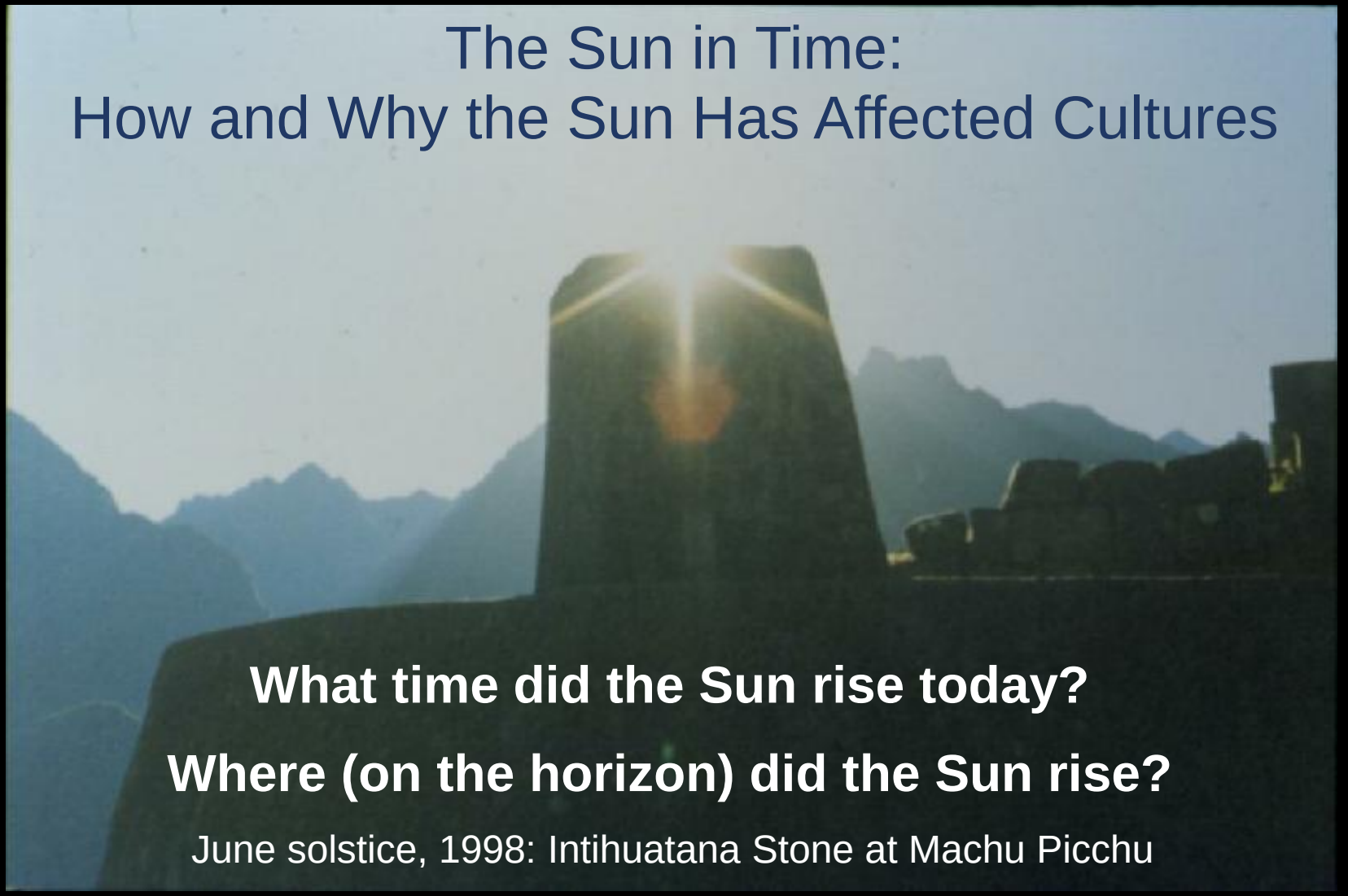
# The Sun in Time:
# How and Why the Sun Has Affected Cultures



**What time did the Sun rise today?**

**Where (on the horizon) did the Sun rise?**

June solstice, 1998: Intihuatana Stone at Machu Picchu

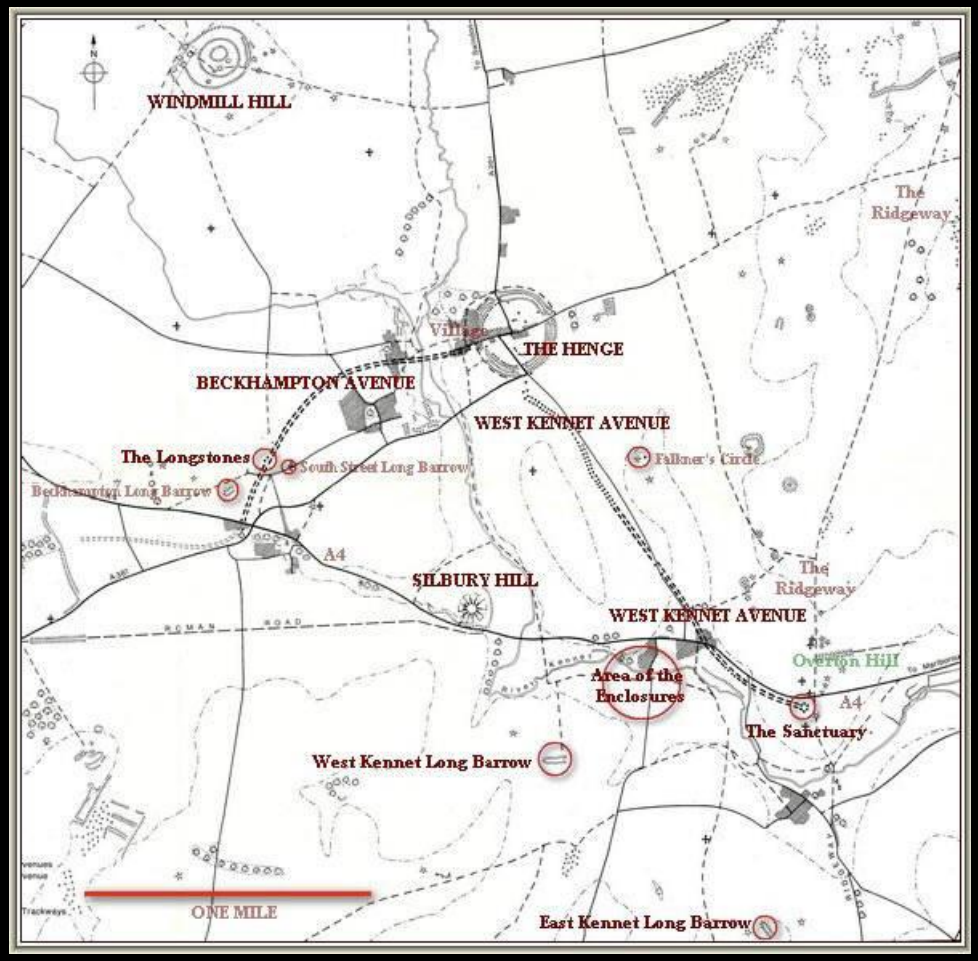
Mitzi Adams, M.S.
Heliophysics and Planetary Group
NASA/MSFC

# Observing the Sun in Years Past

Stonehenge
Built, Over Many Years, c. 3000 BCE
Photo from September, 2003

# Standing Stones at Avebury, England

Photo from September, 2003




The area of the circle is about 28.5 acres, the circumference is approximately 0.8 mi.

