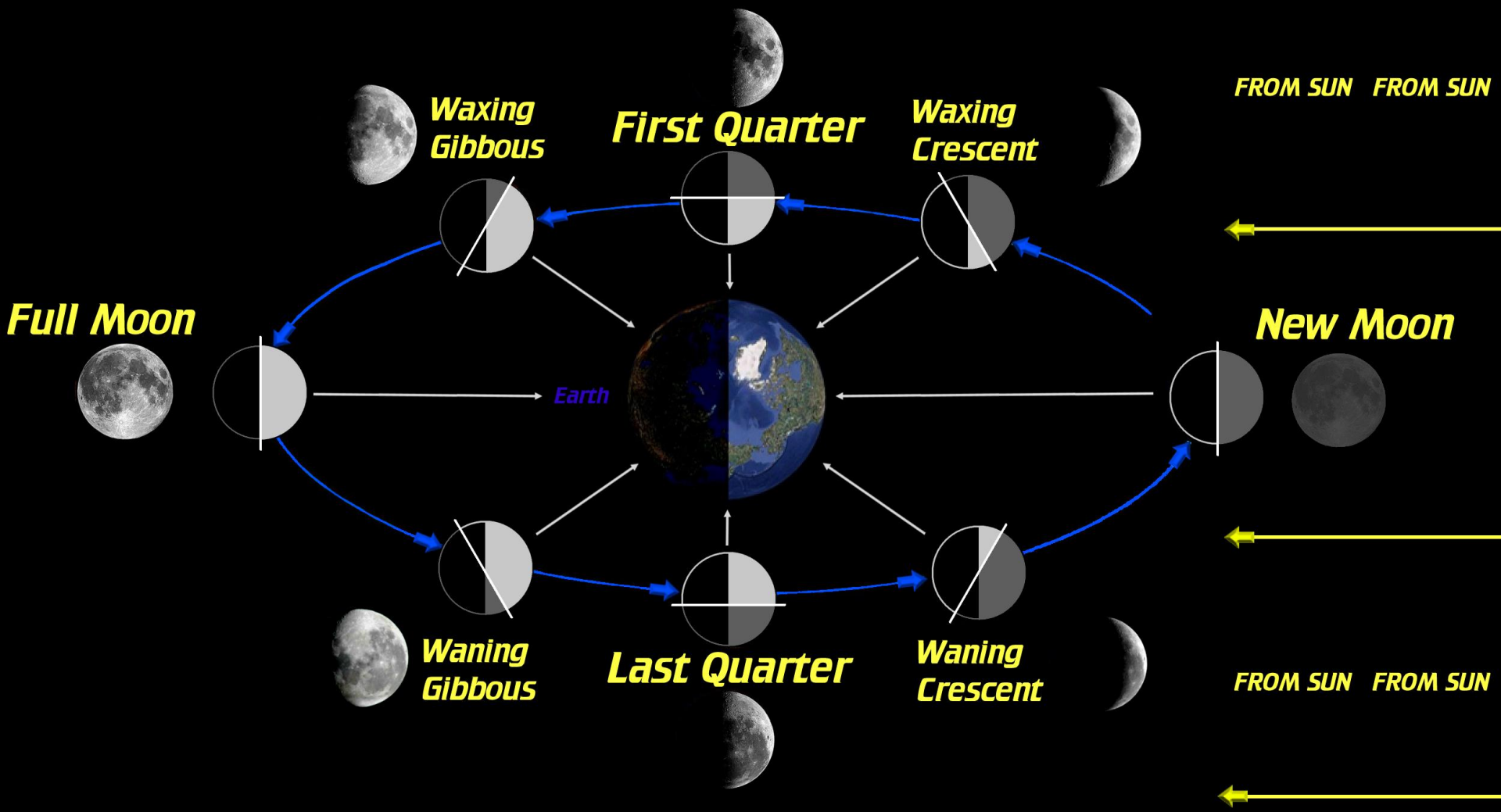
Eclipses

from Bryan Brewer, Eclipse, Inside Cover

Peter K. Detterline image

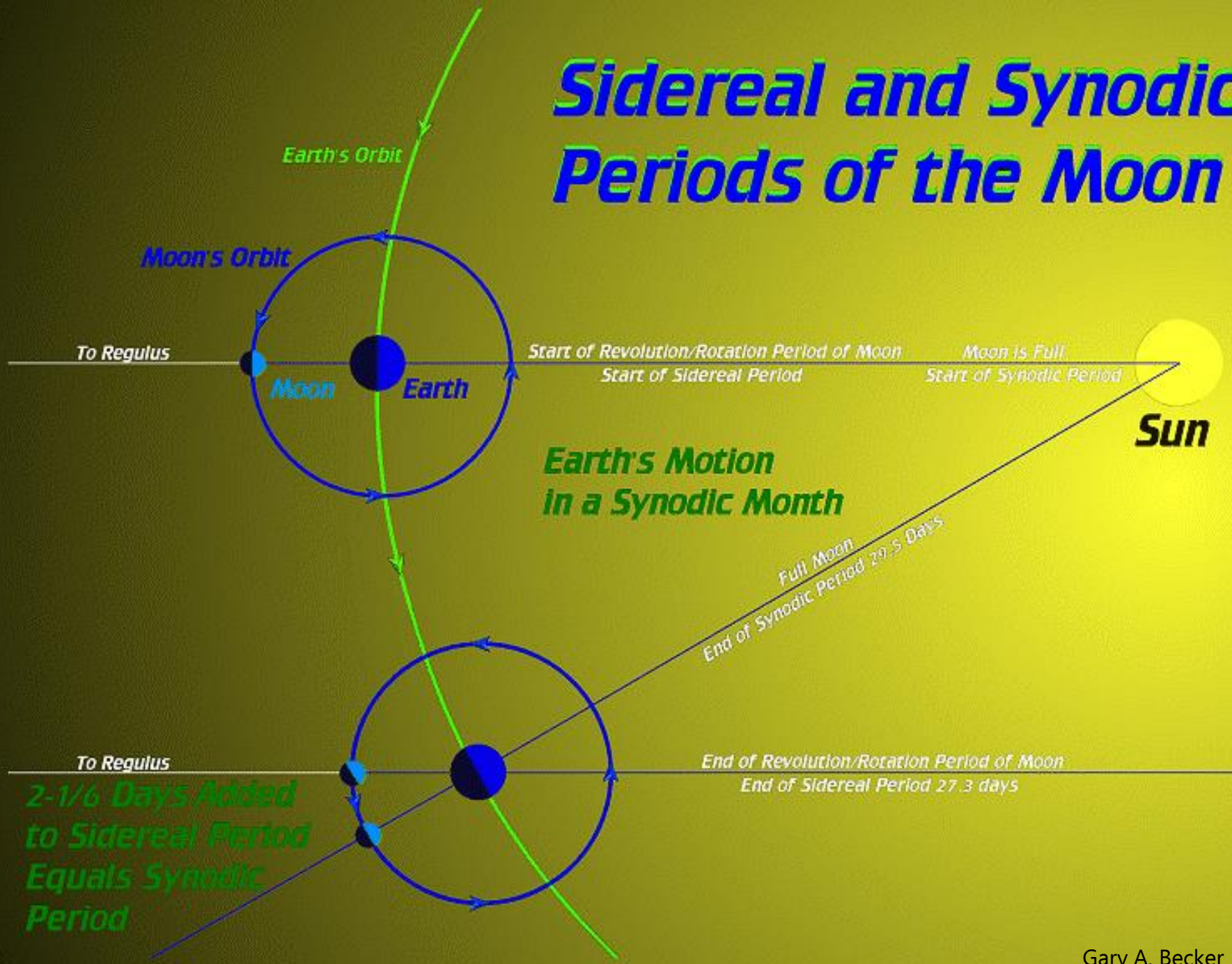
