p>

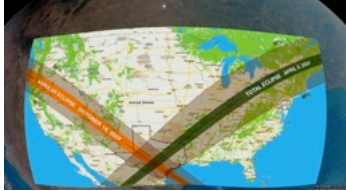
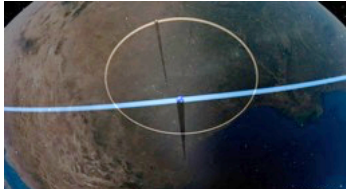

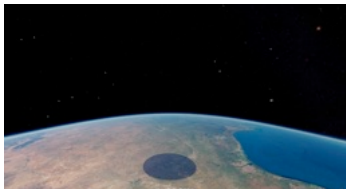

DISCUSSION		<i>Describe a lunar eclipse. Why have more people seen lunar eclipses than solar eclipses? Why do lunar and solar eclipses often happen 2 weeks apart?</i>
SCENE 7		
	05:06	In a lunar eclipse, the Moon moves slowly into Earth's shadow. Because Earth has an atmosphere, the shadow's edge is soft. After about an hour, the Moon is completely within the shadow. It is lit by only the light bent into the shadow by the Earth's atmosphere – by the orange and red colors we see along the horizon just after Sunset. Everyone on the night side of Earth can see a lunar eclipse. For this reason, more people observe lunar eclipses than solar eclipses.
SCENE 8		
	05:40	But what would astronauts on the Moon see during a lunar eclipse on Earth? In the sky, the Earth would slowly cover the Sun for as long as an hour. As totality approached, the Moon's surface would grow darker in deepening hues of orange and red. The Earth eclipsing the Sun would be uniquely beautiful from the lunar surface. Our Moon is the second place where we might someday see a solar eclipse.
DISCUSSION		<i>Describe what astronauts on the moon would see during a solar eclipse on Earth.</i>
SCENE 9		
	06:11	Do solar eclipses happen on other worlds? Mercury and Venus have no moons so there is no opportunity to see eclipses from these planets. The planets with moons lie beyond Earth's orbit. The red planet Mars has two moons, Phobos and Deimos, but they're very small – tiny compared with Earth's Moon.
DISCUSSION		<i>Why don't eclipses happen on other planets or on other moons?</i>
SCENE 10		
 <p data-bbox="232 1570 508 1602">Phobos transit on Mars</p>	06:34	The Perseverance Rover explores an ancient Martian crater called Jezero. Its high-resolution camera surveys the Martian terrain and can also photograph the Sun. On April 2 nd , 2022, Perseverance was in the right place at the right time to capture the potato-shaped Phobos crossing in front of the Sun. Phobos measures just 17 miles in diameter. Earth's Moon is over 150 times larger. When a much smaller object moves across a larger body, like Phobos crossing the Sun, we call it a transit, not an eclipse.
SCENE 11		
	07:16	Jupiter has at least 80 moons including 4 that are as big or bigger than Earth's Moon. In addition, the Sun appears only a fifth as large as it is in Earth's sky. We have observed black dots on Jupiter's clouds. These are shadows cast by Jupiter's larger moons. In this case the moons do not cause an eclipse. They are much bigger than the distant Sun in Jupiter's sky. When an object is much larger than