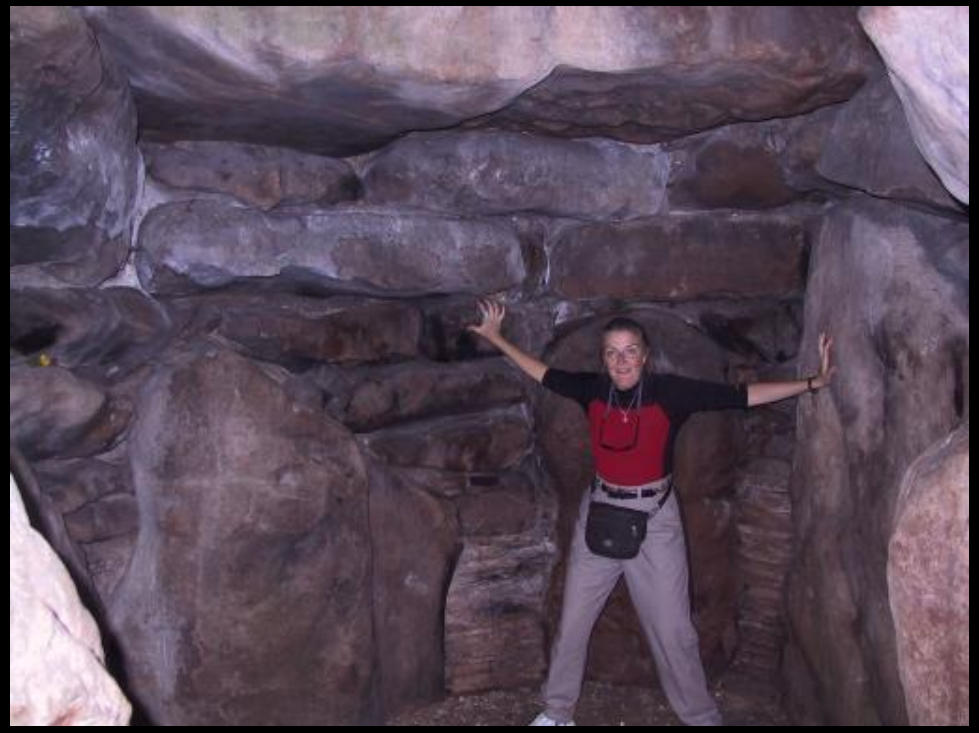
The stone circle of Stonehenge would fit into the outer stone circle at Avebury around 130 times.

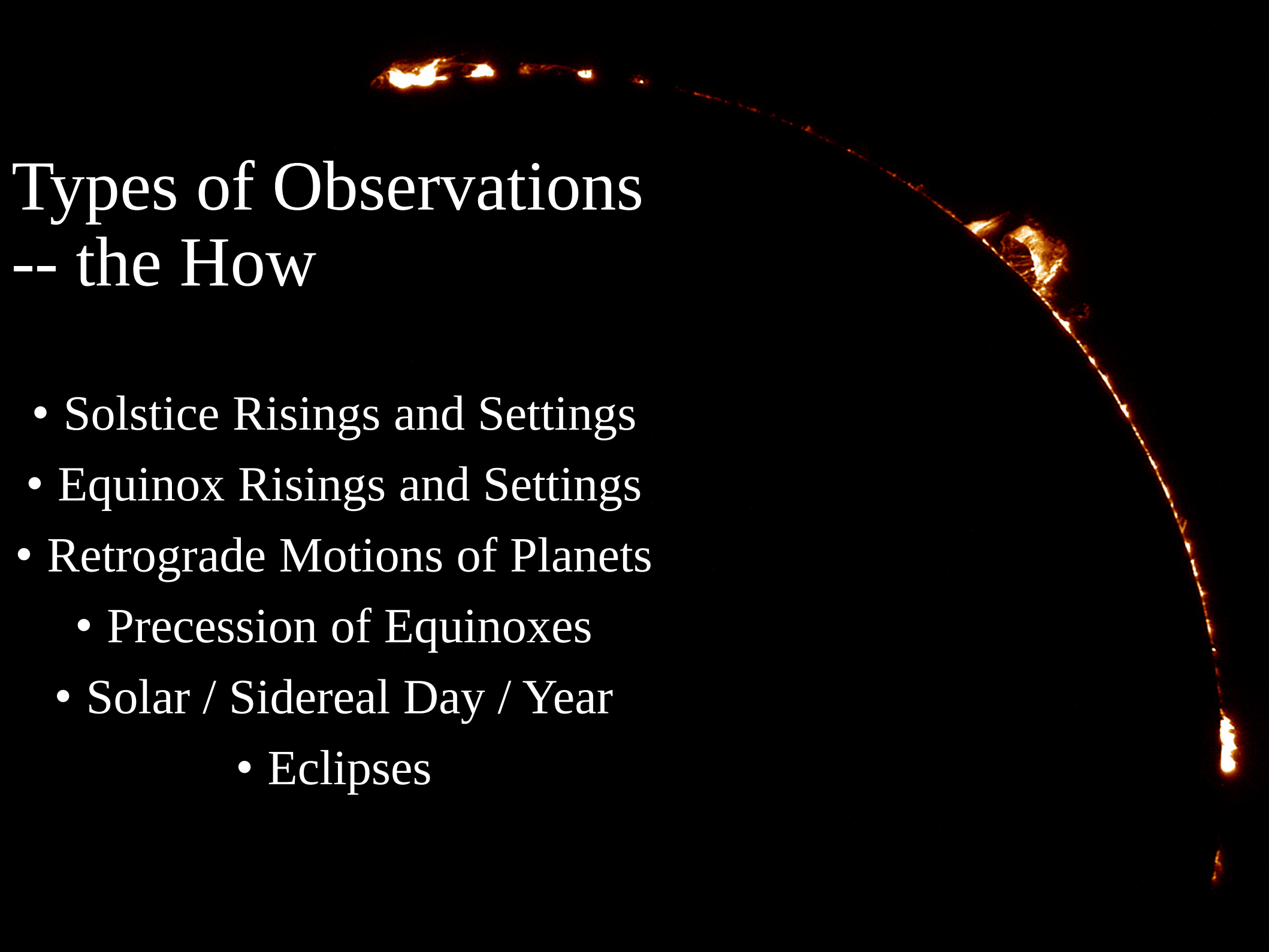
# The Human Desire for Understanding

We Observe, and We Measure, and We Mark

Avebury, September 21, 2003

Silbury Hill
(Sep, 2003)





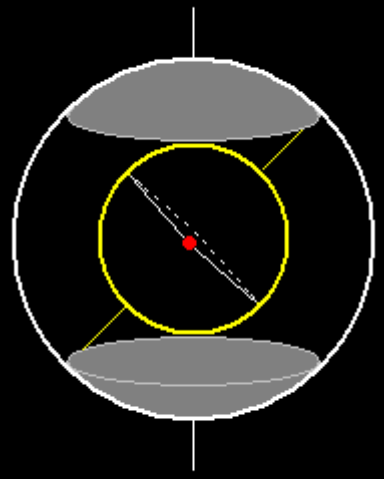
# Types of Observations -- the How

- Solstice Risings and Settings
- Equinox Risings and Settings
- Retrograde Motions of Planets
- Precession of Equinoxes
- Solar / Sidereal Day / Year
- Eclipses

# The Beginnings of Western Science: Creating Order from Chaos -- the Why

Eudoxos, c. 375 BCE: Nested Sphere Model of the Universe

1. Earth is the center of the universe
2. All celestial motion is circular
3. All celestial motion is regular



4. The center of the path of any celestial motion is the same as the center of its motion
5. The center of all celestial motion is the center of the universe

...led to Ptolemy's epicycles and deferents (c. 100 - 1200 C.E.).