Phases of the Moon

Synodic Period of the Moon equals 29.53059 days



Gary A. Becker graphics

Sidereal and Synodic Periods of the Moon

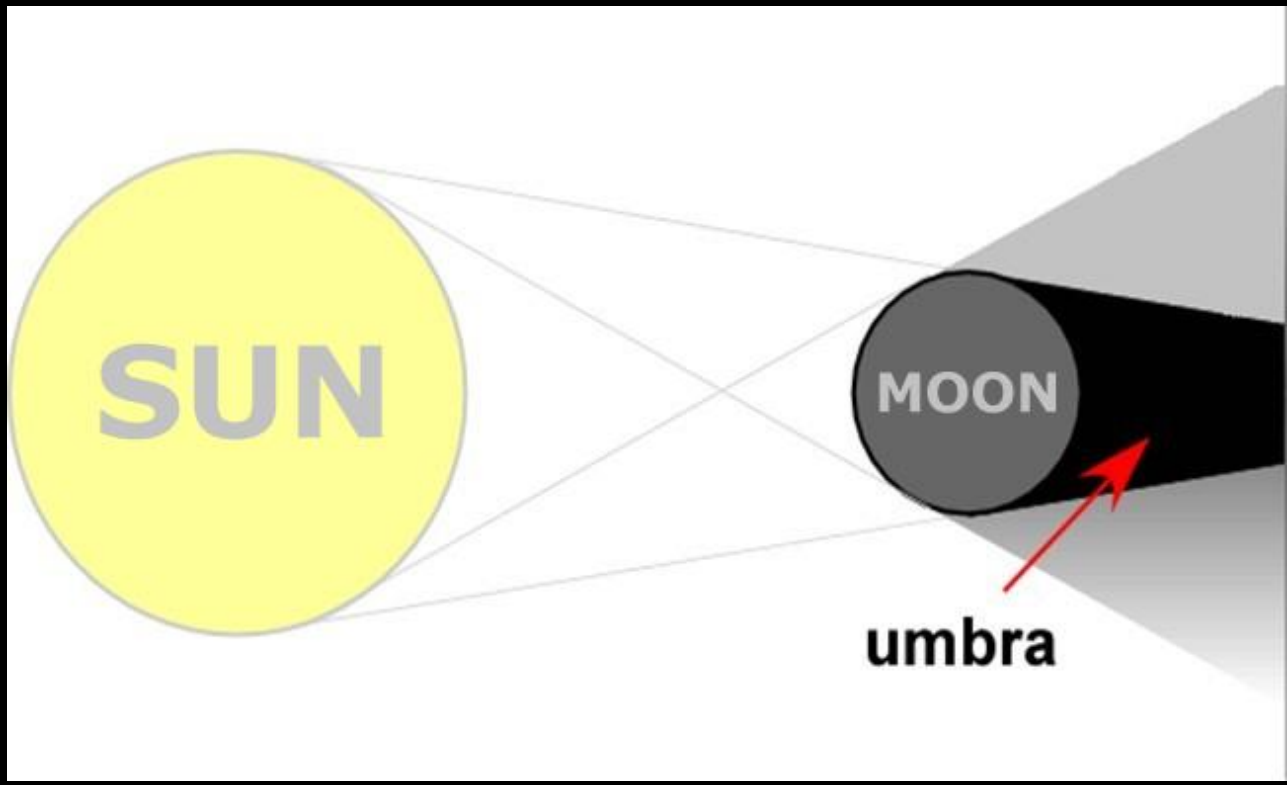


Gary A. Becker

Umbra

- Latin: "shadow"
- The darkest part of a shadow.
- Within the umbra, the source of light is completely blocked by the object causing the shadow.

