

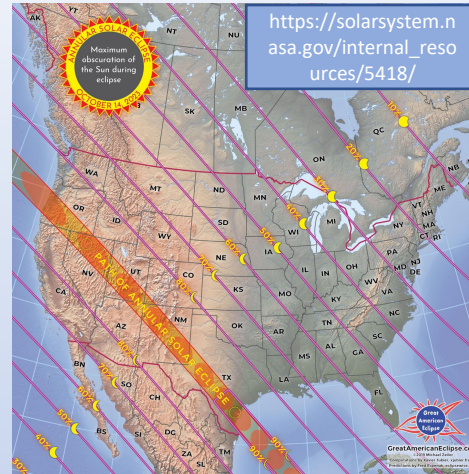
“Ring of Fire” (Annular) Solar Eclipse of October 14, 2023



Art Trevena

Objectives

- Understanding Solar Eclipses
- October 14 Annular Eclipse: Where and how to see it – safely!



Credit:
A. Trevena, 1992



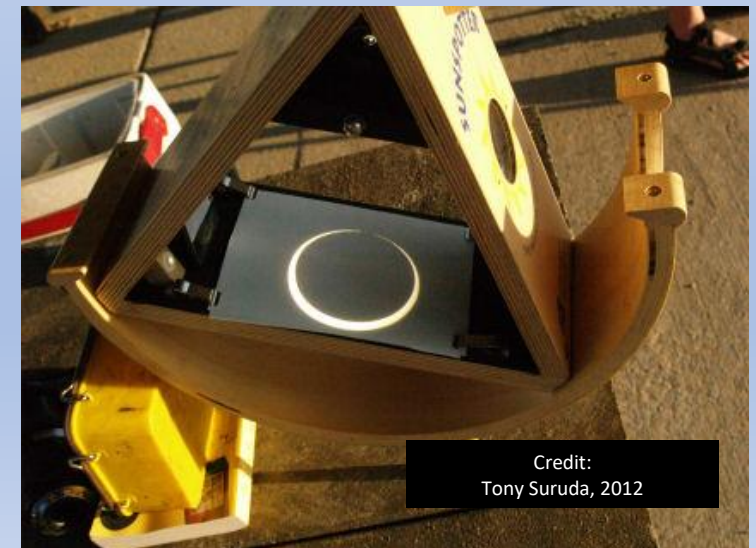
Credit:
J. Tanihara
2012



Credit:
R. Smith, 2012

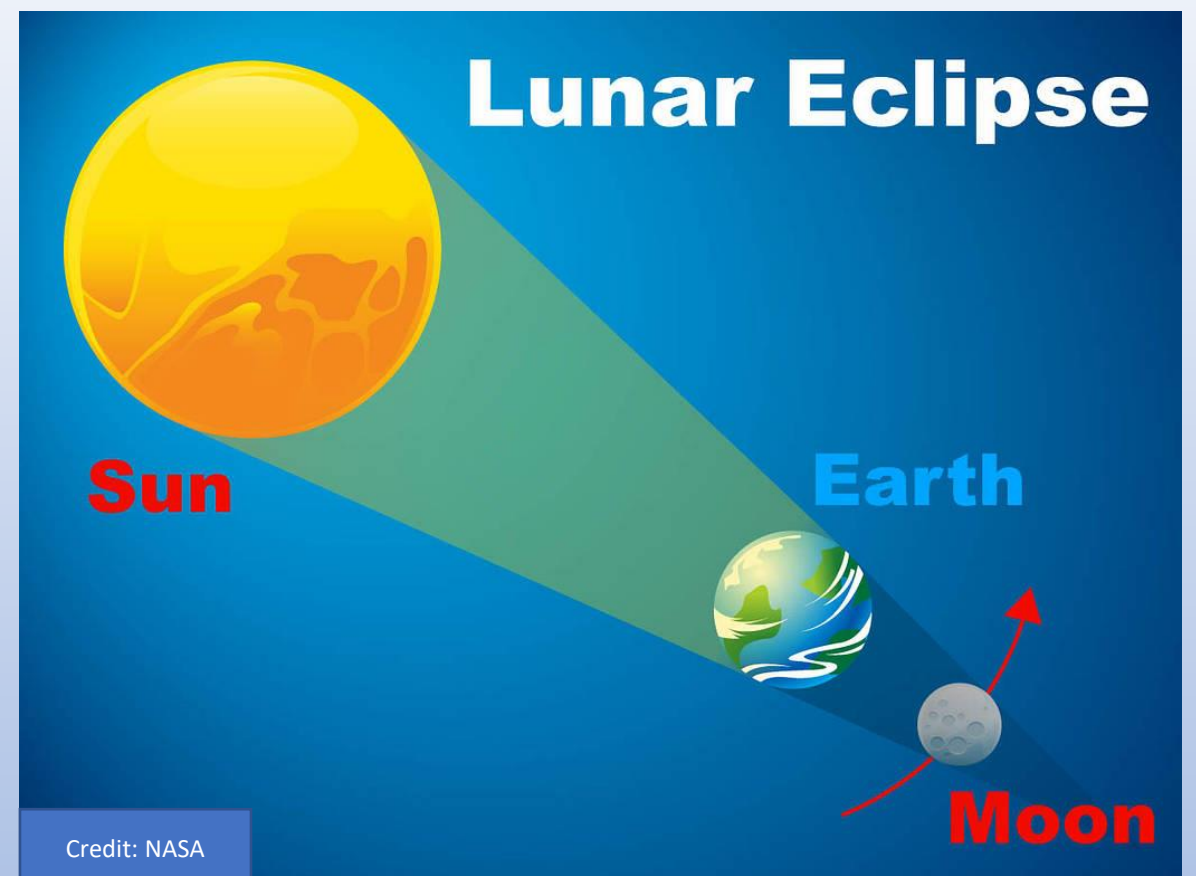
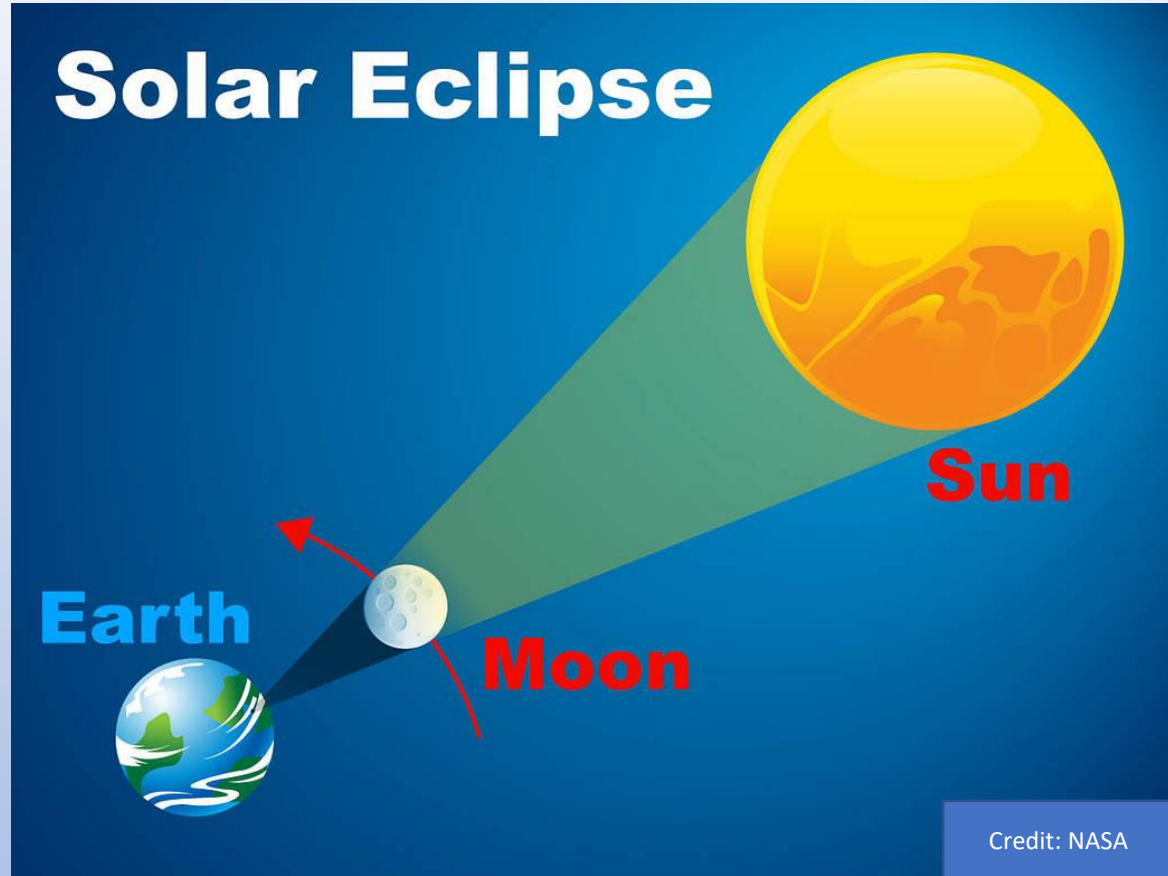
Outline

- Geometry, Types, & Phases of Solar Eclipses
- Predicting Eclipses
- Viewing Solar Eclipses Safely
- Annular Eclipse Phenomena
- Experience Oct. 14, 2023 Annular Eclipse from 4 Corners Region
- Post-2023 Solar Eclipses
- A “don’t miss” event: The April 8, 2024 Total Solar Eclipse