# Meanwhile in Central America
# the Maya Observed Planets, Sun, and Moon
# c. 900 CE

El Castillo, or
Temple of Kukulkan

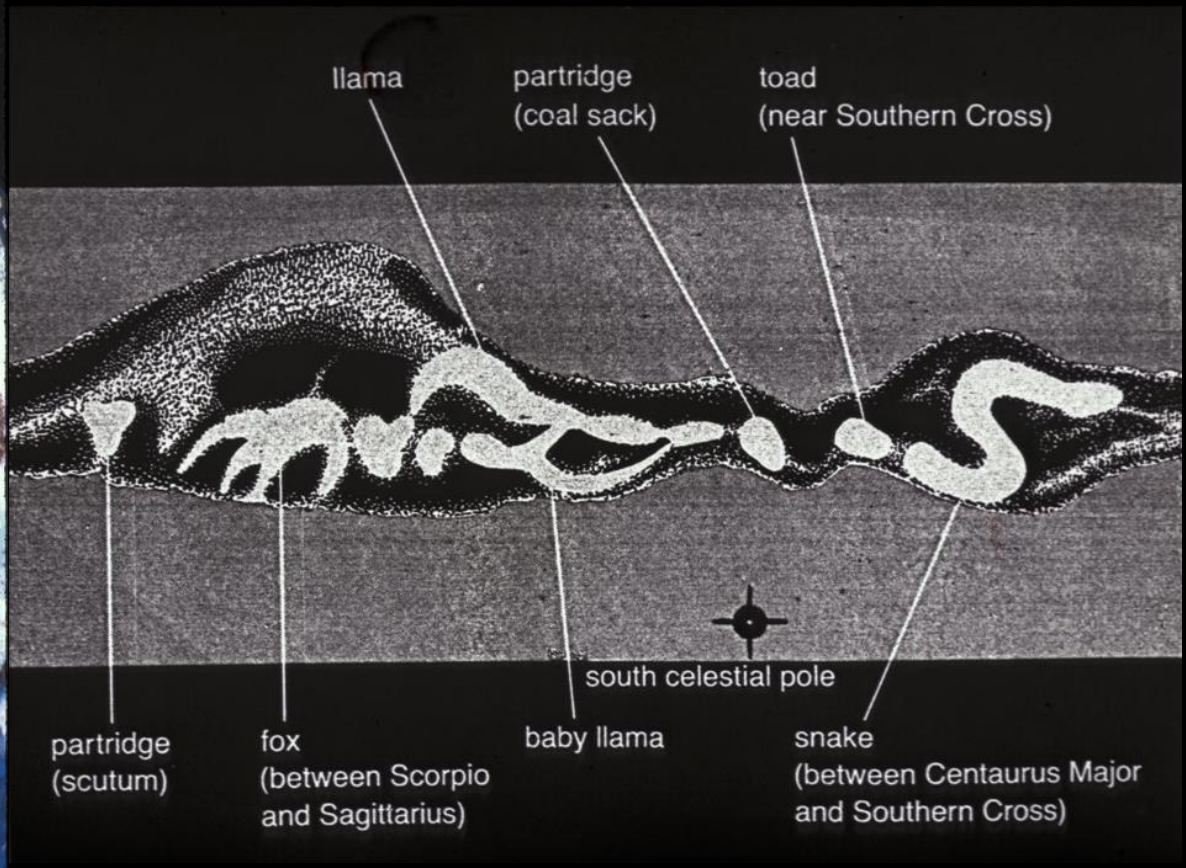
Caracol

Images from 2004

# Observing the Sun in Peru

## Only about 500 - 600 years ago
## c. 1500


# The Inca World View


Images from a March 1990 National Geographic Article by Dr. John Carlson, used with permission.