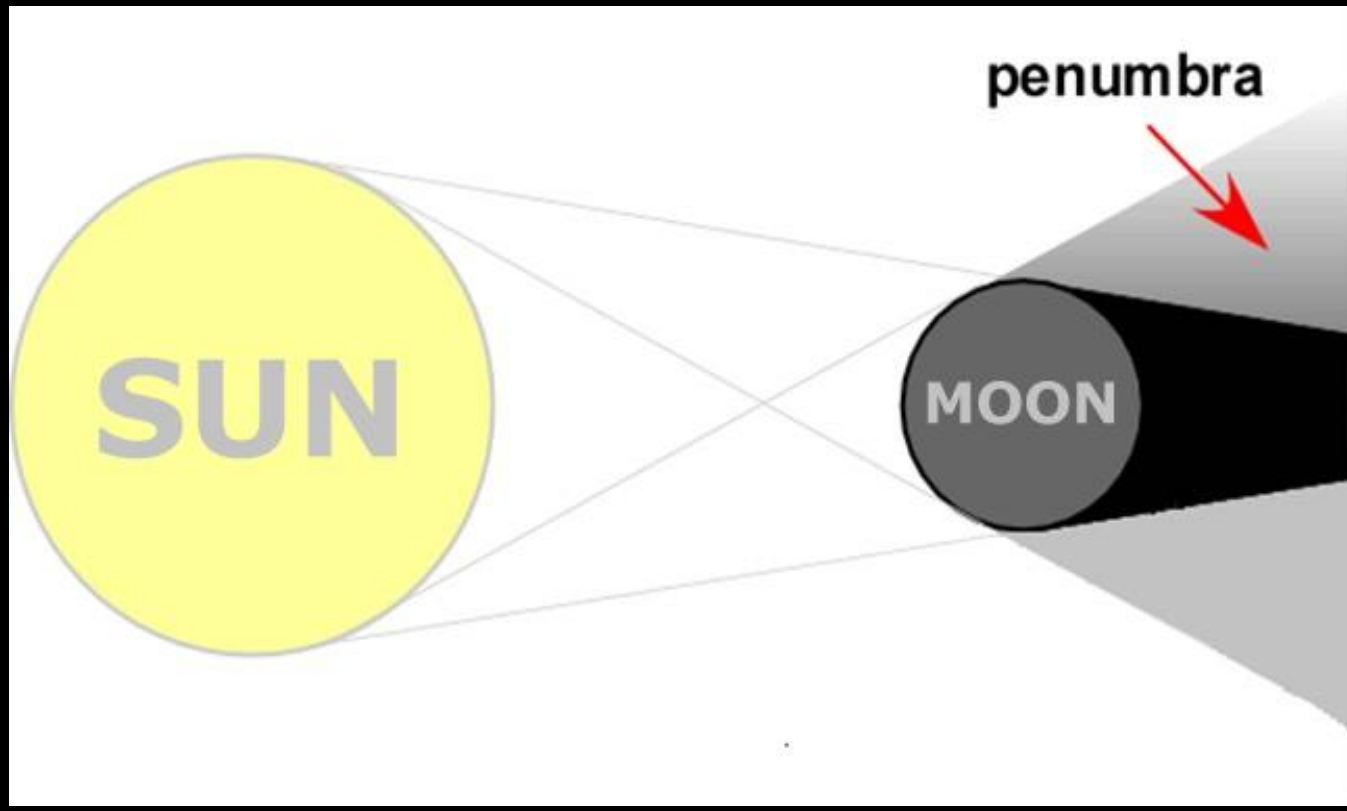
'Umbrella' is a modification of the Latin 'umbella,' which came from 'umbra,' meaning "shade, shadow."