Credit:
Tony Suruda, 2012

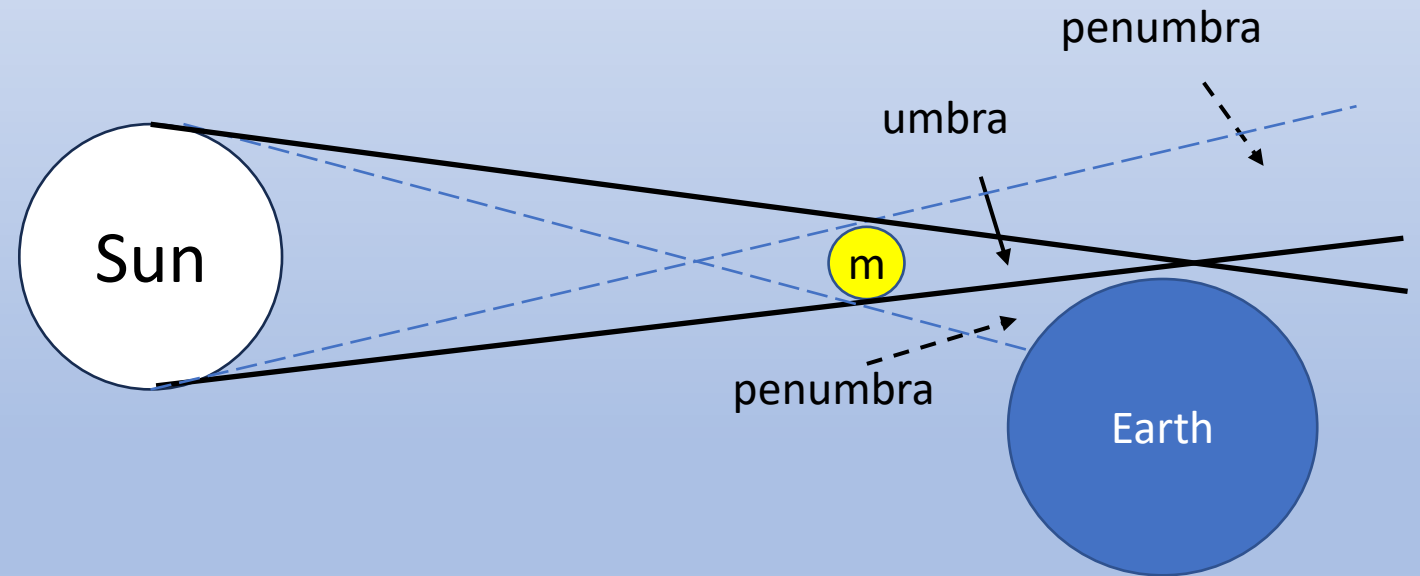
What Causes Eclipses?



- **Solar eclipses**: the Moon moves in front of the Sun, casting its shadow on the Earth. This can happen only at New Moon.
- **Lunar eclipses**: the Moon moves through the Earth's shadow. This can happen only at Full Moon.

Partial Only Solar Eclipse: Shadows & Geometries (not to scale)

Partial Only
Eclipse

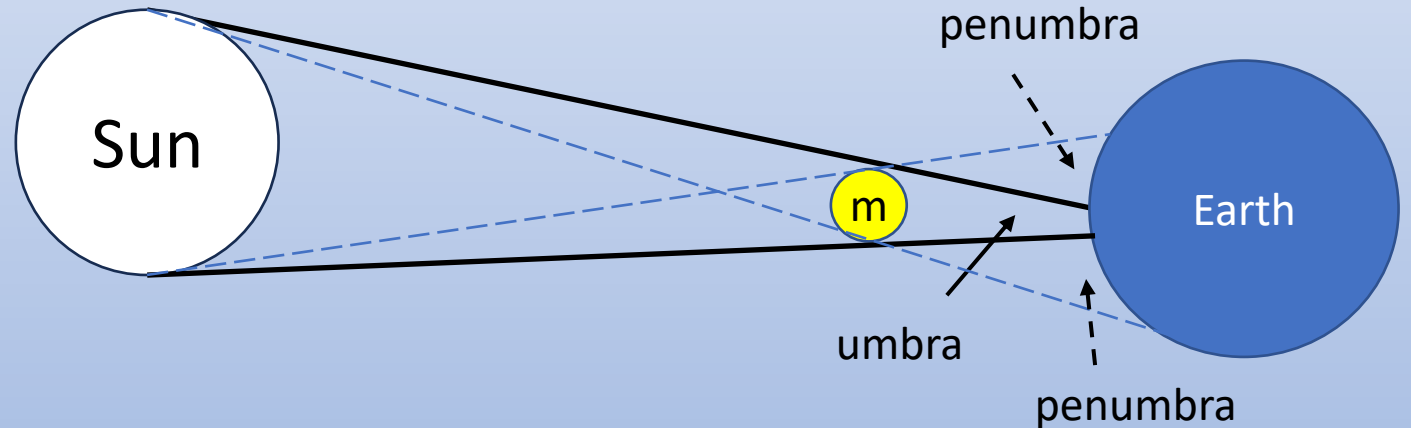
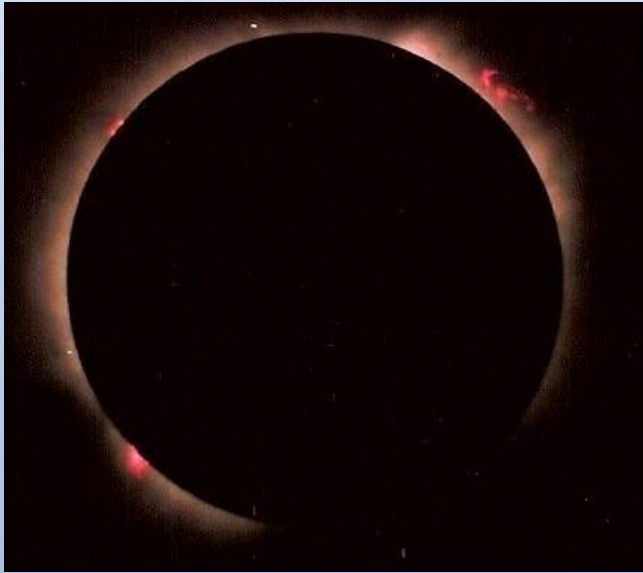


- A partial eclipses is visible from the penumbra
- The umbra (where a total eclipse is visible) passes above (or below) the Earth. There is no total eclipse

Total Solar Eclipse: Shadows & Geometries

(not to scale)

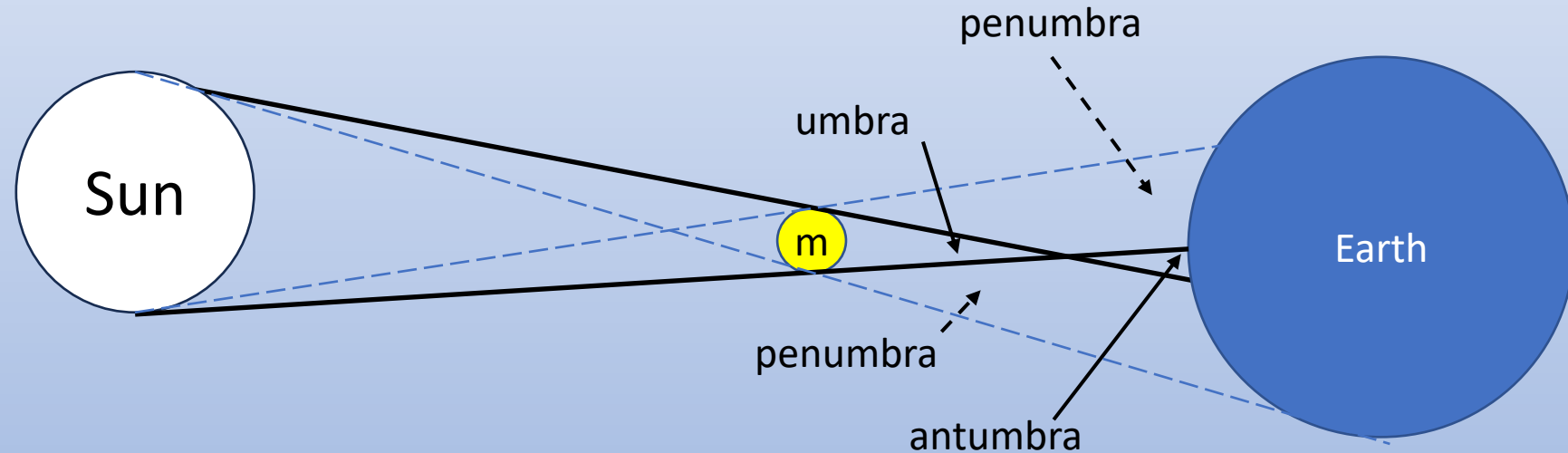
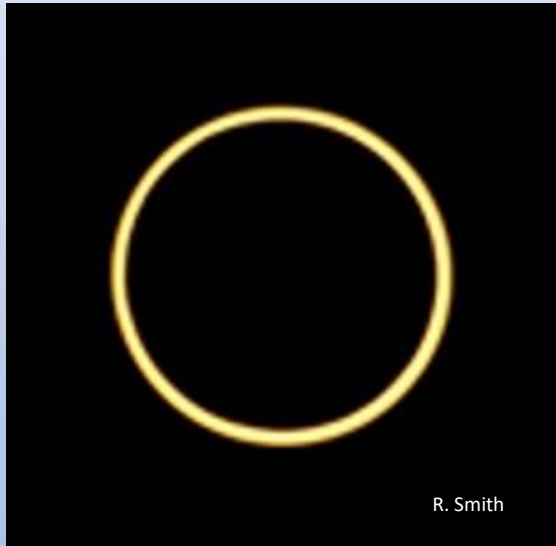
Total
Eclipse



- A partial eclipses is visible from the penumbra
- A total eclipse is visible from the umbra

Annular Solar Eclipse: Shadows & Geometries (not to scale)