Cusco Town Square 1982


Qorikancha 2006

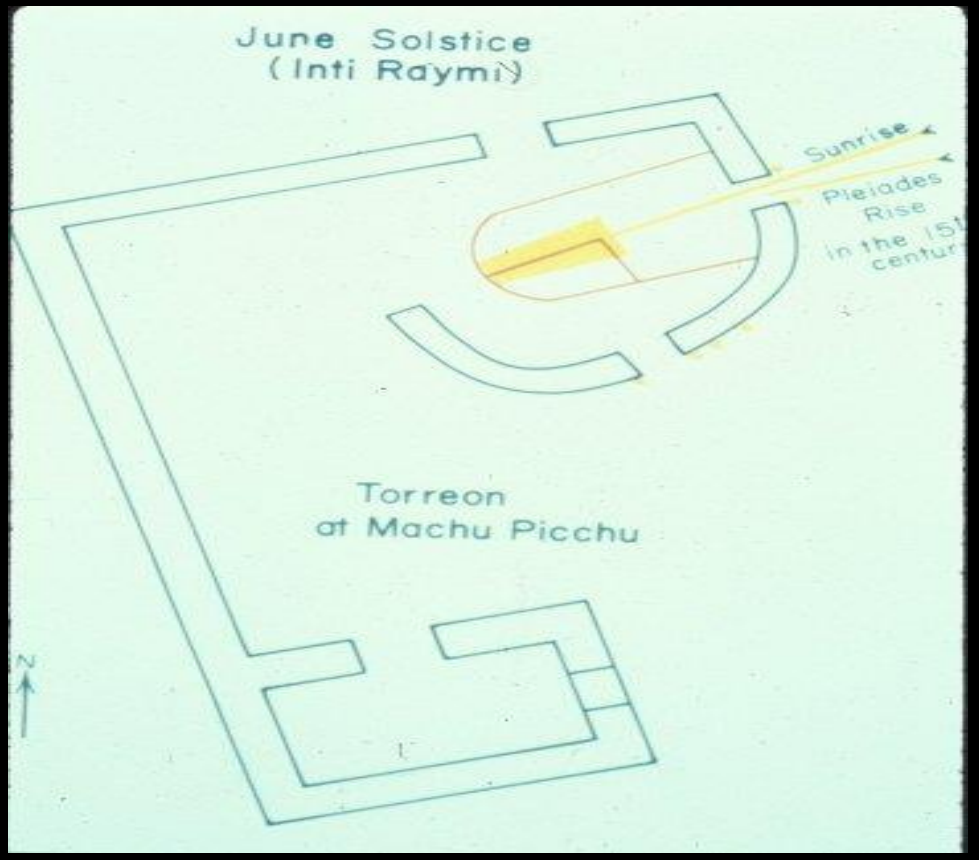

Cusco Town Square 2006


Sacsayhuaman 2006


Chinchero
Autumnal Equinox
2006

On Inca Trail to Machu Picchu Sun Gate
2006

Machu Picchu from Sun Gate


June Solstice
(Inti Raymi)
Sunrise
Pleiades
Rise
Torreon
at Machu Picchu
N

# Intihuatana

From Mountains to Jungle -- Iquitos

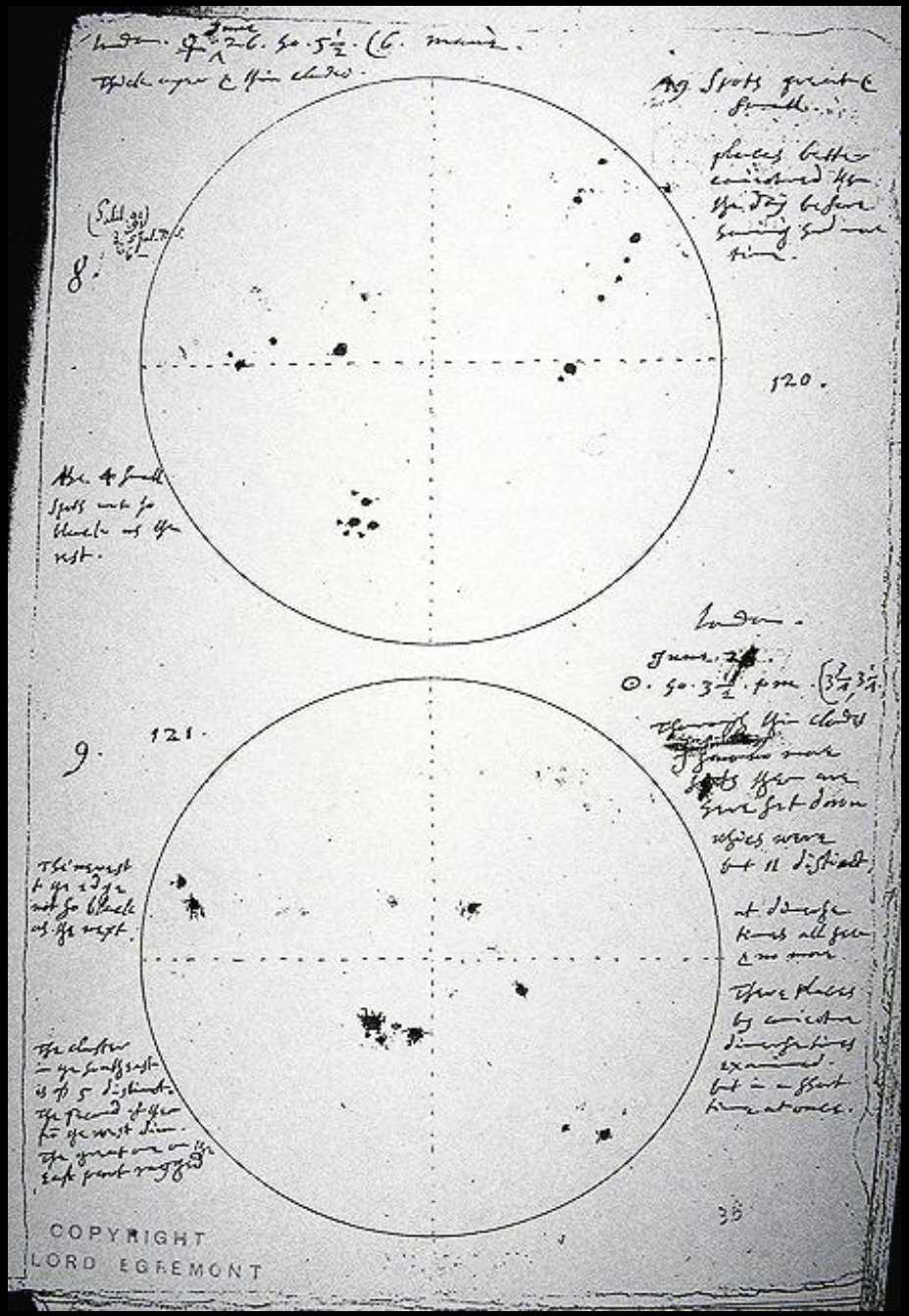
Cacao

Cashews

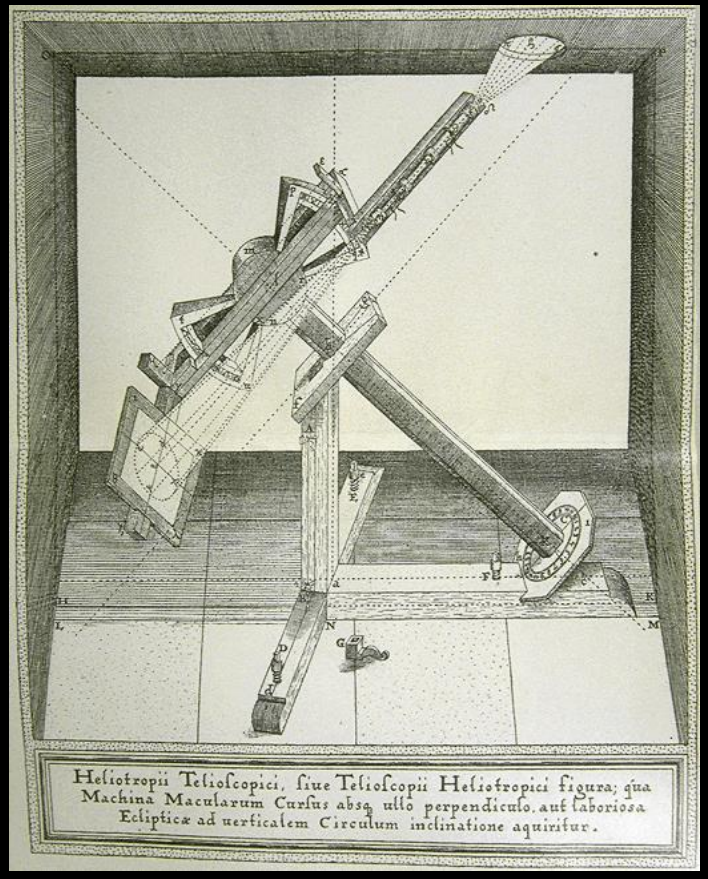
# On the Road to Modern Solar Observations

Meanwhile in Europe, c. 1610...

# Galileo Galilei, Christoph Scheiner, Thomas Harriot




These three began to use the telescope to study the Sun. Scheiner's telescope is below. (From the Rosa Ursina, published in 1630, in the public domain.)

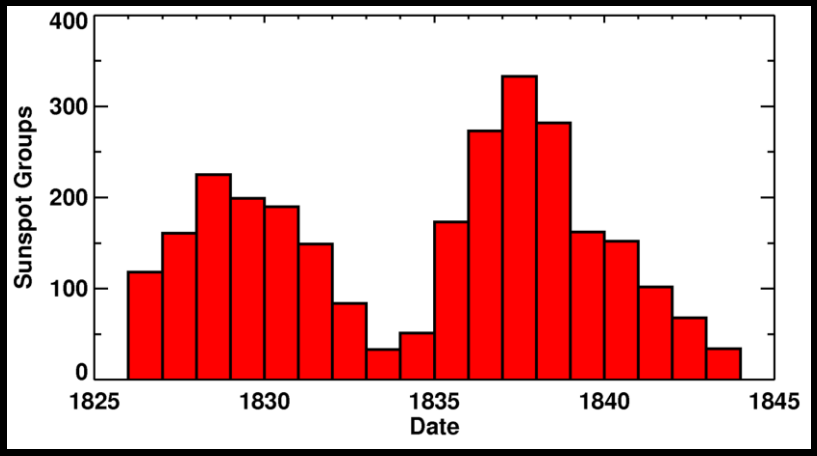



Thomas Harriott's sunspot drawings, used with the kind permission of Lord Egremont.

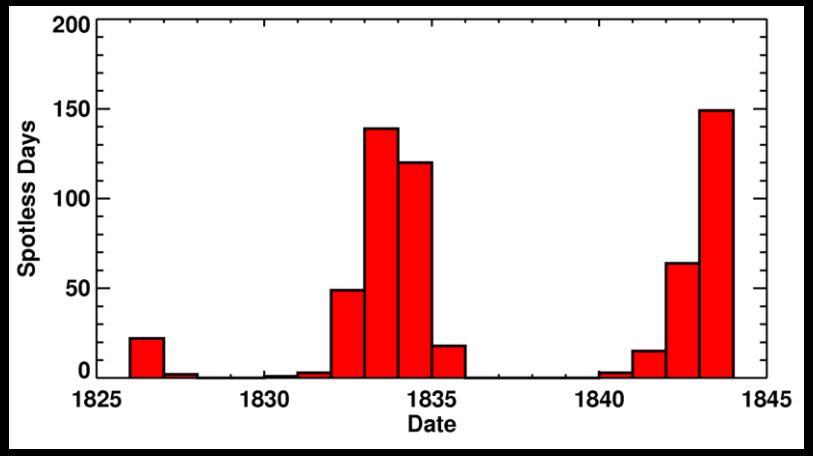
# Sunspot Cycle Discovery

**~ 230 years after Galileo, Heinrich Schwabe, an amateur astronomer in Dessau, Germany, discovered that the number of sunspot groups and the number of days without sunspots increased and decreased in cycles of about 10-years.**

