Solar Eclipses:

Nature's Cosmic Coincidence

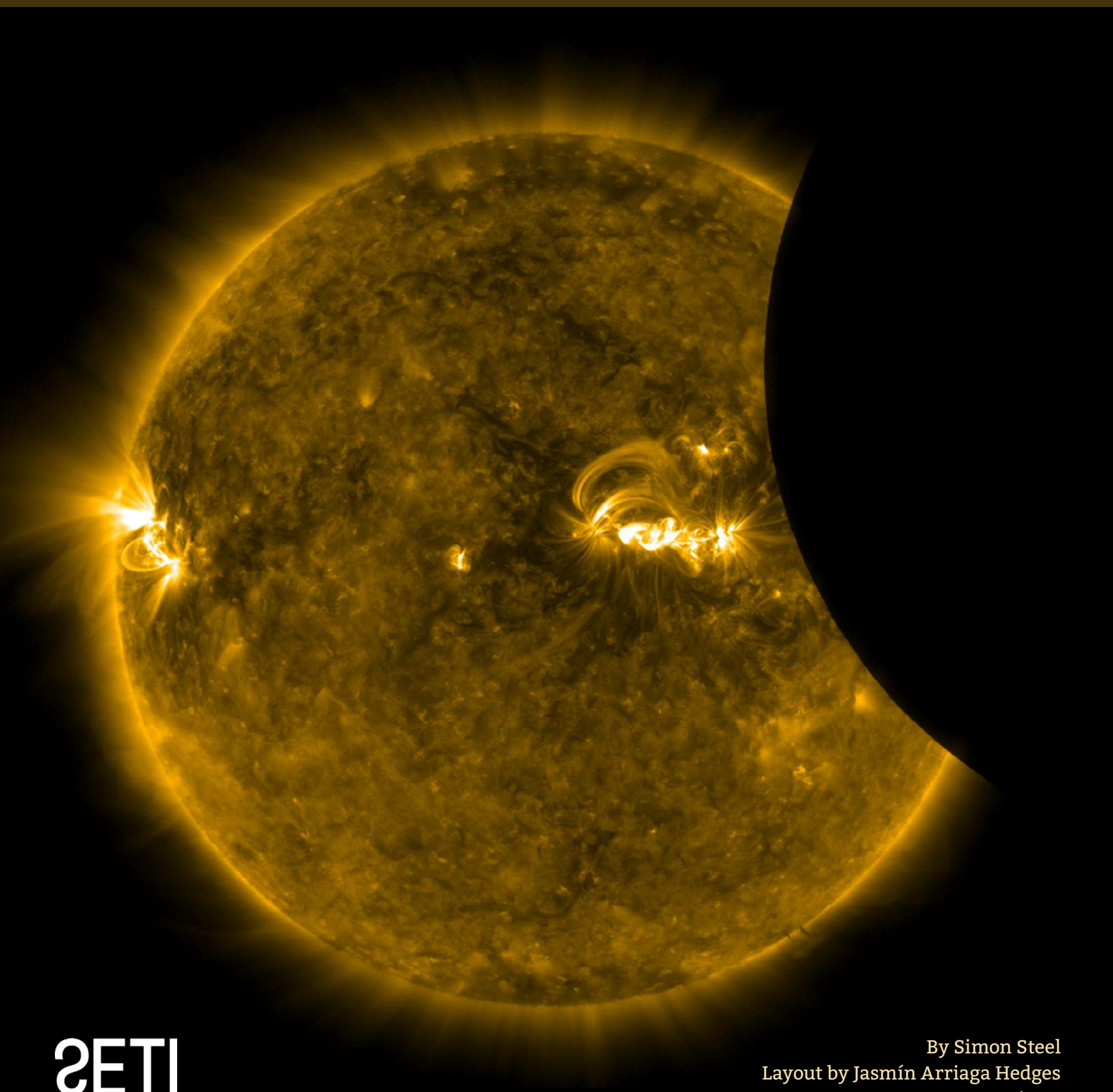

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Table of Contents

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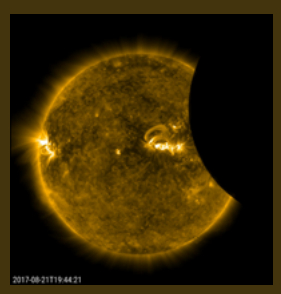


Cover photo: The Moon's disc passes across the face of the Sun during the 2017 total solar eclipse, as seen from NASA's Solar Dynamics Observatory

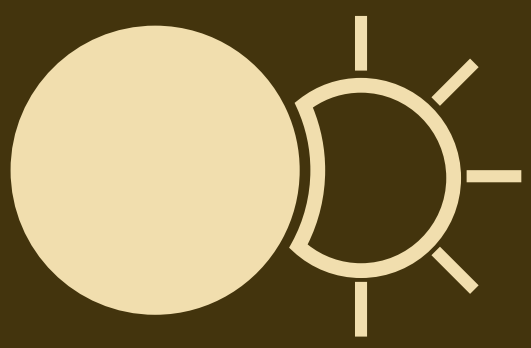
Image Credit: NASA/GSFC/Solar Dynamics Observatory

2024 Eclipse

On April 8, 2024, a 100 mile-wide strip of North America, from Mexico to Eastern Canada will pass under the shadow of our Moon as our one natural satellite aligns perfectly between the Earth and the Sun. The swiftly moving shadow passes overhead, fleetingly turning day into night. As humans stand mesmerized, birds will go to sleep, nocturnal mammals will come out from their burrows, and the night sky, with its thousands of stars, will be unveiled as the Sun's glare is extinguished. That is, if it isn't cloudy. Total solar eclipses are one of the most dramatic and emotional experiences nature offers us, and to see one forever changes our appreciation of the cosmos.