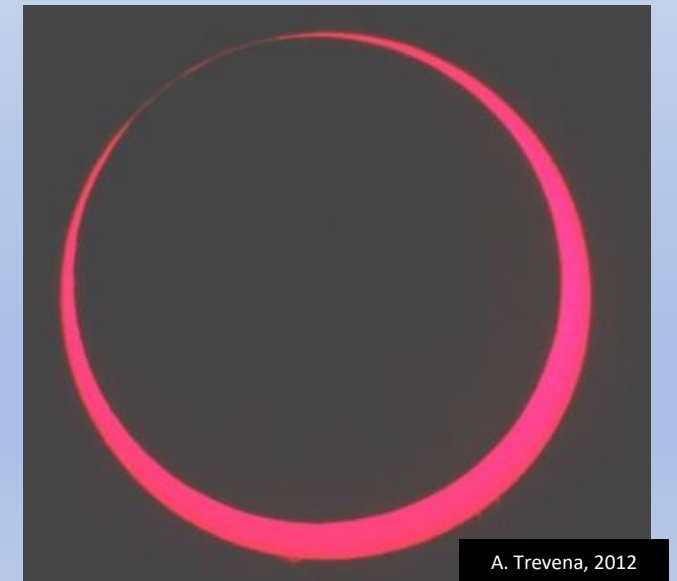
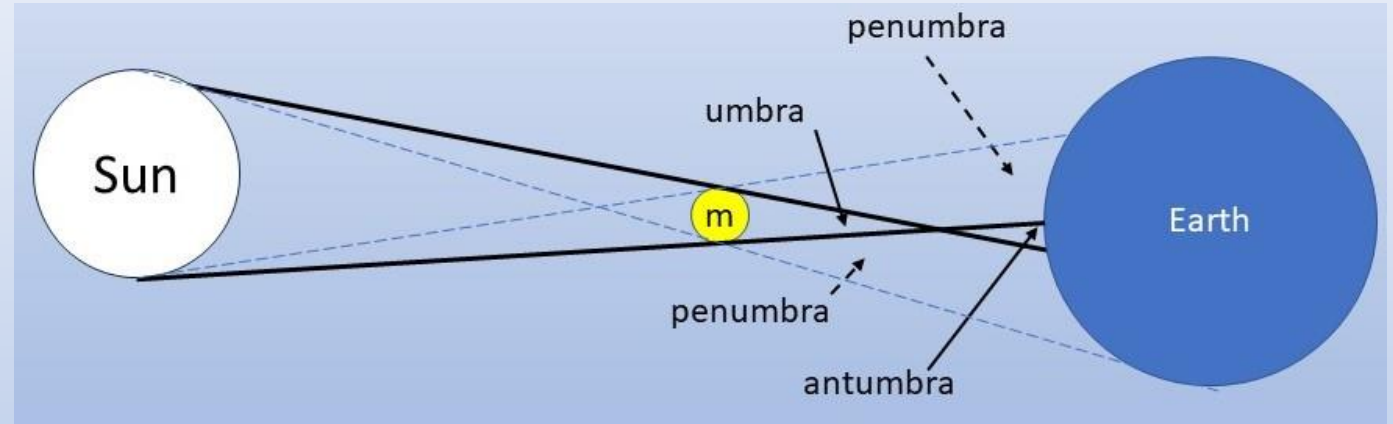
Annular Eclipse



- A partial eclipses is visible from the penumbra
- An annular (“ring-of-fire”) eclipse is visible from the antumbra
- The umbra falls short of Earth, so no total eclipse occurs

Why do Annular Eclipses Happen?

- Moon's umbral shadow can fall short of the Earth's surface (by more than 20,000 miles!).
- Highly elliptical orbit of the Moon.
- On average, the Moon is too far away and appears too small to block the Sun completely. Lunar diameter appears 14% smaller at apogee than at perigee.
- Secondary influence: Earth's elliptical orbit about the Sun (the Sun appears 3% larger when Earth is near perihelion in January than when at aphelion in early July).



Surprising (?) Facts About Solar Eclipses

- Solar eclipses are **not rare** – there must be at least 2 each year somewhere on Earth!
- There can be as many as 5 solar eclipses in a year (e.g., 1935)!
- Partial solar eclipses are seen over large areas (8 visible from Montrose, 2000-2024!)
- Solar eclipses are (slightly) more frequent than lunar eclipses
- Annular eclipses are (slightly) more frequent than total solar eclipses
- Paths of annularity (or totality) are narrow (generally < 320 miles wide). But they can be many thousands of miles long
- Annularity and totality are short (< 12m:31s for annularity, < 7m:32s for totality)
- Solar eclipse in 1919 - provided first test of Einstein's General Relativity

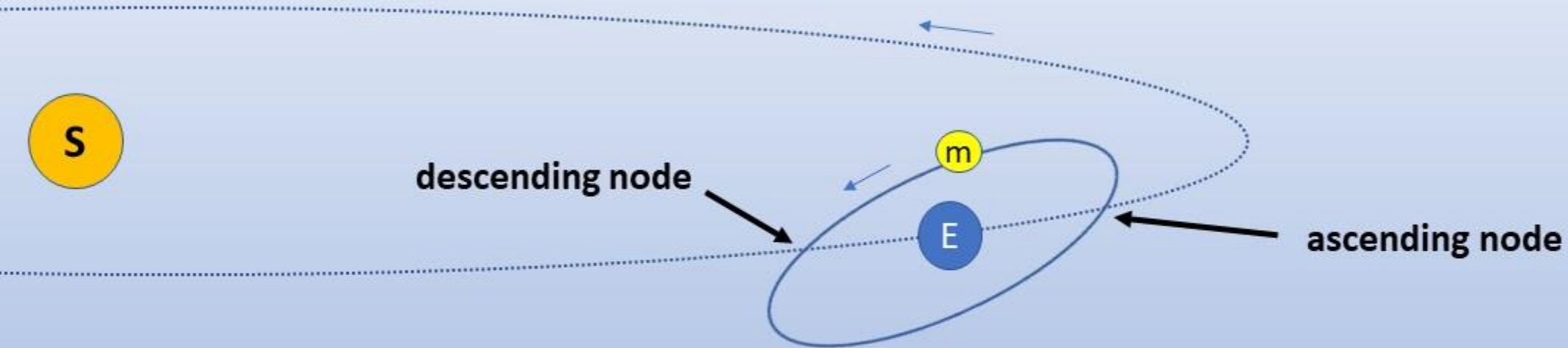
<u>20th Cent.</u>	<u>21st Cent.</u>	<u>Eclipse Type</u>
78	77	partial only
73	72	annular
71	68	total
6	7	annular-total hybrid
<u>228</u>	<u>224</u>	<u>Sum (No. of solar eclipses)</u>

Source: NASA Five Millenium Catalog of Solar Eclipses



Solar Eclipse Periodicity:

Why Don't Eclipses Happen at New Moon Each Lunar Month?



- The Moon's orbit is inclined 5 degrees from Earth' orbit about the Sun
- Those orbital planes intersect at “lunar nodes”
- Solar eclipses can occur only when new Moon occurs within about 15° of a node. Periods around the nodal crossings are called eclipse seasons. These are centered 173 days apart and last for +/- 15 to 18 days.

Predicting Eclipses

- Eclipse Seasons: Every 173 days (30 to 36 days long)
- Saros Cycle: 6585.32 days (18 years + 11.32 days)

Modern eclipse predictions:

- Printed Canons & Other Publications
- Sky & Telescope and Astronomy Magazines

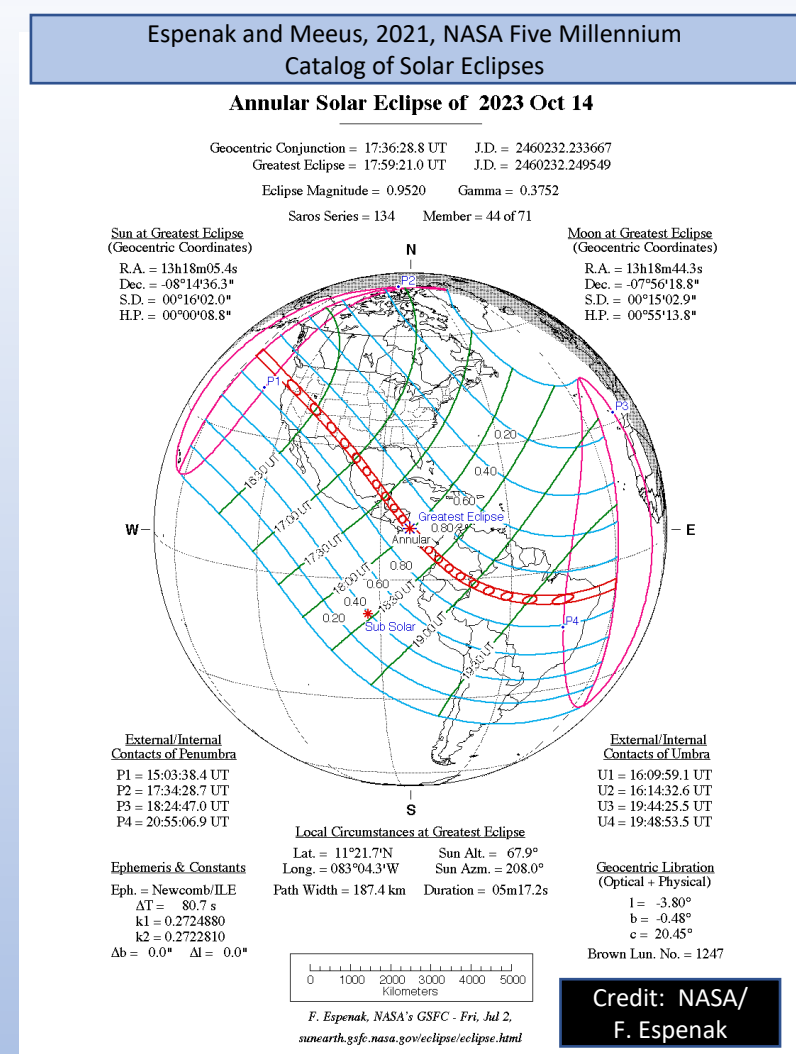
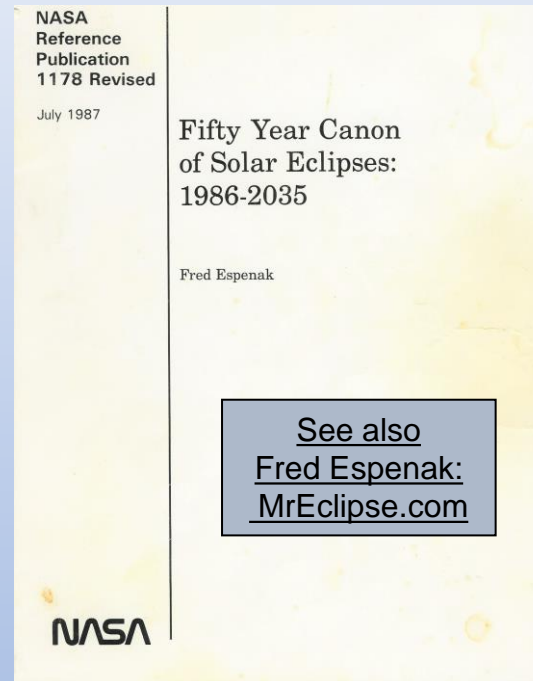
- Websites:

<https://eclipse.gsfc.nasa.gov/SEcat5/catalog.html>

<https://www.greatamericaneclipse.com/>

<https://eclipsophile.com>

http://xjubier.free.fr/en/site_pages/Solar_Eclipses.html



Safe Viewing: Partial & Annular Phases of Solar Eclipses

Never View
the Sun
Directly!

melted
cross-hairs!