**Schwabe's data for 1826 to 1843**

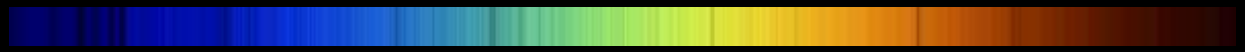



**Number of Sunspot Groups per Year**

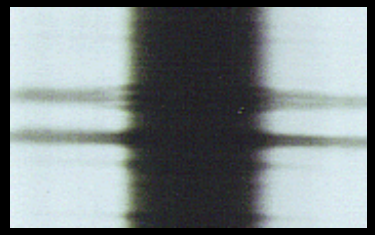


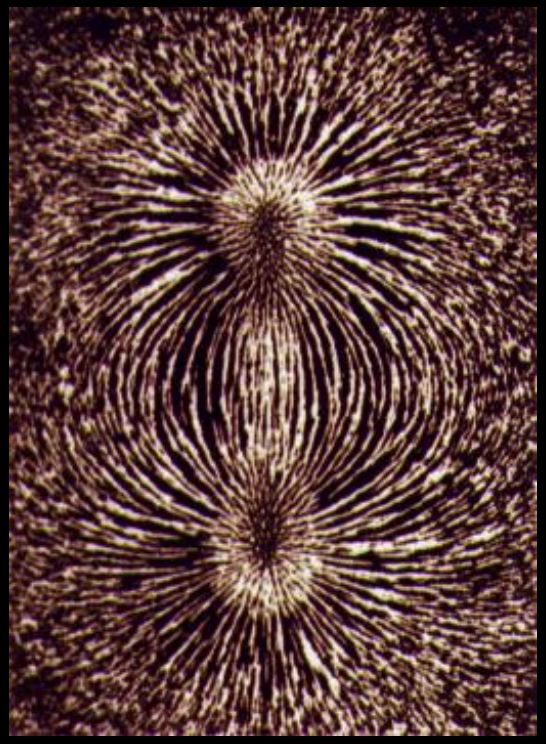

**Number of Spotless Days**

# Measuring Magnetic Fields



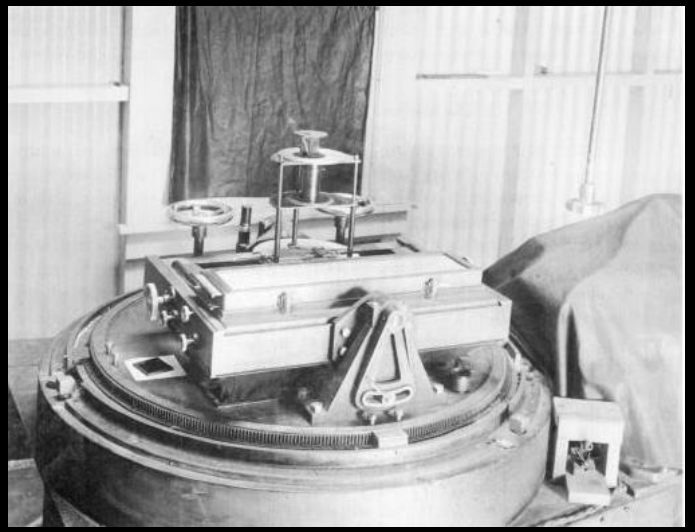
Fraunhofer, early 1800s





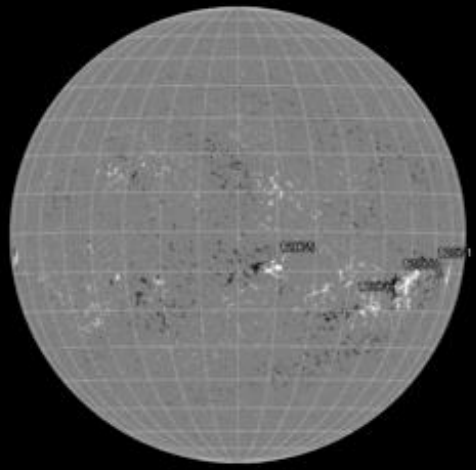
Zeeman, 1886

George Ellery Hale, early 1900s

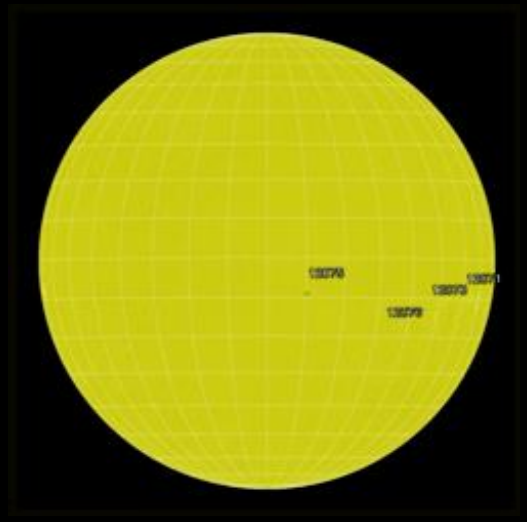


Artist’s Concept: Solar Dynamics Obervatory
Launched 2010

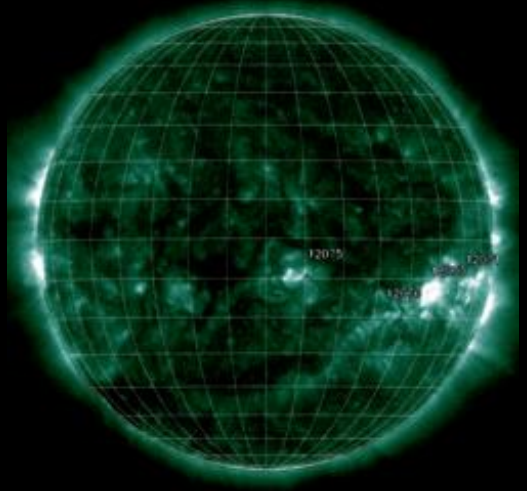
# A Selection of SDO Images



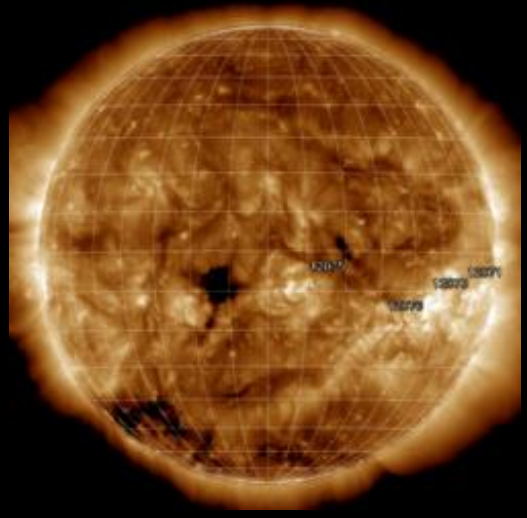
HMI



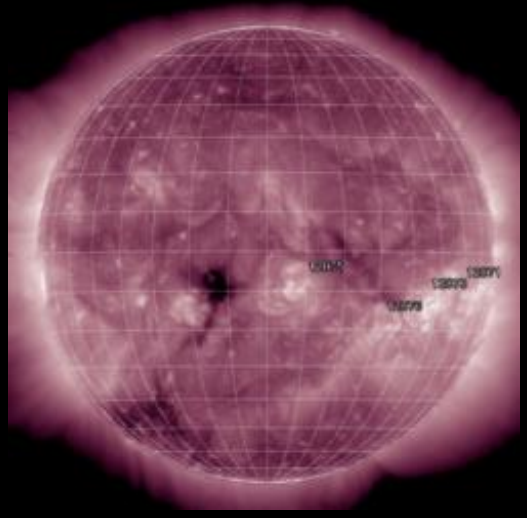
HMI - 6173 Å



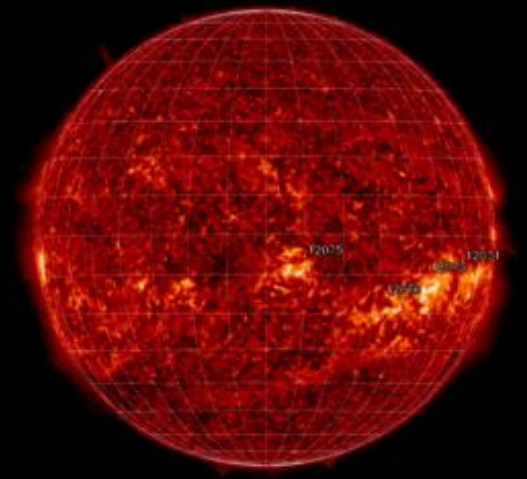
AIA - 94 Å



AIA 193 Å



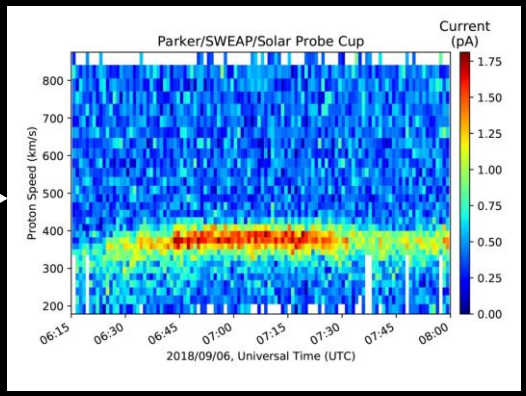
AIA 211 Å



AIA 304 Å