		the object it's covering, we call the event an occultation, not an eclipse.
SCENE 12		
	07:49	Only Earth has the right size moon to cover the Sun and create dramatic eclipses. It is very unusual for an inner planet like Earth to have such a large companion moon. Planets close to the Sun must compete with the Sun's gravity to capture a moon, so their moons tend to be small – but not Earth's.
SCENE 13		
	08:14	<p>Let's go back over 4 billion years – to a time when Earth had no moon. The young Sun brought little order to its unruly solar system. Too many objects shared the same flattened disk. Colliding rocks coalesced into boulders, mountains, and then into worlds. Another planet the size of Mars had formed in an orbit crossing Earth's. A collision was inevitable. It was just a matter of time. And the universe has always had plenty of time. Gradually life, carried on the tides, climbed from the sea onto the land.</p> <p>In time, creatures learned to watch and record the motions of the Sun and Moon overhead. Without this collision, Earth would have no Moon, no eclipses, and maybe no intelligent life to observe and predict them.</p>
DISCUSSION		<i>How could the moon have helped in the development of intelligent life on Earth?</i>
SCENE 14		
	09:42	Eclipses gave us our first views of the Sun's layered atmosphere. In the very last seconds before totality, a thin crescent Sun suddenly breaks into a string of beads – light coming through valleys along the Moon's limb. The bright photosphere's last rays produce a diamond ring as the solar disk disappears behind the Moon. Now we see the Sun's much fainter upper atmosphere, called the chromosphere, and the corona. Red glowing gases, seen along the Sun's limb during totality, belong to gigantic eruptions in the Sun's atmosphere. Here ionized gases rise upward along arches in the Sun's magnetic field and fall back, still trapped by the Sun's gravity.
SCENE 15		
	10:30	The Sun's magnetic field lines become tangled and twisted enough to break, sending streams of hot gases into space in a Coronal Mass Ejection or CME. If the timing is right, observers might photograph a CME during totality. Earth's magnetosphere redirects most particles and protects the surface below. Understanding this connection between the Sun and Earth began with observations of the Sun's upper atmosphere during total solar eclipses.
SCENE 16		

	11:05	<p>The first drawing of a solar eclipse may date back to Ireland over 5,000 years ago. In 1865, archaeologists excavated mounds called cairns near the modern city of Dublin. This mound, called Cairn L, is famous for a special drawing, carved in its interior stone wall. This drawing may be the first recorded image of a solar eclipse, dating back to the eclipse of Nov. 30, 3340 BCE.</p>
SCENE 17		
	11:38	<p>At least 4,000 years ago, Chinese astronomers built observatories to watch, record, and predict celestial events such as eclipses. Their long record of eclipse predictions confirmed the accuracy of the Chinese calendar. One Chinese legend reports that Hsi Ho, the official imperial astronomer, failed to predict a solar eclipse. For his grave mistake, the emperor took his head.</p>
SCENE 18		
	12:09	<p>Over 25 hundred years ago, civilizations around the eastern Mediterranean invented models of the solar system to predict alignments in the sky. The word eclipse comes from the Greek word meaning disappearance and abandonment. Babylonians, Greeks, and Romans considered eclipses omens that must be predicted and feared.</p>
SCENE 19		
	12:30	<p>A physical model of their eclipse science has survived in a physical mechanism that was once aboard a ship, sailing from Asia Minor to Ancient Greece.</p>
SCENE 20		
	12:39	<p>This ship sank off the coast of Antikythera, a small island between Greece and Crete. In 1901, divers, searching the wreckage, found remains of this model, called the Antikythera mechanism. It is the world's oldest known analog computer - created over 2000 years ago. Divers recovered 82 pieces of the mechanism, containing 35 gears and 7 dial displays.</p>
SCENE 21		
	13:07	<p>With all gears and dials in place, the Antikythera mechanism could predict the positions of the planets in the sky, moon phases, and eclipses decades into the future. The largest gear is just over 5 inches wide with 223 teeth, the number of months in the saros cycle of eclipses. The left dial on the back identifies moon phases. The right dial predicts solar and lunar eclipses based on the saros cycle. Gears connect the back dials with the display on the front. The large front dial shows the date in the solar calendar as well as the positions of the Sun, Moon, and visible planets.</p>
SCENE 22		