Your Guide to the
Great Solar Eclipse
of 1991

Joe Rao

pin-hole
projection

colander
projection

telescope
projection

Credit:
Laura and David
Gillenwater

"Sunspotter"
telescope
projection

"eclipse glasses"
(black polymer)

#14 welder's
glass

aluminized
glass or mylar

white
light

H-
alpha

full aperture
filters

EAA, Credit: Bryan Cashion

Binoculars!

(with safe solar filters)



“standard binoculars”
with safe, “full aperture”
solar filters

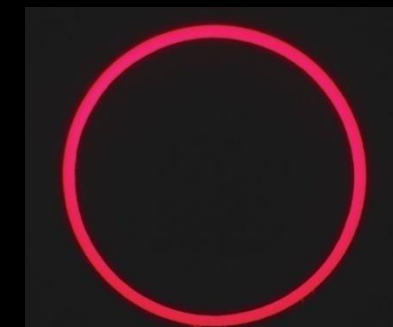


“Mini-SUNoculars 6X30”
with built-in, safe solar filters for
partial phases of central eclipses
& annular eclipses
not useful for totality
(marketed by Lunt Solar Systems)

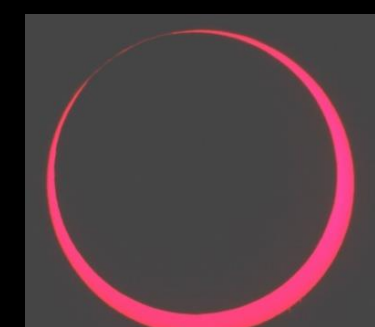
First Contact



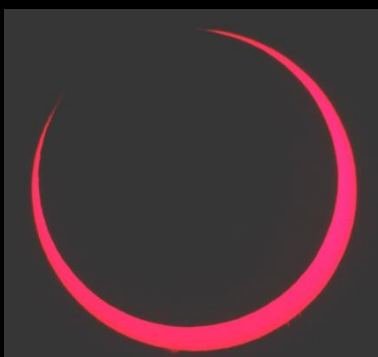
Second Contact



Mid Annularity



Third Contact



Sunset

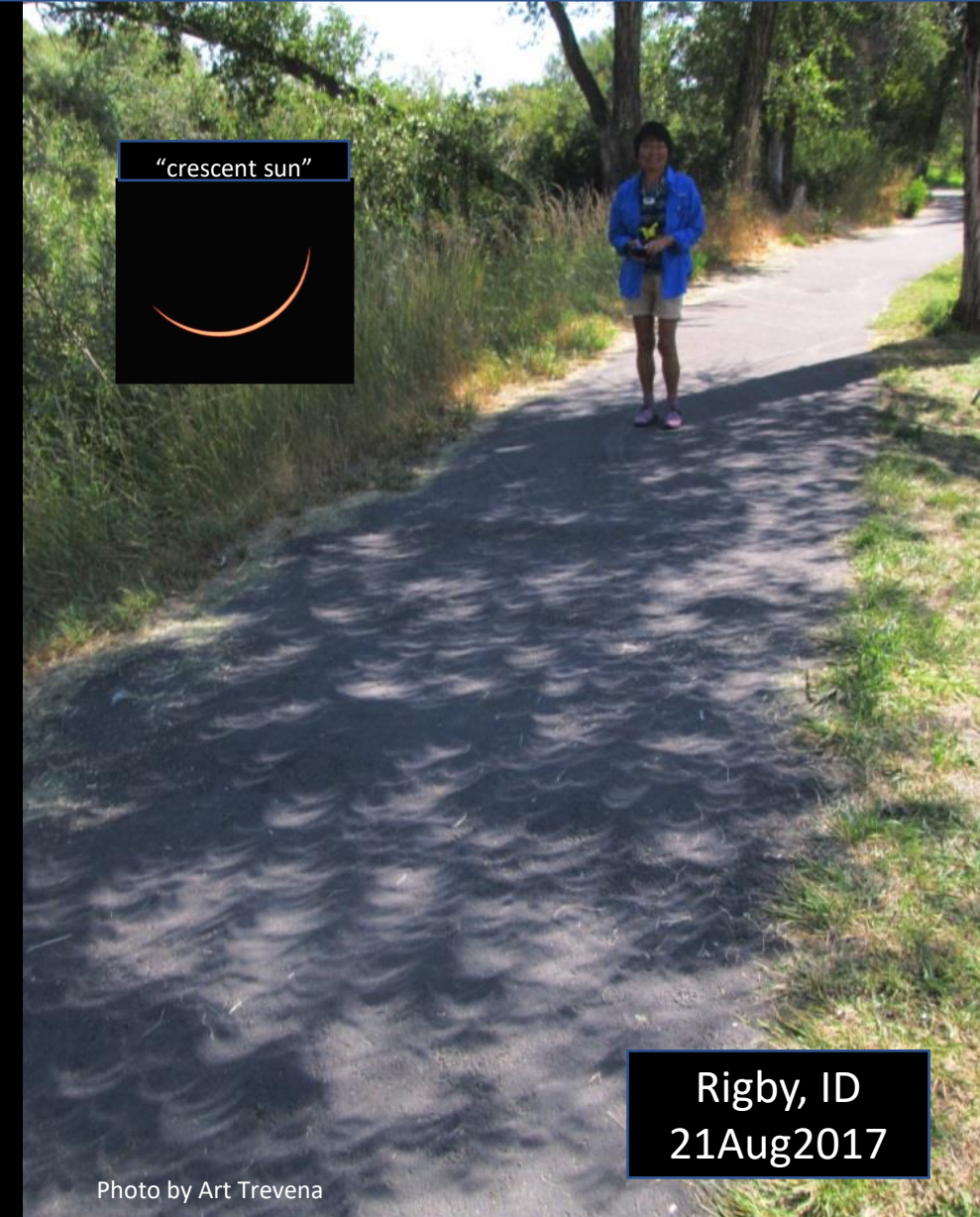
Annular Eclipse Progression, May 20, 2012, from southern Utah
with hydrogen alpha filter. From 40 miles east of Kanab, Utah. Sun is setting in last frame.
by Art Trevena and Joyce Tanihara.



Early Partial Phase of
a Central Eclipse

Credit: Art Trevena,
Aug. 21, 2017

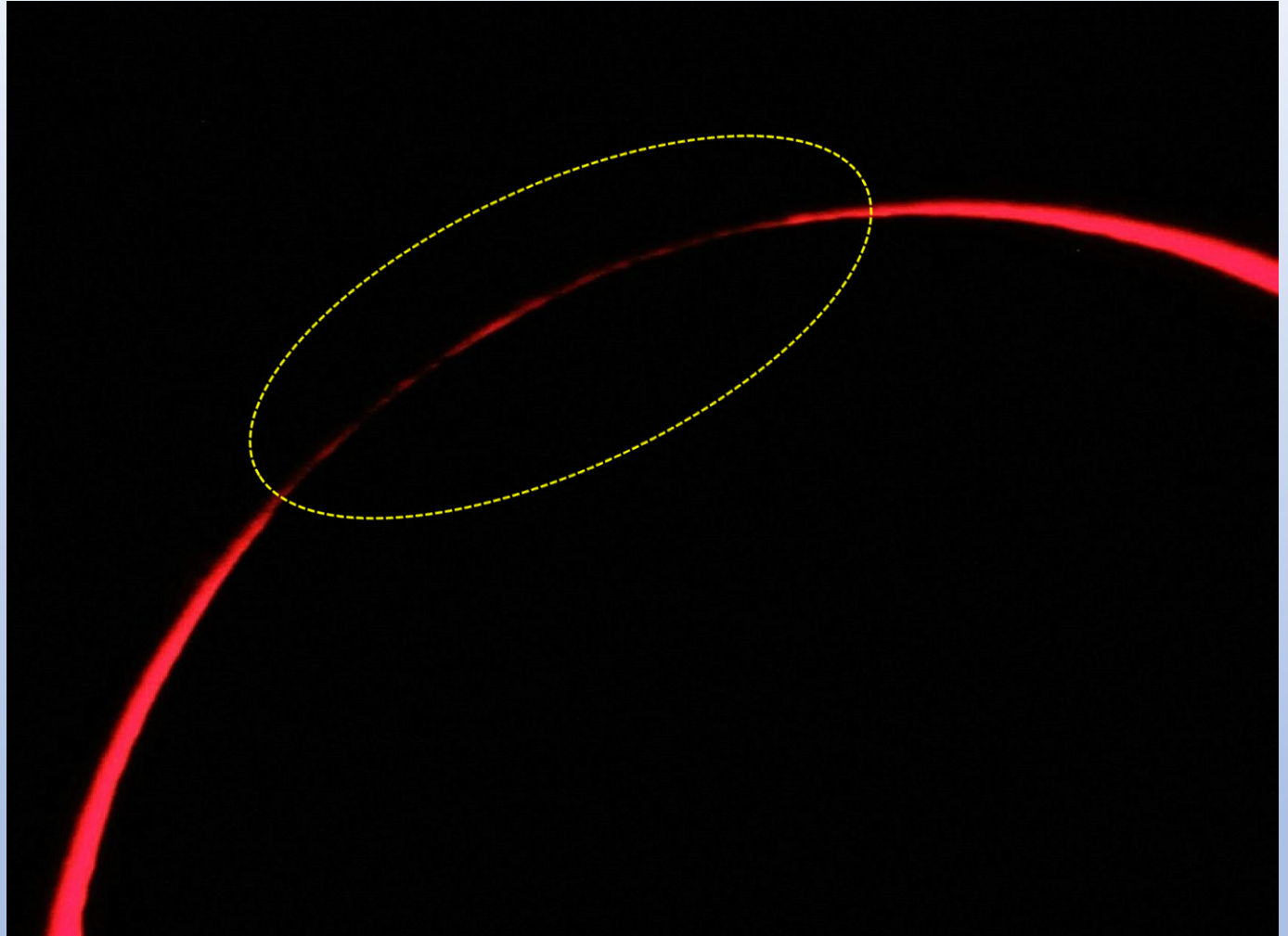
Partial/Annular Eclipse Phenomena: Fading light, sharp shadows, deep blue sky with “steely-gray metallic cast” to landscape, and “projected solar crescents”