Gary A. Becker slide

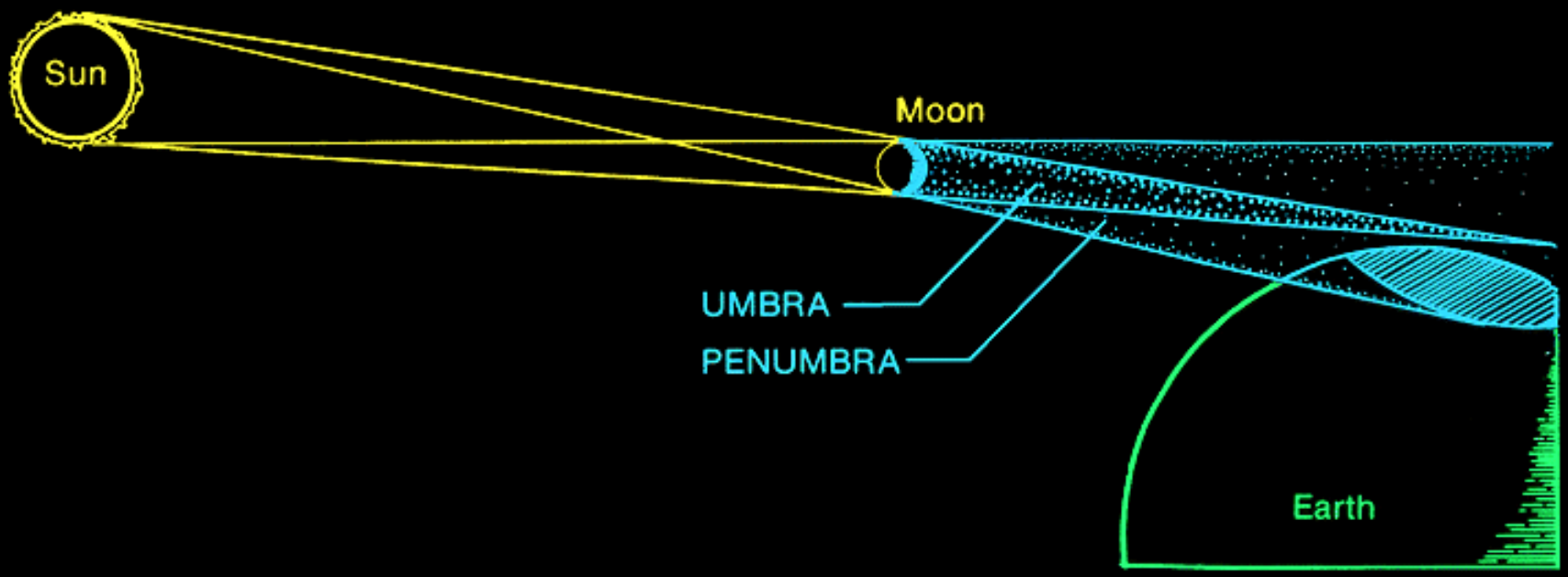
Penumbra

- Latin: “Almost Shadow”
- Lighter part of the shadow.
- Source of illumination only partially blocked