Map: The total solar eclipse will be visible along a narrow track stretching from Texas to Maine on April 8, 2024. A partial eclipse will be visible throughout all 48 contiguous U.S. states. Credit: NASA's Scientific Visualization Studio.

1. A Galactic Tourist Attraction



A total eclipse of the Sun is when our Moon passes between the Sun and Earth. Seeing the light of the Sun disappear for several minutes – broad daylight to night – is one of the most dramatic and visually stunning events you can see. It is a complete coincidence that the disc of our small Moon exactly blocks the disc of the enormous star we call the Sun. The Sun, 400 times the diameter of the Moon, just happens to be 400 times further away. No other planet in the solar system, nor possibly many in the entire galaxy, can boast this alignment of size and distance. If there were ever a reason for aliens to visit Earth as tourists, it would be to watch the Earth's incredible Solar Eclipse!

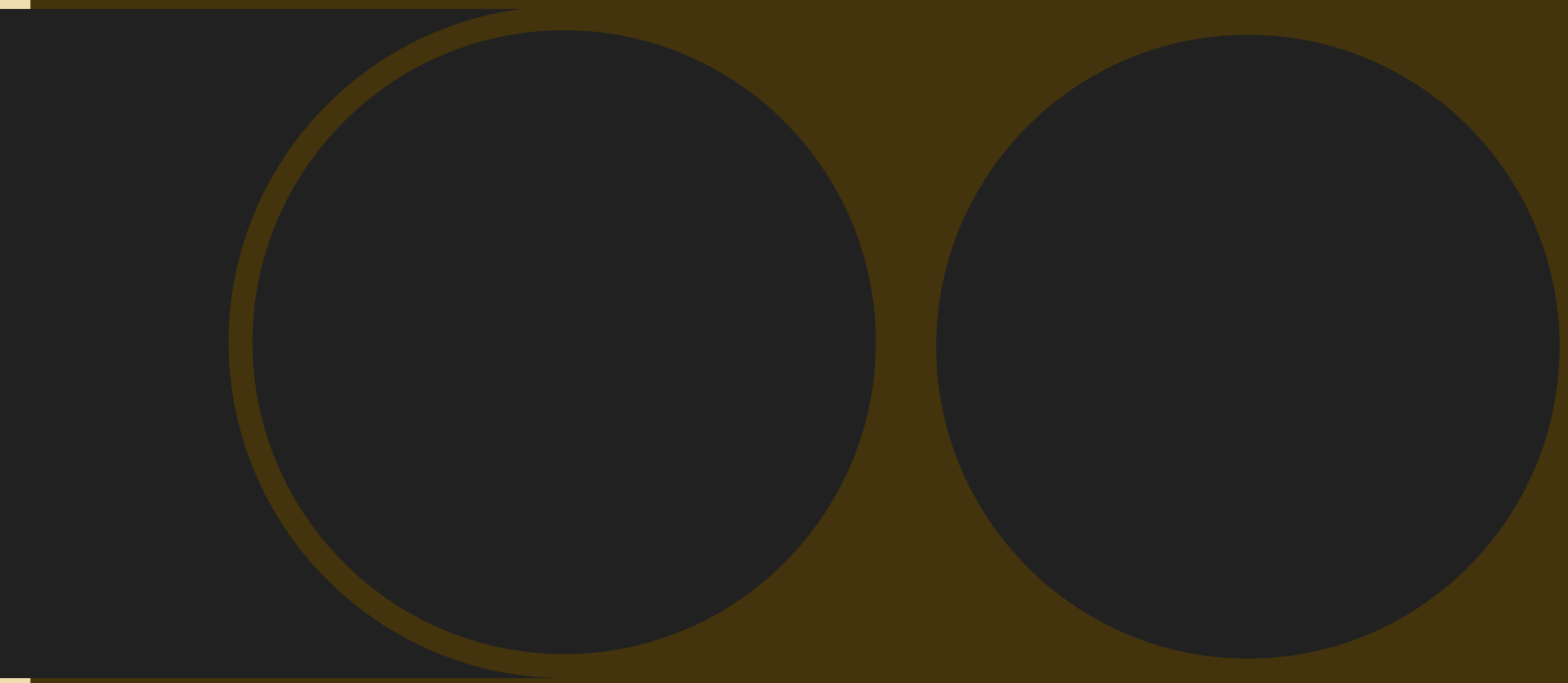


Image: The 2019 total solar eclipse seen from ESO's La Silla Observatory in Chile. Image Credit: ESO/M. Zamani


Marybeth Kitzenberg
ShelbyDiamondstar Photography

2. Totality Not Guaranteed

If planets and moons orbited in perfect circles, and all those circular orbits were in a flat plane like a spinning record, eclipses would be more common and easier to predict. But the real solar system is less well aligned. Since the calculations of Johannes Kepler, in the early 17th century, humans have realized that planetary orbits are ellipses, rather than circles. The Earth's orbit around the Sun is an ellipse, and the Moon's orbit around the Earth is an ellipse. If the Moon happens to be at its distant point (apogee) during the eclipse alignment, its disc will look smaller from Earth and won't completely block the disc of the Sun. We see an annular eclipse - the amazing Ring of Fire.