Baily's Beads During Solar Eclipses

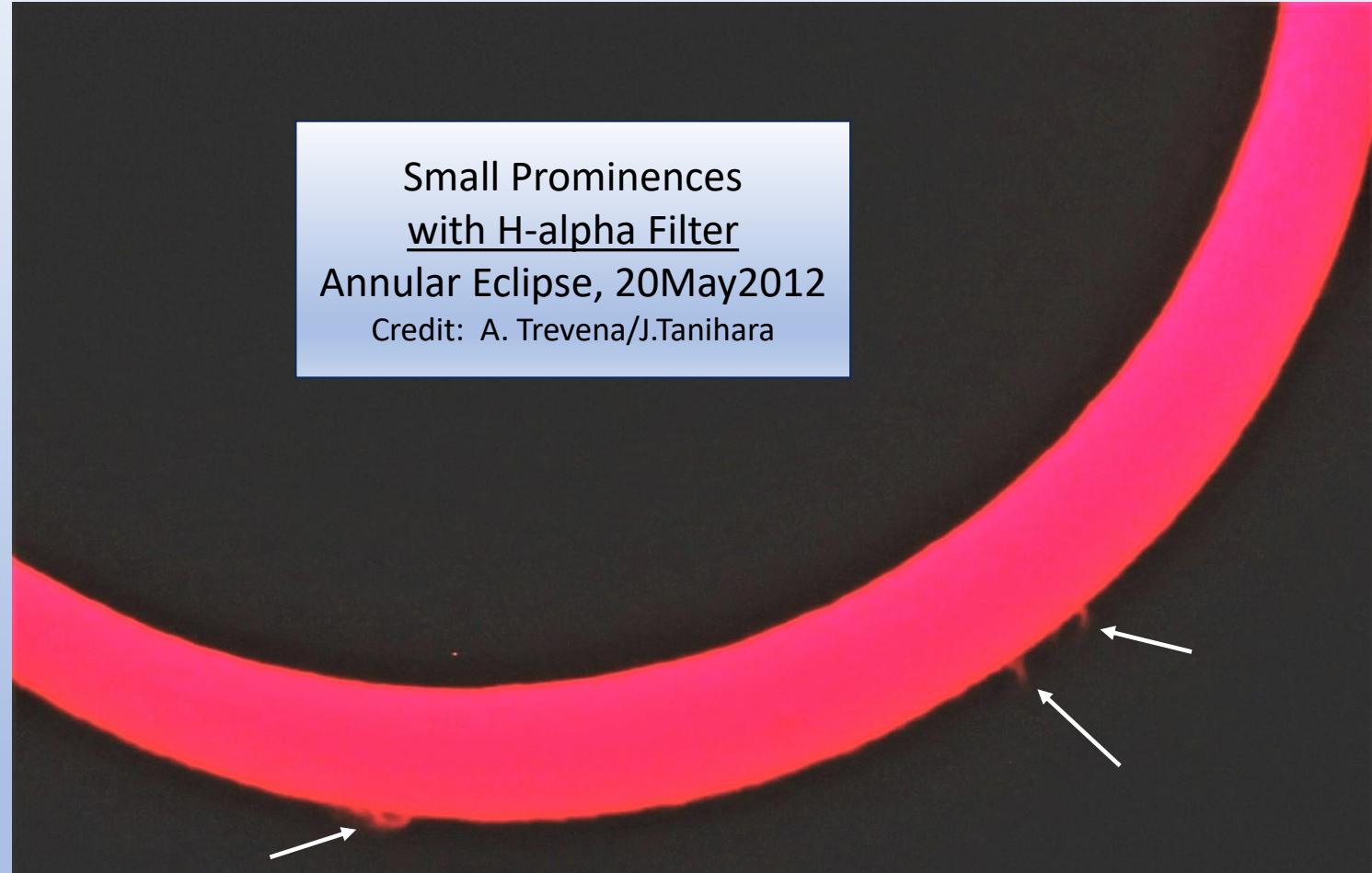
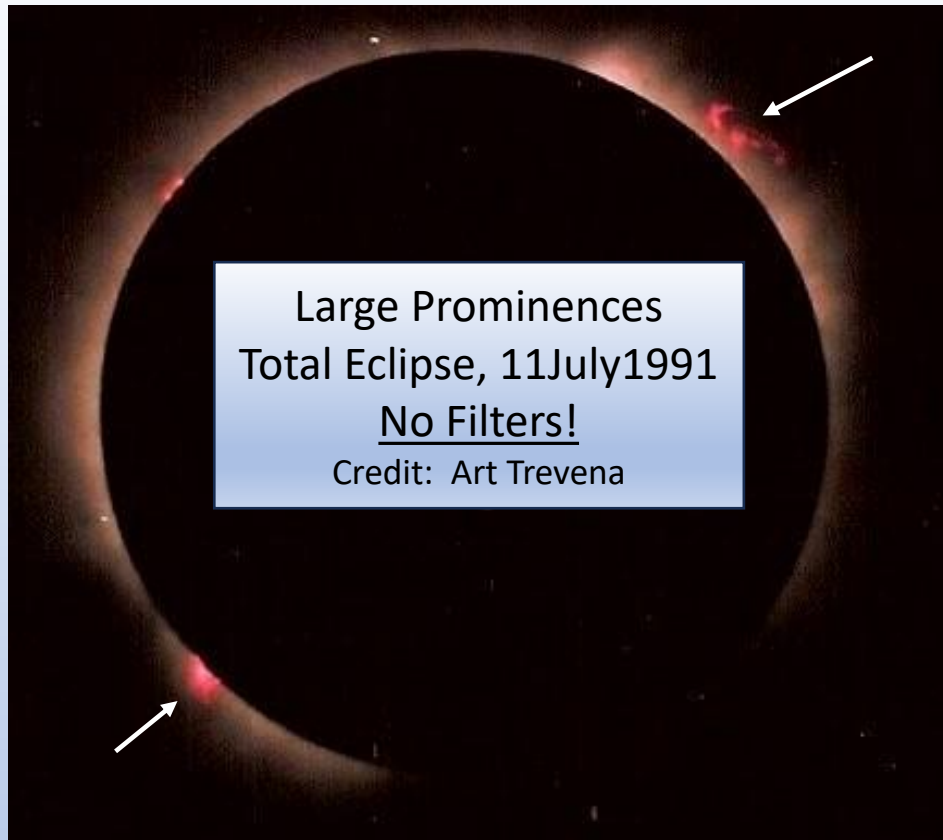


Baily's Beads at Second Contact of a Total Solar Eclipse
August 21, 2017 from Madras, Oregon
Credit: NASA/Aubrey Gemignani



Baily's Beads at Third Contact, May 20, 2012 Annular Eclipse
Image in H-alpha light from 40 miles east of Kanab, Utah.
Credit: Art Trevena and Joyce Tanihara