Gary A. Becker slide

Partial Solar Eclipse

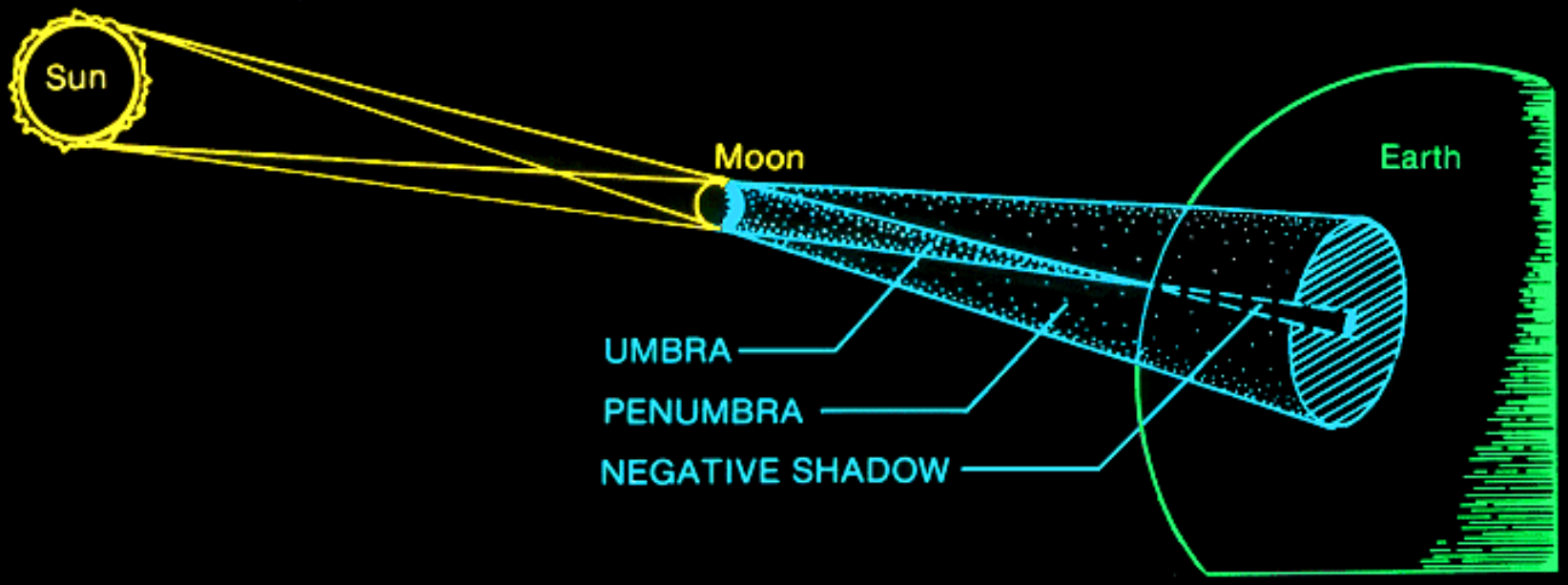


from Bryan Brewer, Eclipse, Earth View, 1979, p. 43

Partial Solar Eclipse, December 24, 1973
Allentown, PA

Gary A. Becker image

Annular Eclipse



from Bryan Brewer, Eclipse, Earth View, 1979, p. 43

Annular Eclipse, May 20, 2012, Chaco Culture National Historical Park, New Mexico