Image: Annular Solar Eclipse over Utah.
Image Credit: MaryBeth Kiczenski,
www.shelbydiamondstar.com

3. When's the Next One?

These days, we can look the answer up online. Two thousand years ago, the first known computer (called the Antikythera Mechanism) could calculate it, and the Babylonians were the first to figure it out. But predicting eclipses is not easy. The Moon's orbit is inclined at 5 degrees to the orbit of the Earth. It doesn't sound much, but it's enough to make the Moon's shadow miss the Earth most of the time. The Moon has to be in the right part of its orbit for things to align, and this happens approximately every six months, a time called an eclipse season. Then, the Earth's axis tilted at 23.5 degrees to its orbit, so the Moon's shadow passes over a different part of our planet seemingly every time (see the table of eclipses at the end of the book!) But if you wait 6585.321 days, a Saros Cycle, all the orbital elements of an eclipse will repeat, and the eclipse will be duplicated! Almost. The 0.321 days, or 8 hours, of the Saros cycle means that, although the eclipse is the same, the surface of the Earth is out of place by a third of a rotation, and your eclipse is now someone else's.

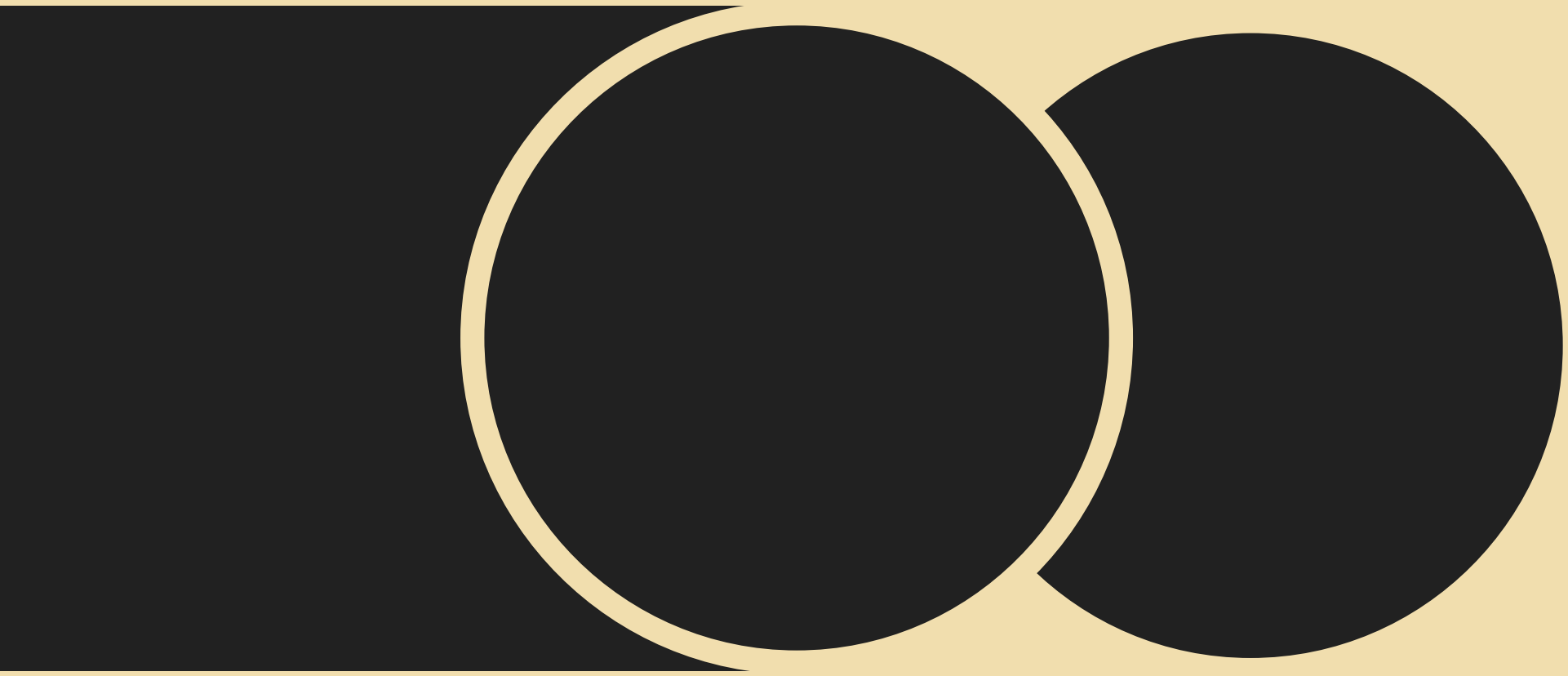
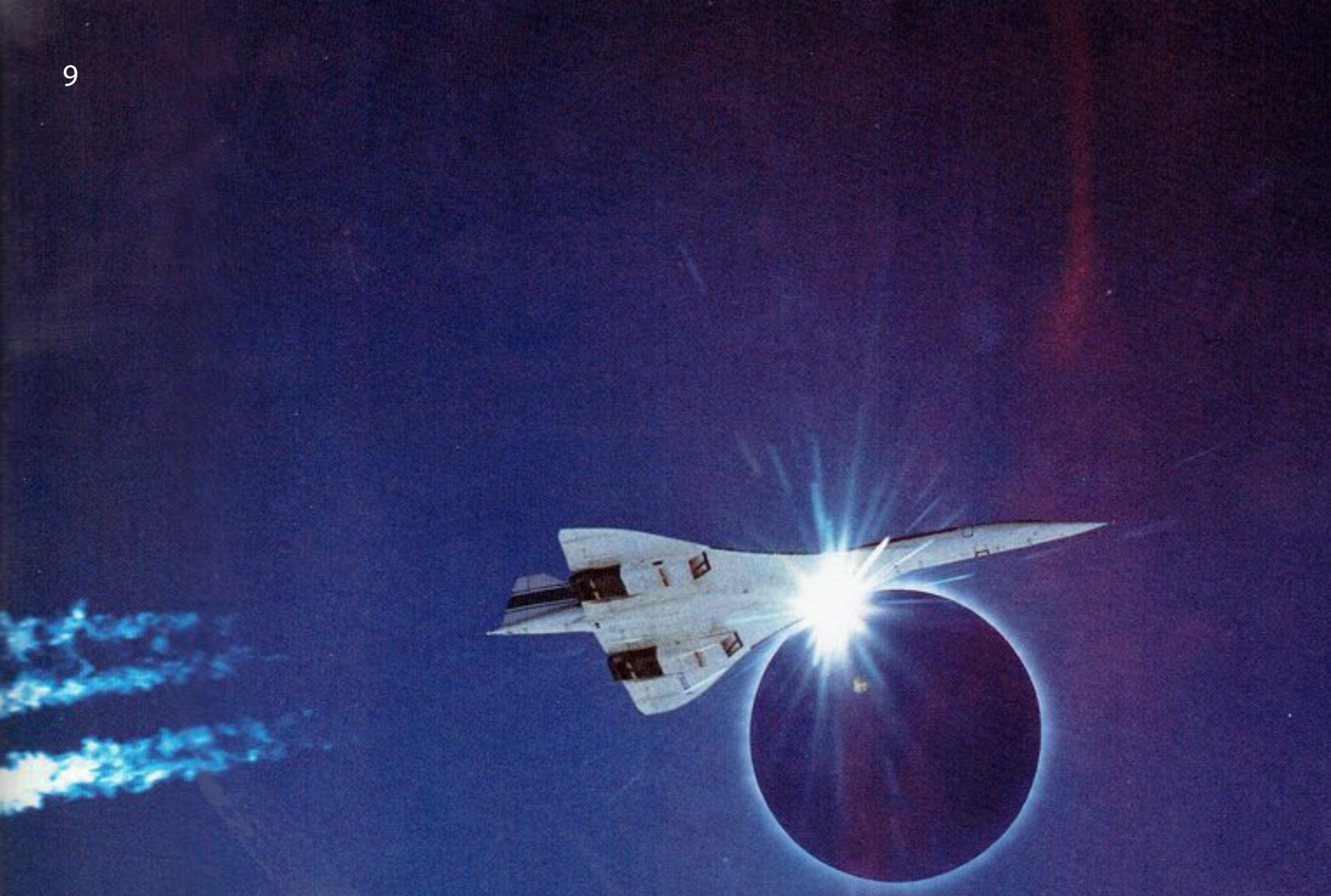


Image: Antikythera Mechanism, National Archeological Museum, Athens.
Image Credit: Simon Steel.



4. Blink and you'll miss it!

The Moon is moving in its orbit. The Earth is rotating on its axis. The Moon's shadow, about 100km (65 miles) wide, sweeps across the landscape at over 3000 km/h (2000 mph). The Sun will be blocked for only a few minutes where you stand (just over four minutes for the April 2024 total eclipse). Or you could chase the shadow. In 1973, astronomers from the US, Britain and France hired a Concorde supersonic airliner capable of flying 2,158 km/h (1,341 mph) at 60,000 ft altitude. Chasing the shadow at twice the speed of sound along the Tropic of Cancer, they managed to make their eclipse experience last over an hour!