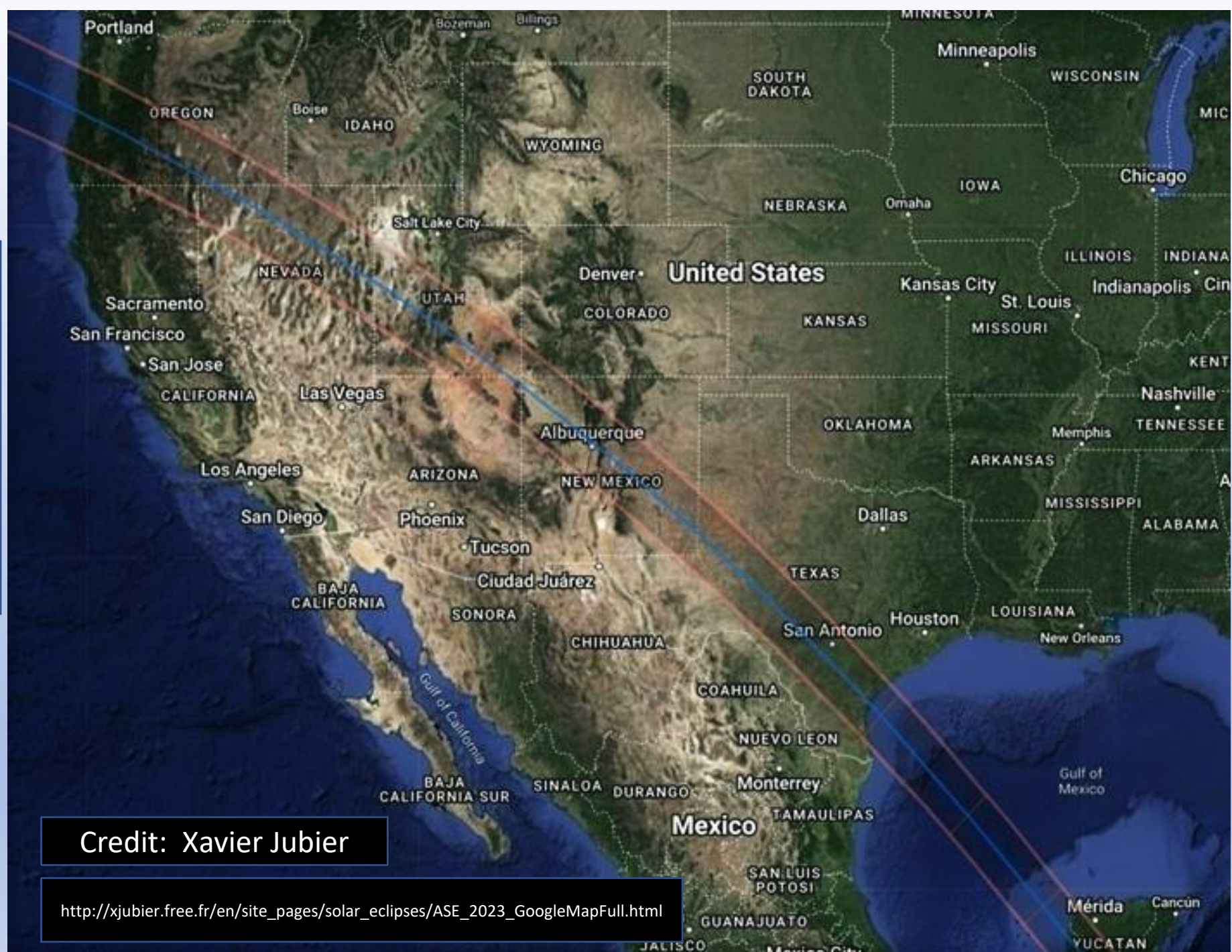
Solar Prominences



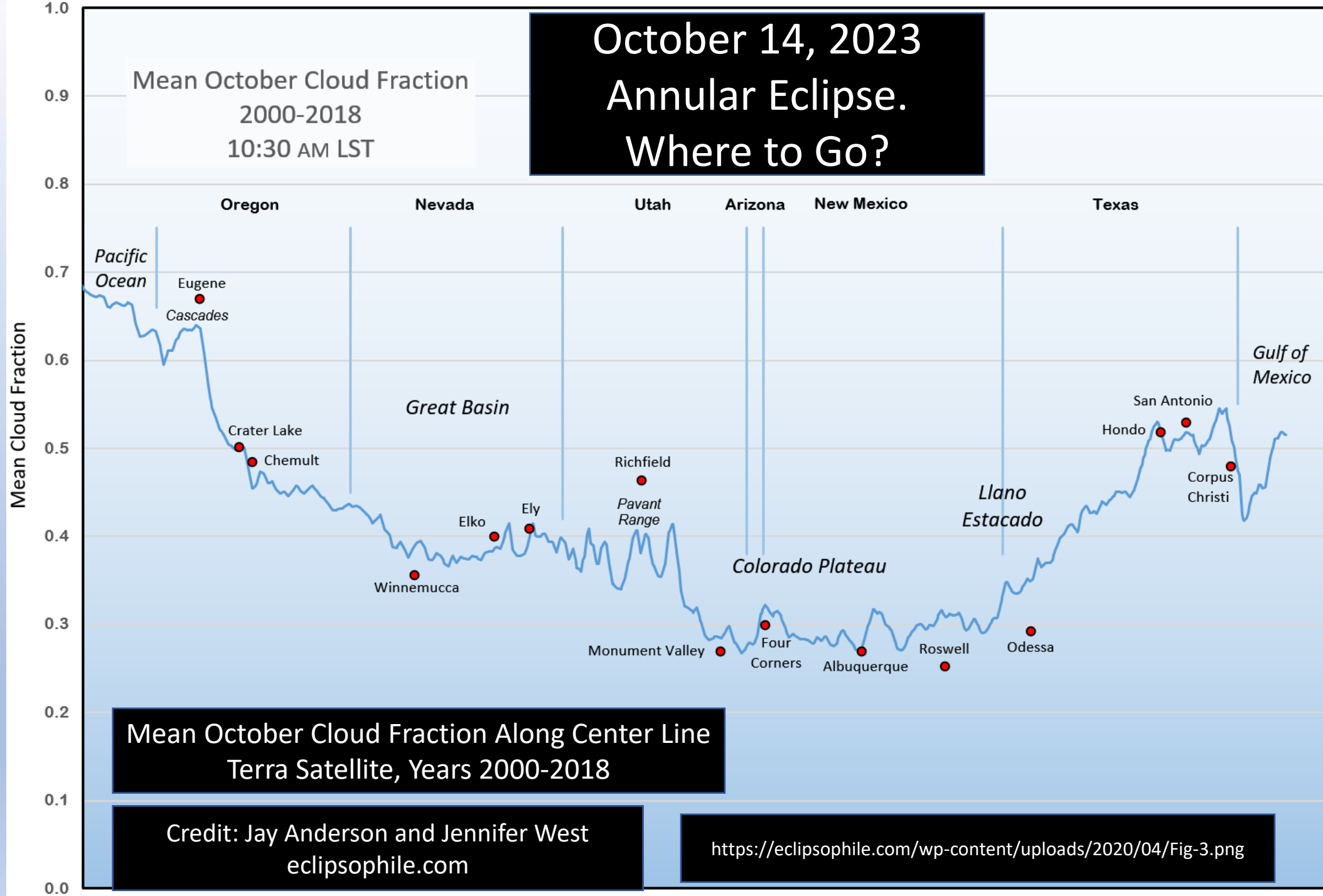


May 20, 2012 Solar Eclipse
Late Partial Phase after Annularity
from 40 miles east of Kanab, Utah
Photo credit: Joyce Tanihara

Annular
Eclipse Path
USA
October 14,
2023



October 14, 2023 Annular Eclipse. Where to Go?



Path of Annularity: Greater Four Corners Area, October 14, 2023

Credit: Xavier Jubier

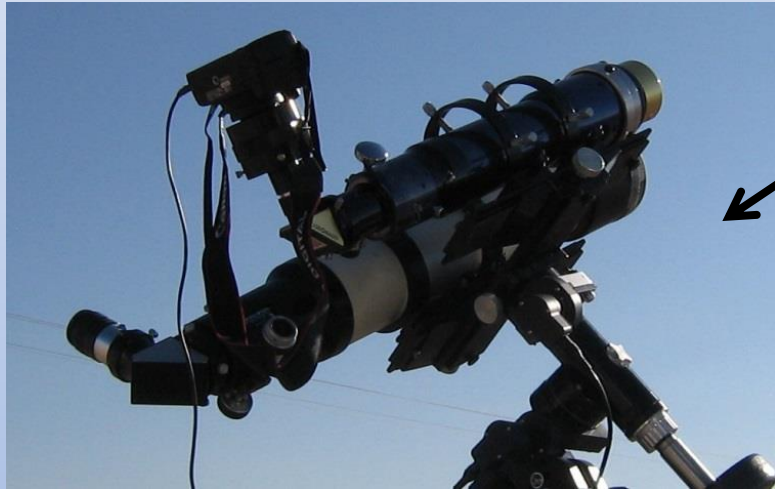
http://xjubier.free.fr/en/site_pages/solar_eclipses/ASE_2023_GoogleMapFull.html

for Four Corners

- 1st contact 9:11 AM MDT
- 2nd contact 10:30 AM MDT
- 3rd contact 10:35 AM MDT
- 4th contact 12:03 AM MDT
- Max annular phase duration 4m:41s



Annular Solar Eclipse Photography

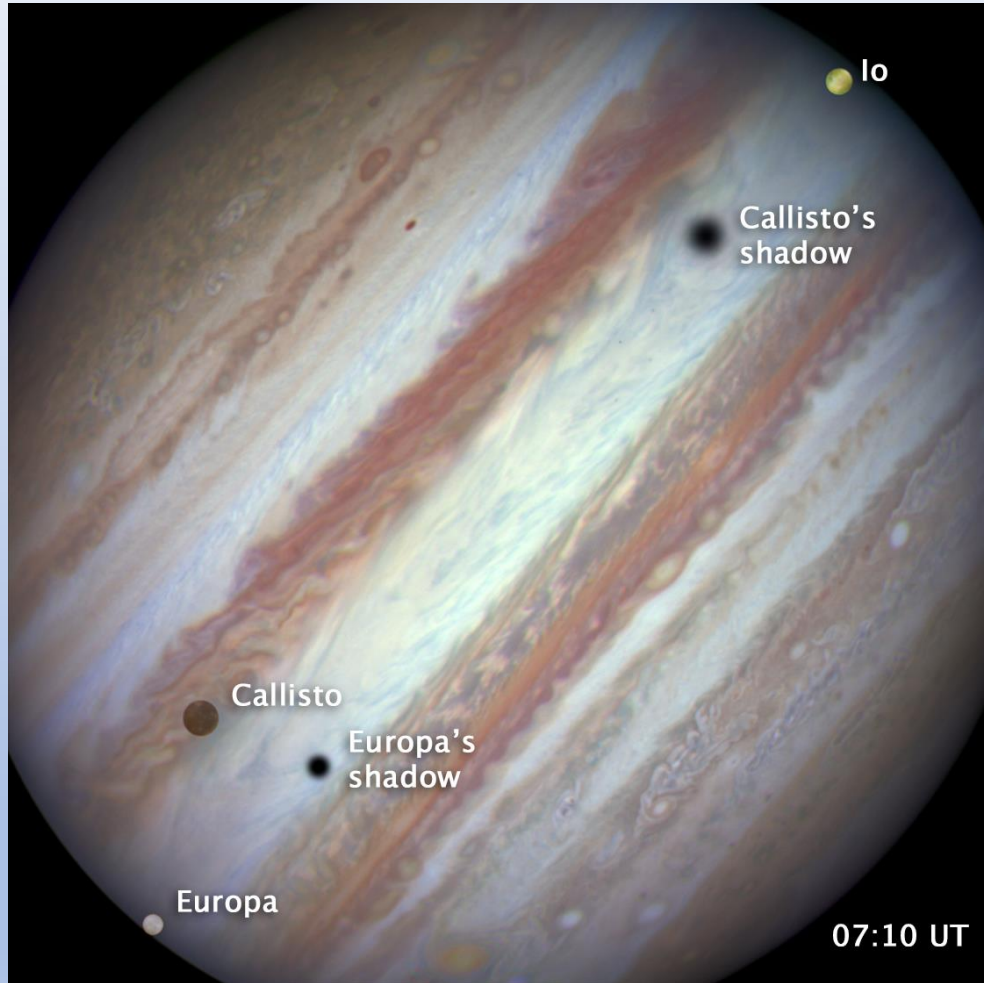


- Don't do it! ... Or keep it simple!
- Allow time for viewing eclipse!!!
- Annularity goes by **very quickly!!!**
- Solar filter absolutely necessary
- Camera on tripod (or mount)
- Cable for shutter control
- Camera w/ adjustable exposures
- Bracket your exposures
- Practice your plan before the eclipse!