	13:56	<p>Before the Renaissance, people believed that the Earth was the center of the solar system. Astronomers moved the Sun to the center with orbiting planets which had orbiting moons. Then they could predict eclipses with great accuracy.</p> <p>Once Galileo turned his newly invented telescope toward the heavens, astronomers had the tool they needed to study details of the Moon and Sun, especially during eclipses. With laws of motion and gravity, astronomers could make solar eclipse predictions for a specific location anywhere on Earth. People no longer feared eclipses. Instead, they began flocking to places where they could witness this awesome event in person.</p>
SCENE 23		
	14:43	<p>On July 29, 1878, newspapers told Americans about an upcoming total solar eclipse. The eclipse path extended from Idaho to the Gulf of Mexico. The first all-female eclipse expedition from Vassar College documented coronal streamers at totality. Other astronomers brought long focus telescopes to look for the mysterious planet Vulcan that had been predicted from Mercury's orbit.</p> <p>The great inventor, Thomas Edison, arrived with his new device to measure the temperature of the Sun's corona – from 93 million miles away. He set up his sensitive equipment in what turned out to be a chicken coop. The darkness of totality caused the chickens to come home to roost. He had little difficulty documenting the panicked chickens, but less success taking the temperature of the Sun's corona.</p> <p>Had Edison's invention worked, he might have discovered that gases in the corona are extremely hot – much hotter than the visible Sun. Different gases glow in different colors, reaching temperatures of millions of degrees.</p> <p>Discoveries like this belong to later eclipses. The 1878 eclipse is the last time Texas would experience totality until the Great Solar Eclipse of 2024.</p>
DISCUSSION		
<i>Solar eclipses have been recorded throughout history. Do a search to find other eclipse stories. Perhaps you can interview someone who has seen a solar eclipse or lunar eclipse.</i>		
SCENE 24		
	16:10	<p>In the 1878 eclipse, astronomers did not find the elusive planet Vulcan. They wondered if it actually existed at all. Over 20 years later scientists determined that Mercury's strange behavior is a result of a gravity well, bending space around the Sun. Einstein's Theory of Relativity predicted such a gravity effect. This bending of space should also affect starlight passing close to the Sun.</p>
SCENE 25		

	<p>16:38</p>	<p>To prove Einstein’s theory, astronomers traveled to South America on May 29 1919. They brought powerful telescopes to photograph stars near the Sun during the solar eclipse. These stars would be visible near the Sun only during totality.</p> <p>Astronomers documented the position of two stars marked with red circles. The Sun’s gravity had definitely shifted their apparent locations -- just as Einstein’s Theory of General Relativity predicted. Blue rings show the true positions of the stars.</p>
<p>DISCUSSION</p> <p><i>Why was a total solar eclipse needed to test General Relativity? What were astronomers trying to observe?</i></p>		
<p>SCENE 26</p> <p>NO SCENE 26</p>		
<p>SCENE 27</p>		
	<p>17:18</p>	<p>In 2017 the Houston Museum of Natural Science hosted over 250 Texans in Casper, Wyoming to observe a total solar eclipse. Their eclipse watching techniques are a guide for how you can observe the 2024 eclipse.</p> <p>Eclipse glasses and viewing cards use a filter material to block over 99.99 % of the Sun’s light. They are required before and after totality.</p> <p>A pinhole acts like a lens, projecting a tiny image of the eclipsed Sun. Groups of pinholes create interesting patterns on any surface. Observers tested colanders, ritz crackers, buttons, and even straw hats to make the best collage of tiny eclipses.</p> <p>Binoculars and telescopes project a much larger image of the eclipse onto a card or translucent screen for observers to photograph. Often a dark Sunspot group will be visible.</p> <p>The same material that makes eclipse glasses and cards can be put on the front lenses of binoculars and telescopes to allow visitors to see a larger image of the eclipsed Sun. These filters may be removed safely only during totality.</p> <p>High magnification telescopes and telephoto lenses must be constantly adjusted as the Earth rotates under the Moon’s shadow. Sturdy tripods that can track the Sun work best.</p> <p>These eclipse observing techniques work for any eclipse – including the annular eclipse of October 14, 2023 and the total eclipse of April 8, 2024.</p>
<p>DISCUSSION</p> <p><i>Why is it dangerous to observe a solar eclipse? Describe ways to observe a solar eclipse safely.</i></p> <p><i>How did astronomers document eclipses before they had cameras? Could you do this too?</i></p>		
<p>SCENE 28</p>		