# Parker Solar Probe
# Closest Approach Dec. 24, 2024

Solar Wind Electrons, Alphas, and Protons (SWEAP) data




11.4 cm (4.5 in) thick carbon-composite shield -- 1377 C (2500 F) in front, ~25 C (72 F) in back

Electric Field Antenna (4)

Low- and high-energy solar particle sensors

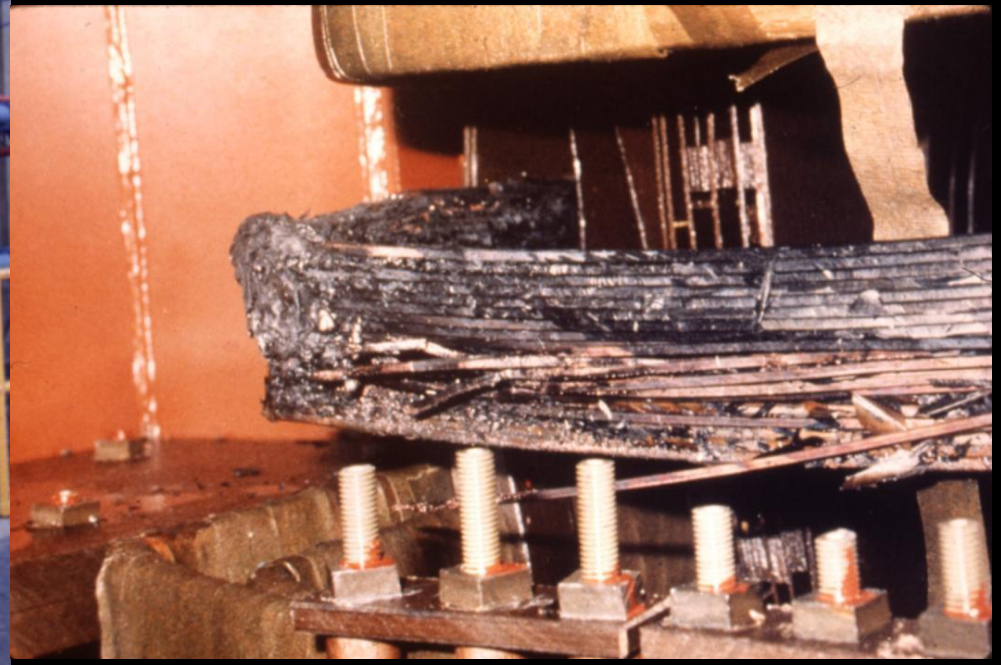
Magnetometer (3)

Coronal White-Light Imager

Closest Approach: about 3.9 million miles (6.2 million kilometers) of the Sun. Speed ~430,000 mph, go from Philadelphia to D.C. in one second

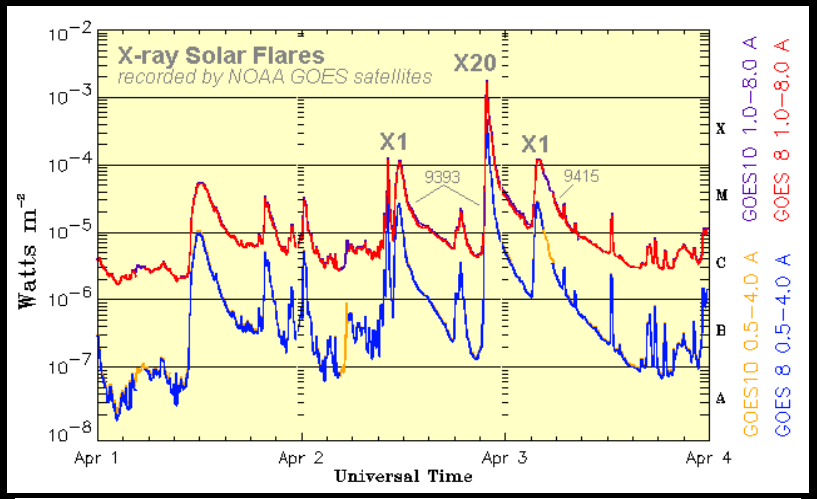
# Why Do We Care?

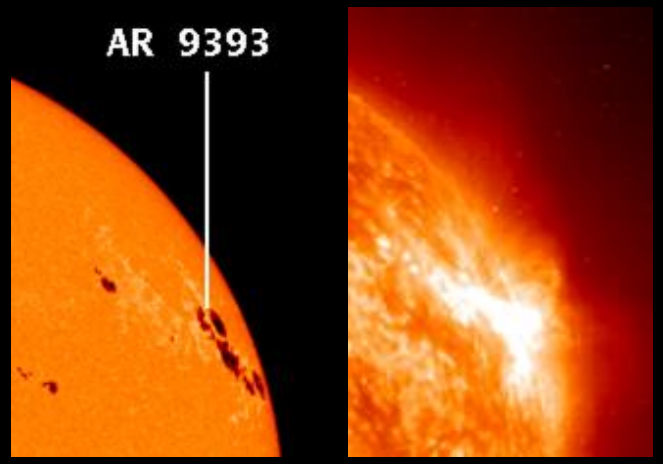
One phase of a 1200 MVA bank of three transformers, knocked out by a solar particle storm in 1989. The unit can cost up to $10 million and replacement can take up to one year. The large blue boxes house copper coils of wire. Note below, the result of the extra induced current.