Solar Eclipse Exposure Guide (F. Espenak)

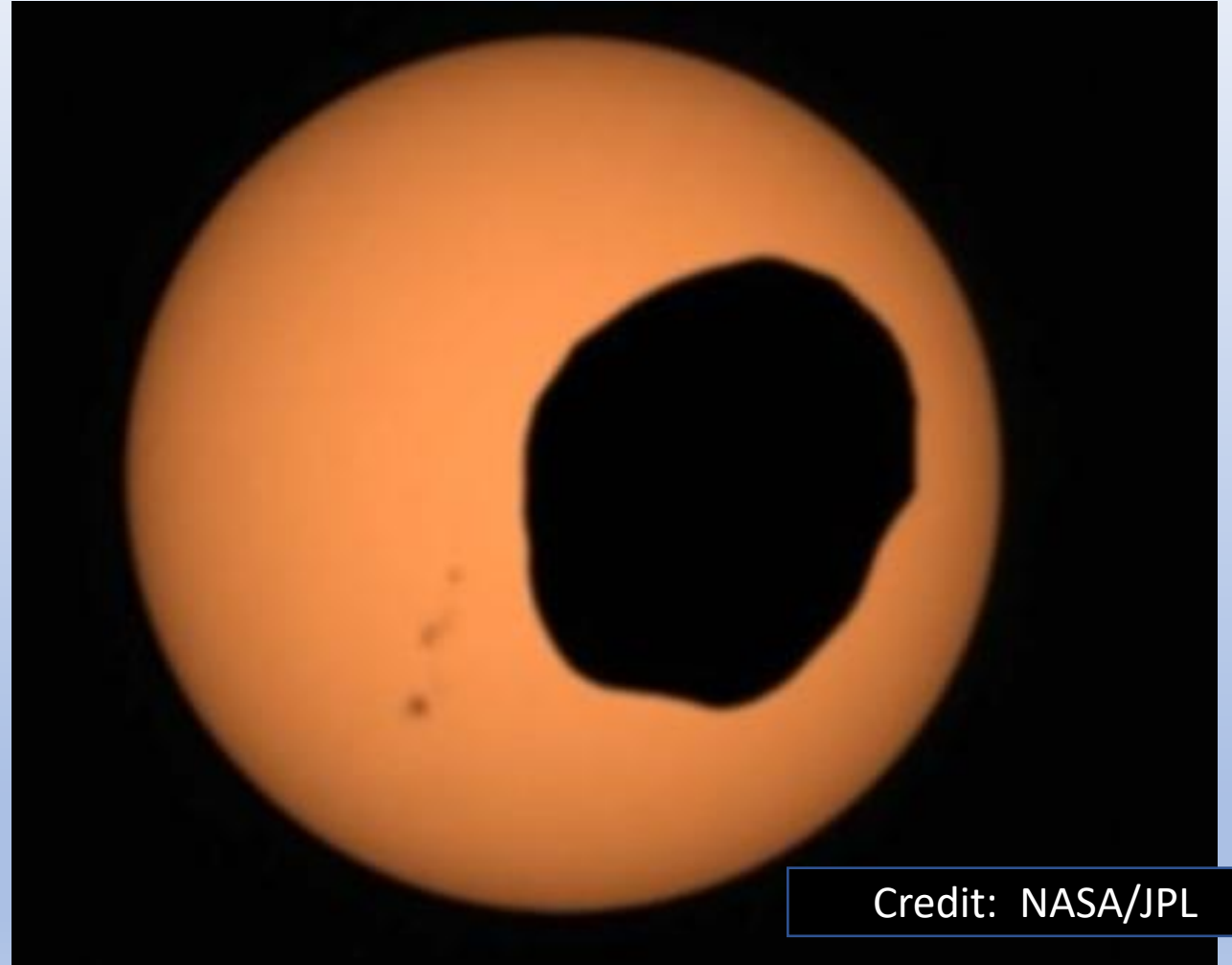
<http://www.mreclipse.com/SEphoto/SEphoto.html>

Simultaneous Solar Eclipses on Jupiter! (23Jan2015)



Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA).

Solar Eclipse on Mars by Phobos (2Apr2022) from Perseverance Rover



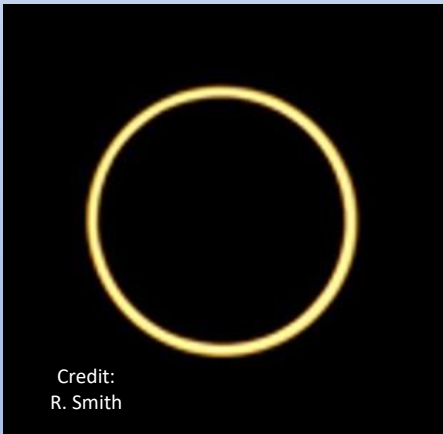
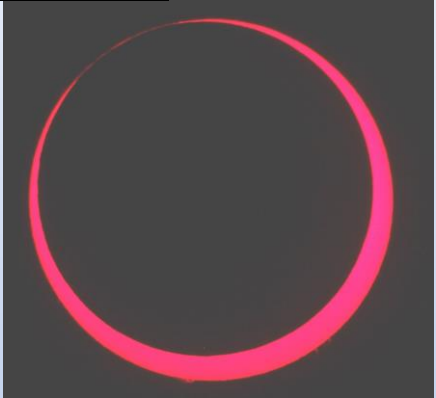
Credit: NASA/JPL

<https://youtu.be/aKK7vS2CHC8>

Future Annular Eclipses on Earth

After October 14, 2023 – none is U. S. A. for 16 years!

Credit:
Trevena/Tanihara



<u>Date</u>	<u>Location</u>
14-Oct-2023	western USA, Central and South America
2-Oct-2024	Pacific Ocean, southern Chile & Argentina
17-Feb-2026	Antarctica, southern Indian Ocean
6-Feb-2027	E Pacific Ocean, S Chile & Argentina, Atlantic Ocean
26-Jan-2028	N South America, Atlantic Ocean, Portugal, Spain
1-Jun-2030	northern Africa to Asia
21-May-2031	Africa, Indian Ocean, India, Thailand/Malaysia, Indonesia
14-Nov-2031	Pacific Ocean (<u>annular/total hybrid eclipse</u>)
9-May-2032	southernmost Atlantic Ocean
12-Sep-2034	Pacific Ocean, South America, Atlantic Ocean
9-Mar-2035	New Zealand, Pacific Ocean

Next annular eclipses in U.S.A.:

- 21-Jun-2039 – Alaska
- 5-Feb-2046 - California, Oregon, Nevada, Idaho

Total Solar Eclipse of 2024 Apr 08

Geocentric Conjunction = 18:36:02.5 UT J.D. = 2460409.275029
Greatest Eclipse = 18:17:13.1 UT J.D. = 2460409.261957

Eclipse Magnitude = 1.0565 Gamma = 0.3432

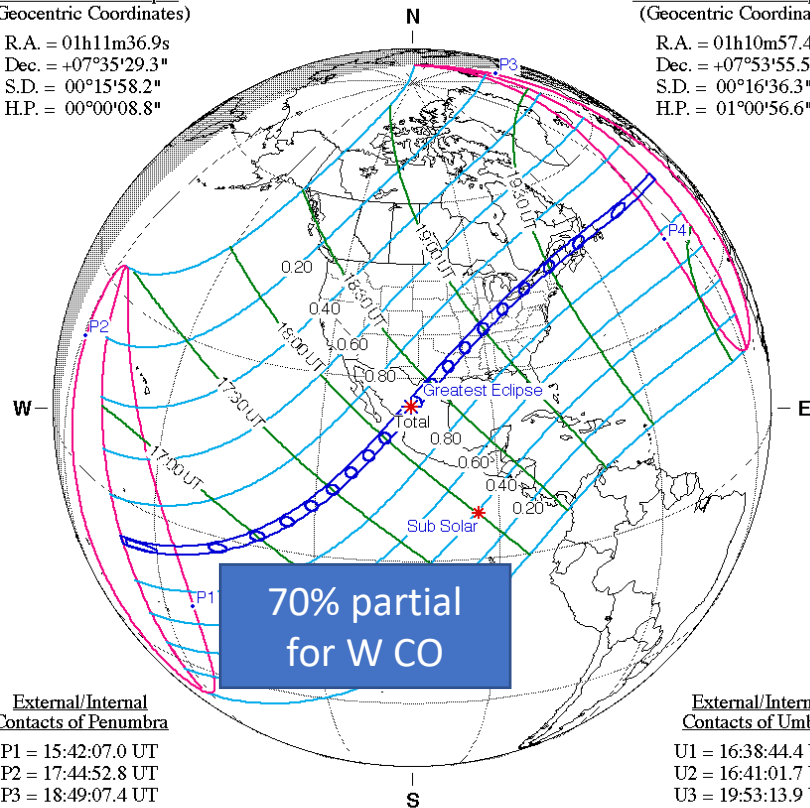
Saros Series = 139 Member = 30 of 71

Sun at Greatest Eclipse (Geocentric Coordinates)

R.A. = 01h11m36.9s
Dec. = +07°35'29.3"
S.D. = 00°15'58.2"
H.P. = 00°00'08.8"

Moon at Greatest Eclipse (Geocentric Coordinates)

R.A. = 01h10m57.4s
Dec. = +07°53'55.5"
S.D. = 00°16'36.3"
H.P. = 01°00'56.6"