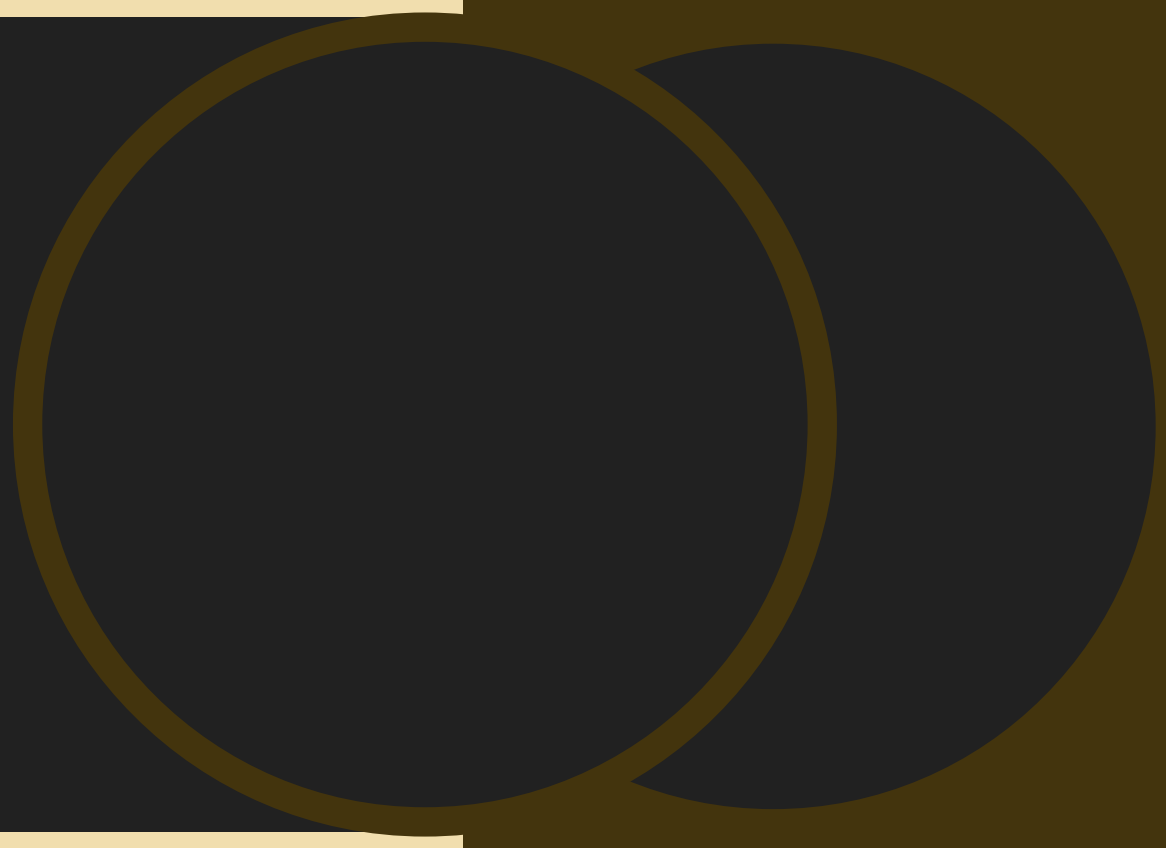


Image: Concorde and the 1973 total solar eclipse, photographed from a chase plane. Image Credit: Arthur Gibson.

5. Eclipses Through Time

The oldest recorded eclipse in human history may have been on Nov. 30, 3340 BCE. A series of spiral-shaped petroglyphs (stone carvings) was found at the Loughcrew Megalithic Monument in County Meath, Ireland. Three millennia later, in the early 6th century BCE, a battle between the Medes and Lydians (in modern-day Turkey) was rudely interrupted by a total eclipse, resulting in a truce and ultimately peace treaty.

The Maya in Mesoamerica were compulsive sky-watchers, following the cyclic motion of Sun, Moon and their favorite planet, Venus. One of the few surviving Maya documents details when eclipses can happen (they understood eclipse seasons), but for the Maya, it was a portent of doom and gloom. For an eclipse was a demon consuming the Sun and it's good to have fair warning of approaching hungry demons.

Further north and a millennium later, a petroglyph carved into the rockface by early Pueblo people At Chaco Canyon in New Mexico may represent an eclipse that occurred there on July 11, 1097. Eclipses, whether messengers of doom, enders of war or a celebration of nature, have been a part of human imagination and fascination from the very beginning of recorded time.