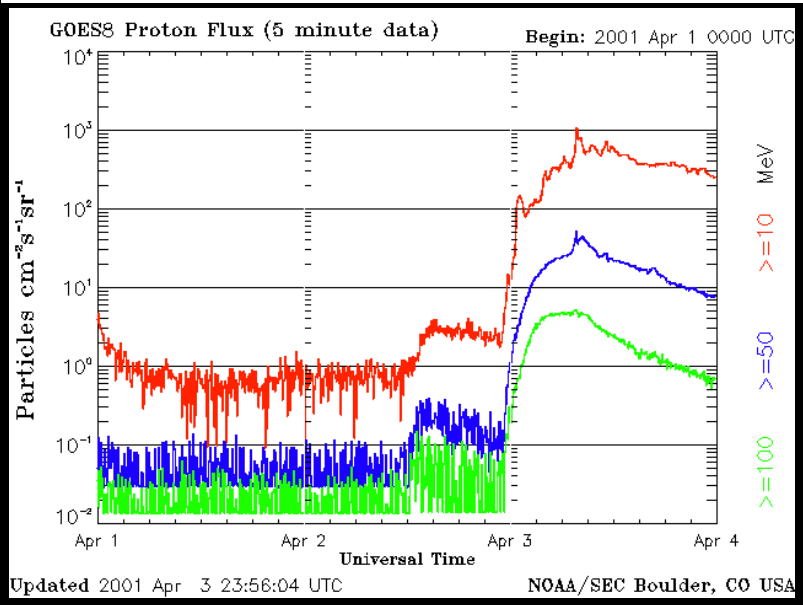


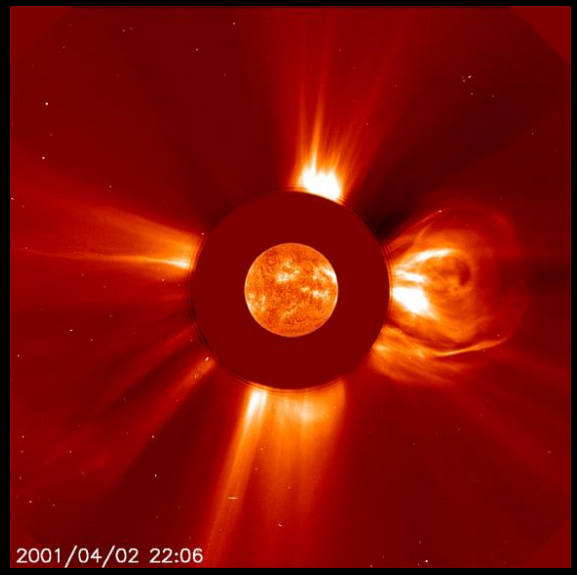
Images Used with Permission from John Kappenman

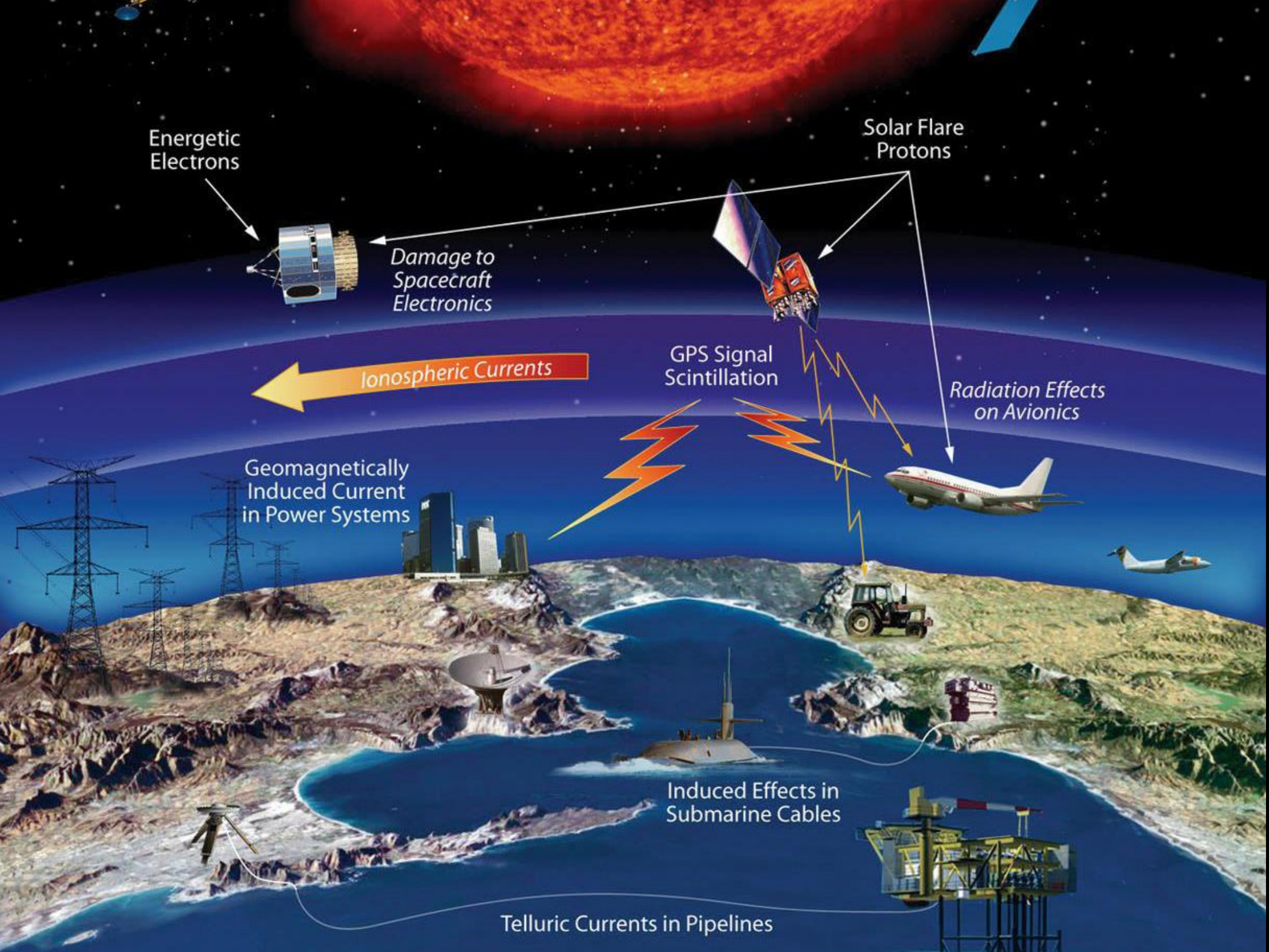
- At 21:51 UT, Monday 2 April 2001, active region 9393 unleashed a major solar flare reclassified as at least an X20 It appears to be the biggest flare on record, most likely larger than the one on 16 August 1989 and definitely more powerful that the famous 6 March 1989 flare which was related to the disruption of the power grids in Canada.




Energetic Electrons
Solar Flare Protons
Damage to Spacecraft Electronics
Ionospheric Currents
GPS Signal Scintillation
Radiation Effects on Avionics
Geomagnetically Induced Current in Power Systems
Induced Effects in Submarine Cables
Telluric Currents in Pipelines

# Two Solar Eclipses Six Months Apart

## October 14, 2023 and April 8, 2024

National Aeronautics and Space Administration

**Diagrams are not to Scale:**
If the Sun's diameter is scaled to 10 cm (3.9 in), Earth would be about 0.09 cm (0.04 in) and 10 meters away (33 feet).

The next **total solar eclipse** visible over the continental United States will be on **April 8, 2024.**

### What is a Solar Eclipse?

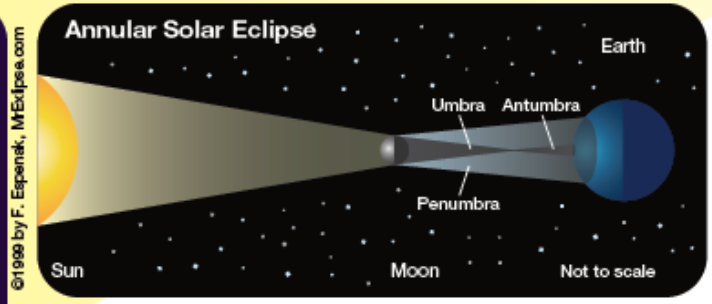
A **solar eclipse** happens when the Moon—as it orbits Earth—fully or partially blocks the light of the Sun, thus casting its shadow on Earth.

### What is a Total Solar Eclipse?

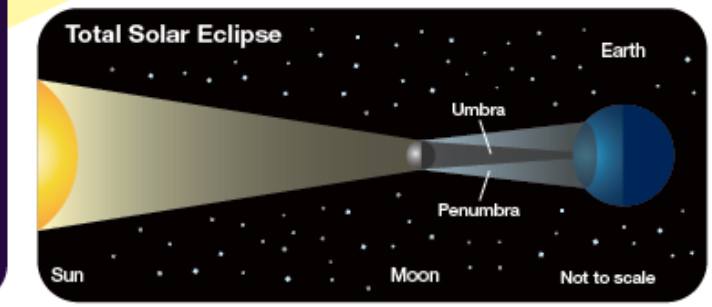
As observed from Earth, if the Moon is closer to Earth in its orbit and is aligned between Earth and Sun, it appears to be the same size as the Sun and a **total solar eclipse** occurs. The Moon blocks all the bright light from the surface of the Sun and the corona can be seen.