	19:05	The October 14, 2023 annular solar eclipse path extends from West to East across the US and on to Central and South America.
SCENE 29		
	19:17	The alignment of the Sun, Moon, and Earth are the same for annular and total solar eclipses. But the Moon's size in the sky does change. It depends on the Moon's distance from Earth. When the Moon is farthest from Earth, it is too small in the sky to cover the Sun. It leaves a ring or annulus of Sunlight at the midpoint of the eclipse.
SCENE 30		
	19:42	Less than 6 months later, a second solar eclipse crosses the US – the first total solar eclipse to reach Texas in over 140 years. On April 8, 2024, everyone in the continental US is near enough to the center line to see at least a partial solar eclipse. The path extends from Mexico, through Texas and 14 other states, and then into Canada.
SCENE 31		
	20:27	The Moon's shadow first reaches land at Mazatlán on the Pacific coast of Mexico. The eclipse enters Texas at Eagle Pass, then it crosses San Antonio, Kerrville, Austin, Waco, Dallas and Fort Worth. The Moon's shadow falls on Little Rock and then Indianapolis. Its path extends east of Lake Superior and Lake Michigan, crossing over Cleveland and Buffalo. In Canada the eclipse touches Montreal and reaches the Atlantic at Gander in Newfoundland. Over 30 million people lie along this path of totality.
SCENE 32		
	20:53	A fisheye timelapse video captures Texans experiencing the solar eclipse of 2017. They donned their glasses as the eclipse began. During the first hour, little changed on the ground. Folks snapped a photo or two with solar filters covering the front of their camera lenses. The light level dropped minute by minute and shadows grew sharper. Animals prepared for night. The yellow and orange colors of twilight surrounded the horizon. This was not a normal day and night. The sky was dark to the west and blue to the east. The daylight felt off-color – different. Totality was near. Then the last bit of Sunlight left the sky and the Sun's magnificent corona appeared, surrounding the dark Moon. Too soon totality ended and the Sun returned. Observers paused in awe. It was over and unforgettable.
DISCUSSION		
<i>Draw how the Sun, Moon, and Earth are arranged in a solar eclipse. Why are some eclipses total and others are annular?</i>		
SCENE 33		

	21:59	<p>Each location has different eclipse timing as the shadow crosses the US. Here are times for the Hill Country of Central Texas.</p> <p>12:15 brings First Contact. The dark new Moon has reached the Sun. For almost an hour the Moon moves slowly over the Sun – a black disk covering the Sun’s bright photosphere. At first, viewers cannot detect the loss of Sunlight. Then about 15 minutes before totality, changes begin to happen rapidly.</p> <p>At second contact, 1:32 pm, the Sun’s photosphere, disappears behind the Moon. Then totality begins with the corona streaming outward and twilight on the Earth below.</p> <p>At 1:36, totality ends, marking third contact.</p> <p>2:55 brings fourth contact, the time when the Moon leaves the Sun. After 2 hours and 40 minutes the eclipse is over. We must wait 21 more years to see the next Totality crossing the United States.</p>
DISCUSSION		<i>Describe how totality differs from a normal sunset. List the stages of a total solar eclipse.</i>
SCENE 34		
	23:15	<p>On a longer timescale, the Moon is slowly inching away from Earth. In over a hundred million years, the Moon will no longer be able to cover the Sun’s disk. Then no one on Earth will ever see the magic of a total solar eclipse again. The celestial experience of April 8, 2024 is wonderful, rare, and fleeting: a special moment to share in cosmic time on a special planet with a very special moon.</p>
CREDITS		ENDING CREDITS
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SCRIPT		Carolyn Sumners
DIRECTOR		Adam Barnes
PRODUCER		Carolyn Sumners
ASSOCIATE PRODUCER		Patricia Reiff
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MUSIC		Shai Fishman, Fish-I Studios
AUDIO PRODUCTION		Adam Barnes
GRAPHICS		Bethany Elliot Xavier Jubier Colin Law

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ECLIPSE TEMPERATURES		Miloslav Druckmüller
BEIJING AND LEPTIS MAGNA PHOTOGRAPHY		Gary Young
LOUGHCREW, IRELAND PHOTOGRAPHY		Terence Murtagh
CASPER, WY PHOTOGRAPHY		David Garza Tamara Ledley David Temple Donna Wright
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