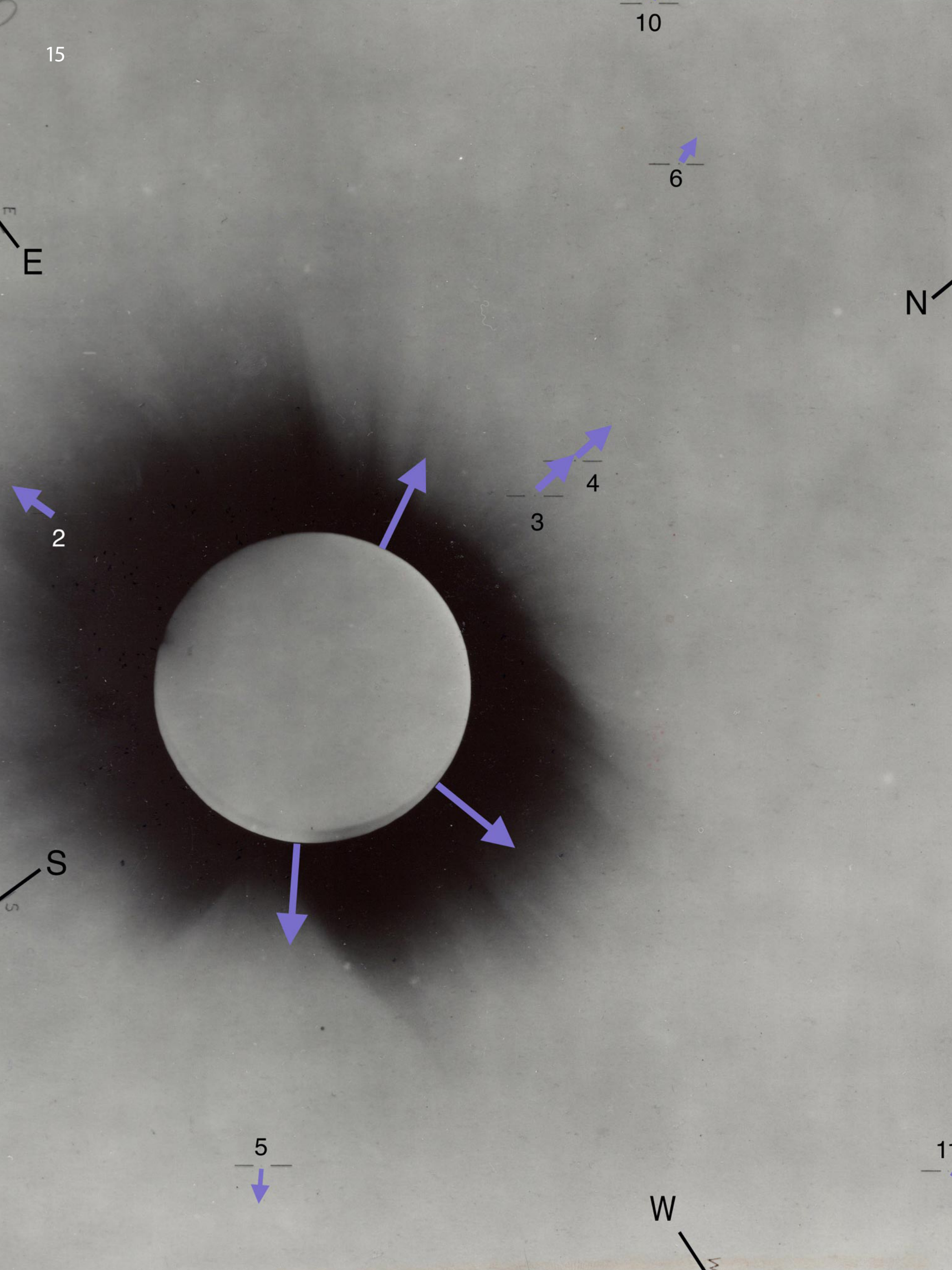
Image: Petroglyph possibly representing the 1097 total solar eclipse, Chaco Canyon, New Mexico.
Image Credit: National Parks Service.

6. Lovely (Solar) Weather We're Having

The Sun, a giant ball of ionized hydrogen and helium gas heated by nuclear fusion, has a beautiful and dynamic atmosphere that is completely overwhelmed by the glare of the full Sun. Except during an eclipse. With the Sun's blinding disc is blocked by the Moon, the Sun's chromosphere (Sphere of Color) is revealed as bubbling pink flares and streams of hydrogen plasma.

Beyond the chromosphere is the Sun's corona (crown), a gossamer stream of ultra-hot ionized gas, whipped up into a frenzy by the sun's magnetic field and blasted into space as the solar wind. As the Sun approaches its 11-year maximum of activity, this wind can become a storm, sending particles smashing into the Earth's upper atmosphere. This is not good news for the electronics on satellites or for the health of astronauts, but it does give us one of nature's most psychedelic light shows, the beautiful green and red curtains of light called aurorae, reminding us that Earth is pretty good at shielding its lifeforms from the Sun's full fury.