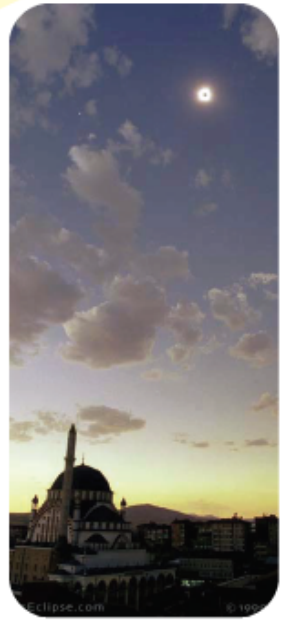
### What is an Annular Eclipse?

As observed from Earth, an **annular eclipse** occurs when the Moon is aligned between Earth and Sun and is far enough from Earth to appear smaller than the Sun so that a ring (annulus) of sunlight remains visible around the Moon.







**The predicted path of the October 14, 2023 annular eclipse and the April 8, 2024 total solar eclipse.**

**Duration of Greatest Eclipse for Annular:**
*5 min 17 sec* (18:00 UT=13:00 CDT=1 p.m. CDT)

**Location of Greatest Eclipse:**
*11 deg 22 min N; 83 deg 6 min W* (Central America)

**Duration of Greatest Eclipse for Total:**
*4 min 28 sec* (18:18 UT=13:18 CDT=1:18 p.m. CDT)

**Location of Greatest Eclipse:**
*25 deg 17 min N; 104 deg 8 min W* (Mexico)




**Annular Eclipse**
Tokyo, Japan,
May 20, 2012



**Total Eclipse**
Lewisville, Idaho,
August 21, 2017

**Never look directly at the Sun unless you have filters that you know are safe.**

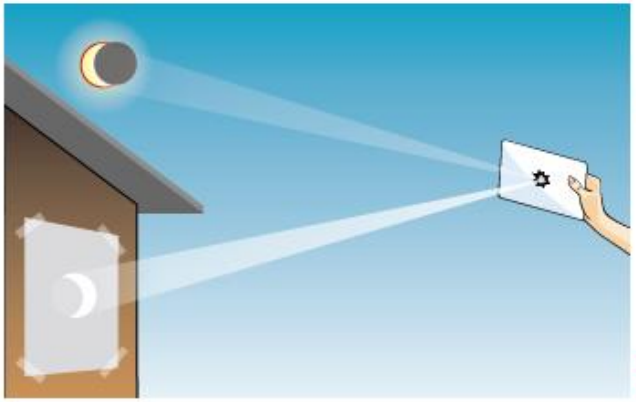
**For more information:** https://solarsystem.nasa.gov/eclipses/future-eclipses/eclipse-2023/
https://solarsystem.nasa.gov/eclipses/future-eclipses/eclipse-2024/
https://solarsystem.nasa.gov/eclipses/safety/
https://eclipse.aas.org/resources

www.nasa.gov

**Mitzi Adams** • *mitzi.adams@nasa.gov* • **256–961–7626**

# Safely Observing the Sun

**WARNING: Never look directly at the Sun without proper eye protection.**
**You can *seriously* injure your eyes.**



For any **total** solar eclipse, if the Sun is not 100% covered in your area, please travel to an area inside the path of totality to experience a fully eclipsed Sun. **You will be disappointed if you don't!**

## Mirror in an Envelope

**Slide a mirror into an envelope with a ragged hole cut into the front.** Point the mirror toward the Sun so that an image is reflected onto a screen at least 5 meters (about 15 feet) away. The longer the distance, the larger the image.

**Do not look at the mirror, only at the screen.**

## Local Area for Path of Annularity—October 14, 2023

| Location | % Covered | Start (CDT) | Max (CDT) | End (CDT) |
|---|---|---|---|---|
| Eugene, OR | 89% | 10:05AM | 11:18AM | 12:39PM |
| Battle Mountain, NV | 89% | 10:06AM | 11:23AM | 12:48PM |
| Sevier, UT | 89% | 10:08AM | 11:28AM | 12:56PM |
| Monument Valley, UT/AZ | 89% | 10:10AM | 11:31AM | 1:01PM |
| Albuquerque, NM | 90% | 10:13AM | 11:37AM | 1:09PM |
| San Antonio, TX | 90% | 10:23AM | 11:54AM | 1:33PM |

## Local Area for Path of Totality—April 8, 2024

| Location | % Covered | Start (CDT) | Max (CDT) | End (CDT) |
|---|---|---|---|---|
| Vanderpool, TX | 100% | 12:13PM | 1:33PM | 2:54PM |
| Monument Valley, UT/AZ | 60% | 12:18PM | 1:28PM | 2:42PM |
| Sulfur Springs, TX | 100% | 12:25PM | 1:45PM | 3:04PM |
| Shreveport, LA | 98% | 12:27PM | 1:47PM | 3:07PM |
| Little Rock, AR | 100% | 12:33PM | 1:52PM | 3:11PM |
| Memphis, TN | 98% | 12:37PM | 1:56PM | 3:15PM |
| Cape Girardeau, MO | 100% | 12:41PM | 2:00PM | 3:17PM |
| Paducah, KY | 100% | 12:42PM | 2:01PM | 3:18PM |
| Indianapolis, IN | 100% | 12:50PM | 2:07PM | 3:23PM |
| Columbus, OH | 99% | 12:55PM | 2:12PM | 3:27PM |
| Amherst, OH | 100% | 12:58PM | 2:14PM | 3:28PM |
| Buffalo, NY | 100% | 1:04PM | 2:20PM | 3:32PM |
| Burlington, VT | 100% | 1:14PM | 2:27PM | 3:37PM |
| Baxter State Park, ME | 100% | 1:20PM | 2:32PM | 3:40PM |

JAVA Script Solar Eclipse Explorer
http://eclipse.gsfc.nasa.gov/JSEX/JSEX-NA.html

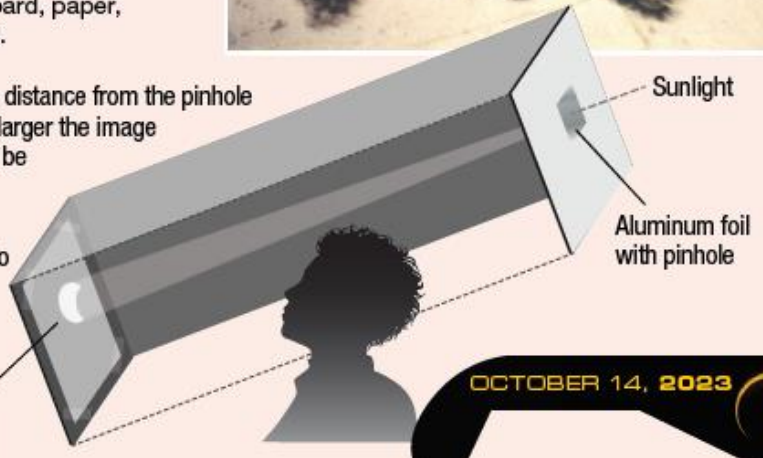
## Strange Shadows!

Sunlight through trees produces projected crescents during partial phases.

Photograph (below) Copyright© Elisa J. Israel

## Go Stick Your Head in a Box

You can make this simple "eclipse telescope" with some cardboard, paper, tape, and foil.




**Sun Funnel**
Make this device for your telescope with simple instructions at: **https://eclipse2017.nasa.gov/make-sun-funnel**

## Cool in the Shades

Contact your local astronomical society to pick up a pair of eclipse glasses or visit this site for suggested resources:
**https://eclipse.aas.org/resources/solar-filters**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