External/Internal Contacts of Penumbra

P1 = 15:42:07.0 UT
P2 = 17:44:52.8 UT
P3 = 18:49:07.4 UT
P4 = 20:52:13.8 UT

External/Internal Contacts of Umbra

U1 = 16:38:44.4 UT
U2 = 16:41:01.7 UT
U3 = 19:53:13.9 UT
U4 = 19:55:29.1 UT

Local Circumstances at Greatest Eclipse

Lat. = 25°17.5'N Sun Alt. = 69.8°
Long. = 104°07.2'W Sun Azm. = 149.4°
Path Width = 197.5 km Duration = 04m28.1s

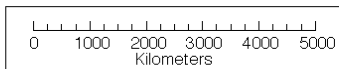
Ephemeris & Constants

Eph. = Newcomb/ILE
 $\Delta T = 81.2$ s
 $k1 = 0.2724880$
 $k2 = 0.2722810$
 $\Delta b = 0.0''$ $\Delta l = 0.0''$

Geocentric Libration (Optical + Physical)

$l = 2.00^\circ$
 $b = -0.46^\circ$
 $c = -20.75^\circ$

Brown Lun. No. = 1253

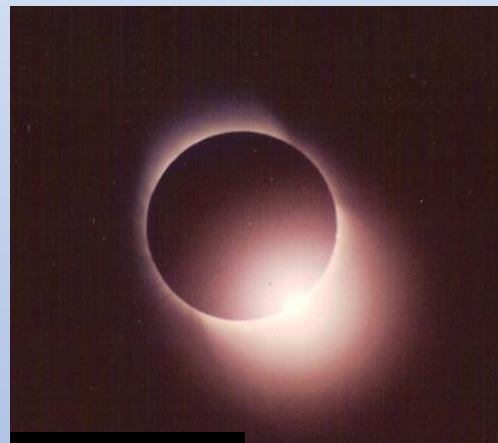


F. Espenak, NASA's GSFC - Fri, Jul 2,

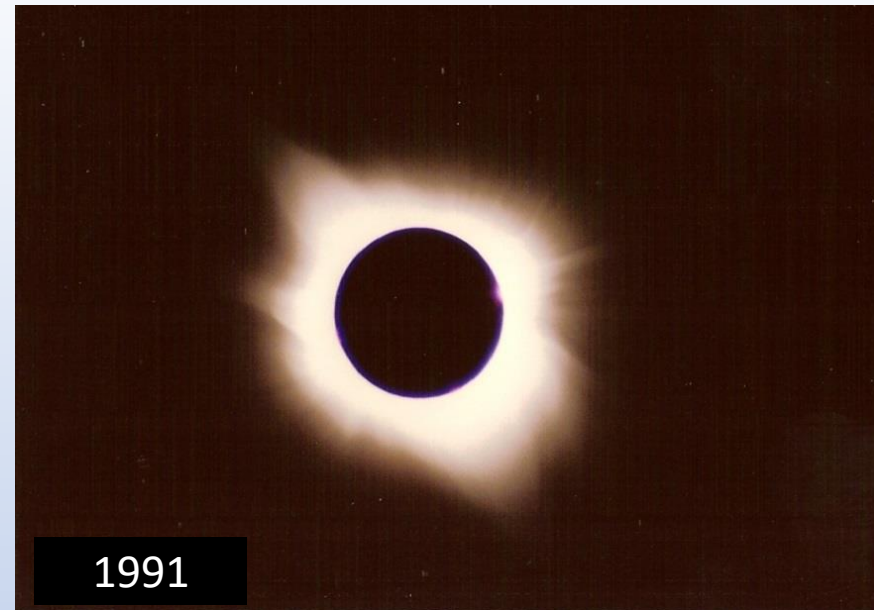
sunearth.gsfc.nasa.gov/eclipse/eclipse.html

APRIL 8, 2024

TOTAL SOLAR ECLIPSE!



1994



1991



1998

Photos by Art Trevena

Why Travel to See a Total Solar Eclipse?

“Some people see a partial eclipse and wonder why others talk so much about a total eclipse. Seeing a partial eclipse and saying that you have seen an eclipse is like standing outside an opera house and saying that you have seen the opera; in both cases, you have missed the main event.”

Prof. Jay Pasachoff, 1983



7/11/1991, Mexico



8/21/2017, Idaho, DSSN 63

“... a vision magnificent beyond description.”

General Albert. J. Myer, 1869, co-founder, National Weather Service



2/26/1979, Montana, DSSN 153

DSSN = Daily Sunspot Number,
Royal Observatory of Belgium

Photos by Art Trevena



7/11/1991, Mexico, DSSN 235



11/3/1994, Chile, DSSN 56



2/26/1998, Curacao, DSSN 56

Total Solar Eclipse Phenomena

Darkness in the west, moving upward toward the Sun !

“...a palpable body of darkness, rising upward in a great wall...”

Mary R. Smith, 1878

Twilight at Mid-day!

looking southeast during totality
11July1991, San Jose del Cabo

photo by “Bob S.”

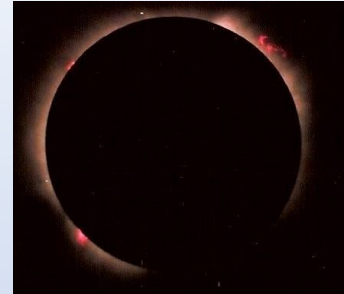
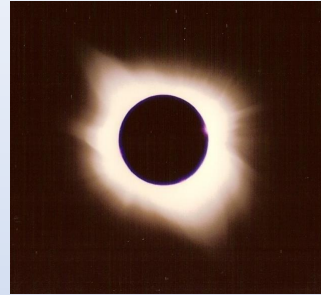
360° twilight!

Looking northwest, 11July1991.
Street lights on during totality!

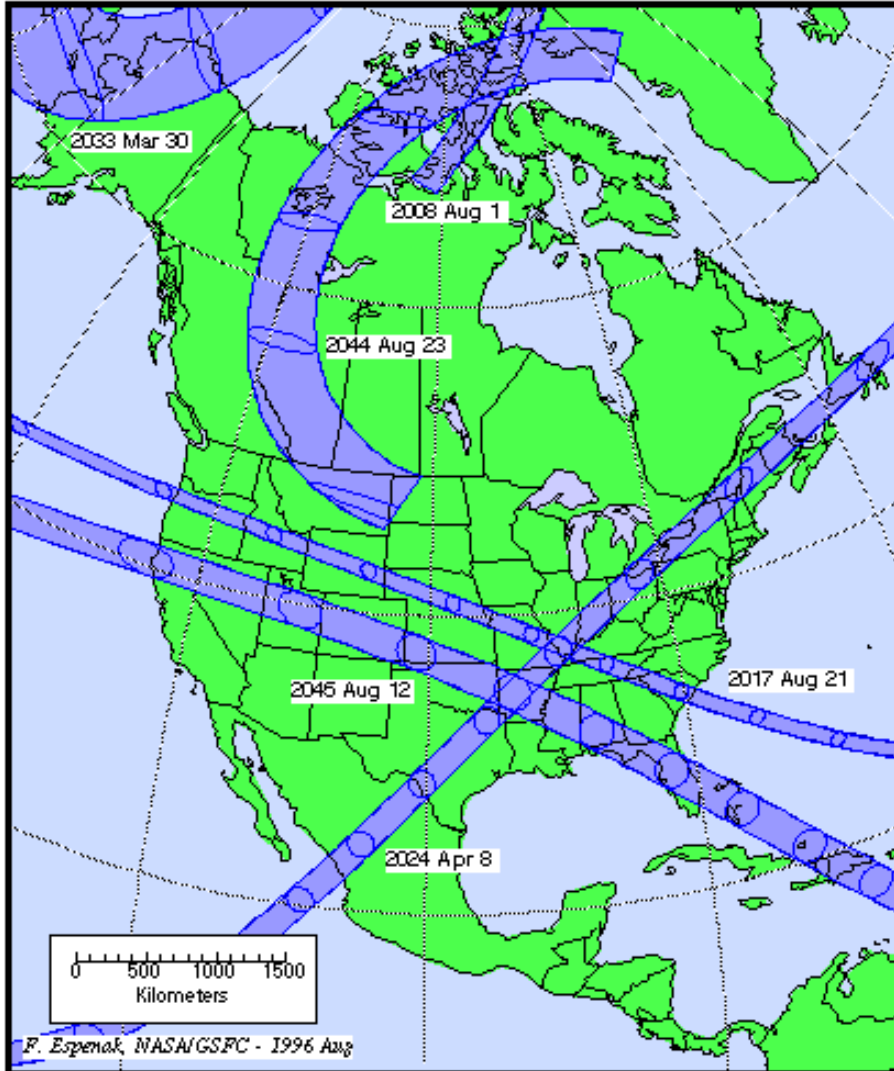
photo by “Bob S.”

Future Total Solar Eclipses for North America

...or globally...
if you just can't wait!



Total Solar Eclipses: 2001 - 2050



<u>Date</u>	<u>Location</u>
8-Apr-2024	Mexico, USA (TX to ME), southeastern Canada
12-Aug-2026	Arctic Ocean, Greenland, Iceland, Atlantic Ocean, Spain
2-Aug-2027	Atlantic Ocean, Spain, N Africa, Arabia, Somalia, Indian Ocean
22-Jul-2028	Indian Ocean, Australia, New Zealand
25-Nov-2030	Namibia, Botswana, S Africa, Indian Ocean, Australia
14-Nov-2031	central Pacific Ocean (<u>hybrid eclipse</u>)
30-Mar-2033	easternmost Siberia, W and N Alaska
20-Mar-2034	Africa, Arabia, Iran, Pakistan, China
2-Sep-2035	China, N Korea, Japan, Pacific Ocean
<u>2036 to 2043</u>	(6 total solar eclipses; but none in USA)
23-Aug-2044	Greenland, N & W Canada, Montana, North Dakota
12-Aug-2045	USA (CA to CO to FL), Caribbean, N and E South America

Be Safe,
Good Luck,
and
Happy
Eclipse
Chasing!

Questions?



Photo Credit: Joyce Tanihara
May 20, 2012