Image: Solar chromosphere and corona visible during 2017 total eclipse.
Image Credit: ESO.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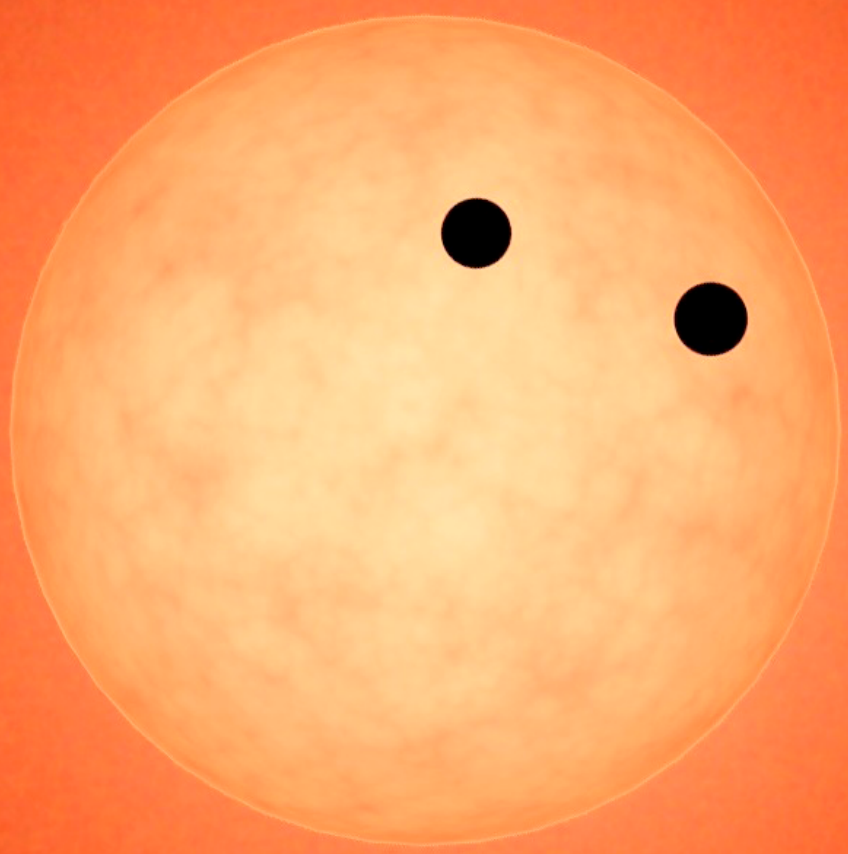
7. The Bending of Space

In Einstein's theory of gravity, mass distorts the shape of space, but how do you prove such an outrageous idea? With a solar eclipse, of course! The Sun is a big mass, so it bends space a lot. Follow a beam of light from a distant star as it skims past the Sun on its way to Earth, and the light appears to bend around the Sun (light always travels in straight lines, but a straight line through curved space is a curve!) To see stars so close to the Sun, you need to block out the Sun – with the Moon. This is what astronomer Arthur Eddington did in 1919, photographing the Sun during an eclipse. The background of stars appeared to have shifted - their light had traveling through the curved space around the Sun's mass. It was the first proof of Einstein's theory of gravity, an effect we now call gravitational lensing, and an ominous sign that the universe was about to become very weird.

Image: Negative photographic plate of 1919 total solar eclipse, with the displacement of stars from their expected locations. Image Credit: Royal Observatory Greenwich.



8. Eclipses and Exoplanets

A solar eclipse from Earth is a special thing, thanks to the coincidence of the apparent sizes of the Sun and Moon. What if a planet passed between the Earth and the Sun? Mercury does it quite often, and Venus did so back in 2004 and again in 2012, but the effect is barely noticeable. Venus is physically bigger than our Moon but much farther away from Earth, so the resulting mini-eclipse, called a transit, dims the sun so slightly that you need special detectors to measure the drop.

It turns out that transits are a great way to discover planets orbiting other stars. These exoplanets (short for extra-solar planets) block the light of their sun as they transit across its disc, as seen from our perspective. Not only do you discover the planet, but the transit can reveal information about the planet's size, its orbit, density (and therefore what it's made of) and, in some cases, the weather patterns and atmospheric composition! Of the 5000+ exoplanets now discovered, most of them were found using the transit method. It now seems that practically every star in the sky has its own planetary system!

Image: Artist's rendering of the seven Earth-sized planets orbiting a red dwarf star discovered by the TRAnsiting Planets and PlanetesImals Small Telescope (TRAPPIST). Image Credit: NASA/JPL-Caltech/R. Hurt (IPAC).

9. Anti-Solar SETI

When would an alien civilization try to contact us? New Year's Day? July 4th? If you're going to schedule the arrival of your interstellar message, a moment of cosmic celebration might be the best time. Technosignature searches at the anti-solar point (the point on Earth facing exactly away from the Sun) make sense, not least because the Sun is a horribly loud radio source. But take it one step further, with the Sun, Moon and Earth all aligned for a total eclipse. An advanced alien civilization would know that we know that this is a special cosmic moment, and maybe they would time a transmission to reach Earth from the anti-eclipse side. As you wait eagerly for the Moon's shadow to pass overhead on April 8, 2024, take a moment to ponder whether the real action is going down on the other side of the world!

Caption: The Allen Telescope Array at dusk.
Image Credit: Simon Steel.

10. The Last Eclipse

One day, in the distant future, there will be a last total Solar eclipse. Tidal interactions between the Earth and Moon increase the Moon's distance from Earth by 3.8cm (1.5 inches) every year. As its orbit gets bigger, the Moon's disc gets smaller and smaller as viewed from Earth, until it will no longer cover the disc of the Sun. 1.2 billion years from now, beings from Earth, or beyond, will gather to witness the end of an era, and the eclipses of Earth will pass into legend.

Image: Aliens (or maybe our distant descendants) gather to watch the final total solar eclipse
Image Credit: Simon Steel, generated by Chat GPT/DALL.E.

Solar Eclipse Resources

01 NASA's Eclipse page, with lots of information on eclipses and how to observe them:

https://science.nasa.gov/eclipses/future-eclipses/eclipse-2024/

02 Learn more about NASA's heliophysics missions and how they are helping us understand how the sun works, and how space weather affects Earth.

https://science.nasa.gov/heliophysics

03 Get involved in observing and reporting aurorae with Aurorasaurus:

https://www.aurorasaurus.org

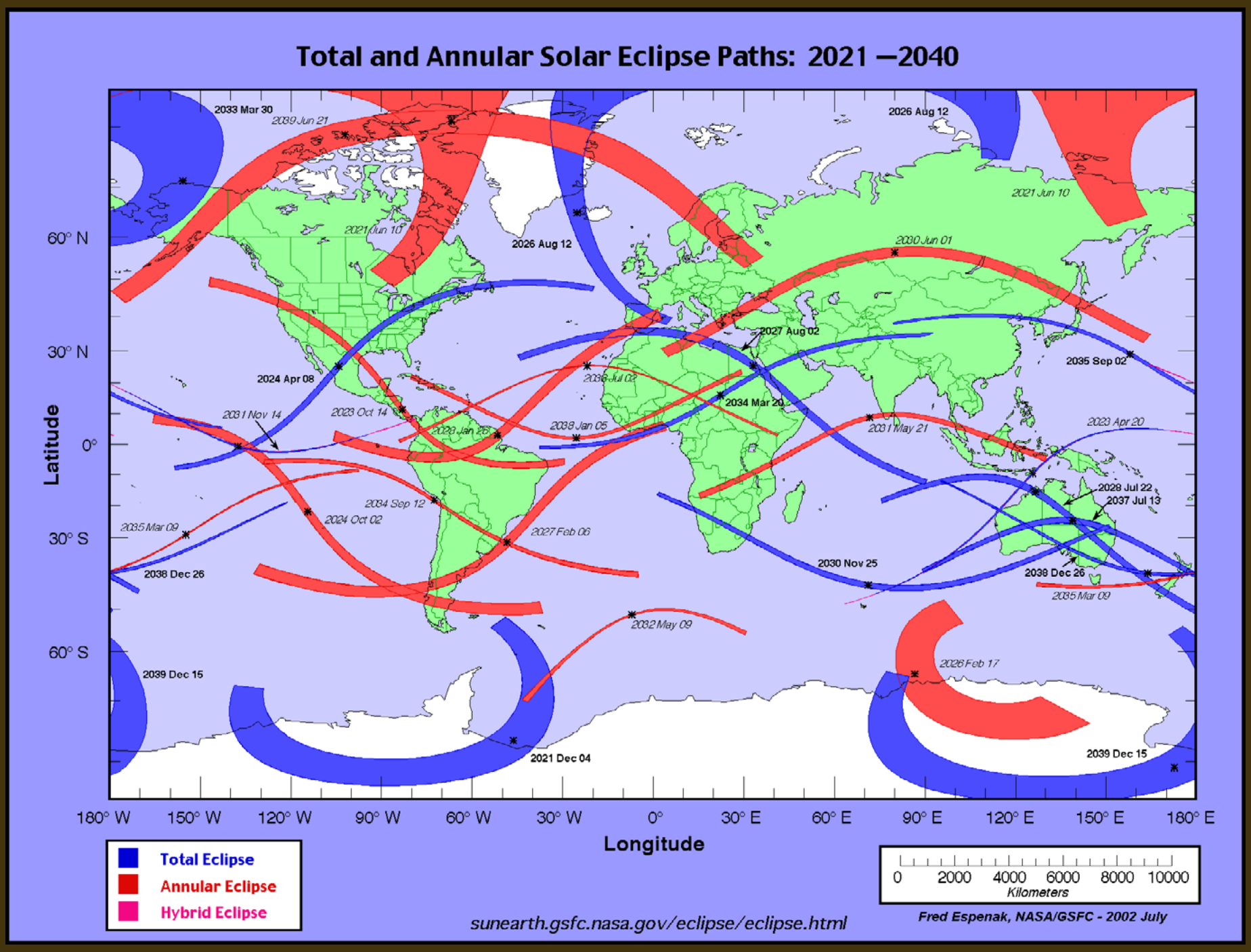
04 Mr. Eclipse – THE online guide to all things eclipse – from Mr. Eclipse himself Fred Espenak

http://mreclipse.com

05 Astronomical Society of the Pacific Eclipse Ambassador Program, Undergraduate Students and Eclipse Enthusiasts will engage their local communities, providing solar viewing glasses as well as context for underserved communities off the central paths:

https://astrosociety.org/education-outreach/amateur-astronomers/eclipse-ambassadors/program.html

List of upcoming Solar Eclipses



April 8, 2024
Total
Mexico, central and northeastern USA

October 2, 2024
Annular
Southern Chile, Southern Argentina

March 29, 2025
Partial
NW Africa, Europe

September 21, 2025
Partial
South Pacific, New Zealand, Antarctic

February 17, 2026
Annular
Antarctica

August 12, 2026
Total
Arctic, Greenland, Iceland, Spain

February 6, 2027
Annular
Chile, Argentina

August 2, 2027
Total
Morocco, Spain, Algeria, Egypt

Map: Total and Annular Solar Eclipse Paths: 2021 -2040
Image Credit: Fred Espinak, NASA GSFC.

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