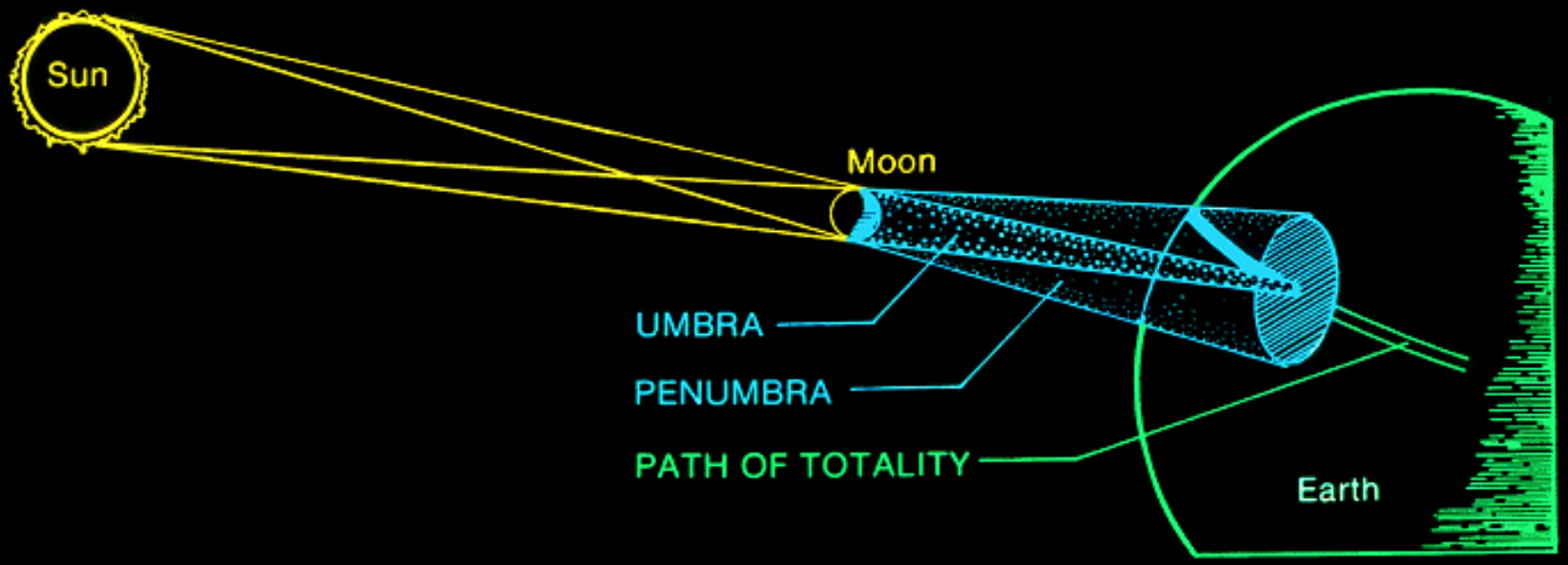
Gary A. Becker image

May 30, 1984-Osceola, NC

Broken Annular Eclipse

Charles Tackus image/Eclipse images, Gary A. Becker

Total Solar Eclipse



from Bryan Brewer, Eclipse, Earth View, 1979, p. 7

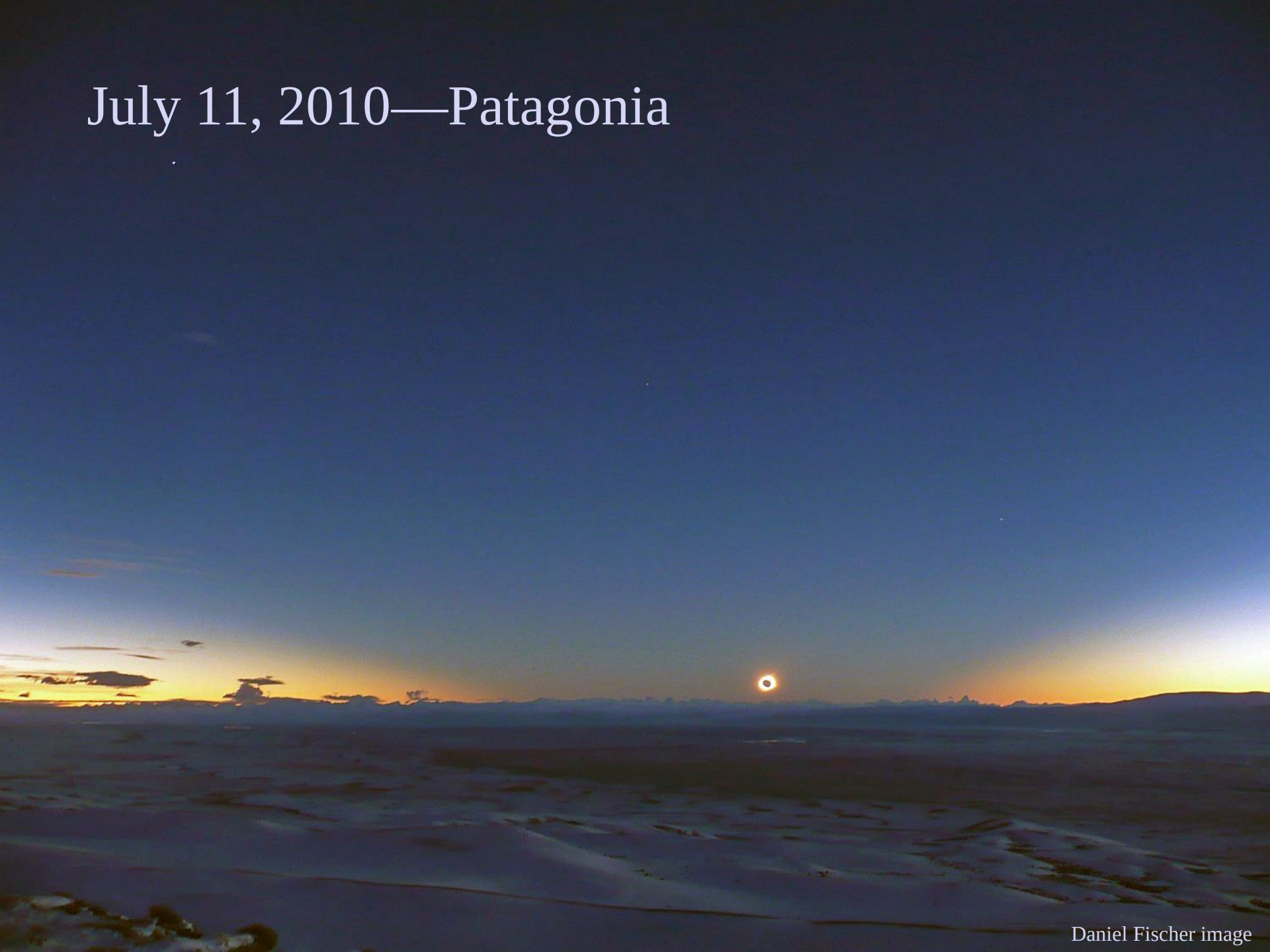
Nov. 23, 2003-Antarctica

© Akira Fujii/DMI

Total Solar Eclipse, August 21, 2017

Gary A. Becker image

July 11, 2010—Patagonia

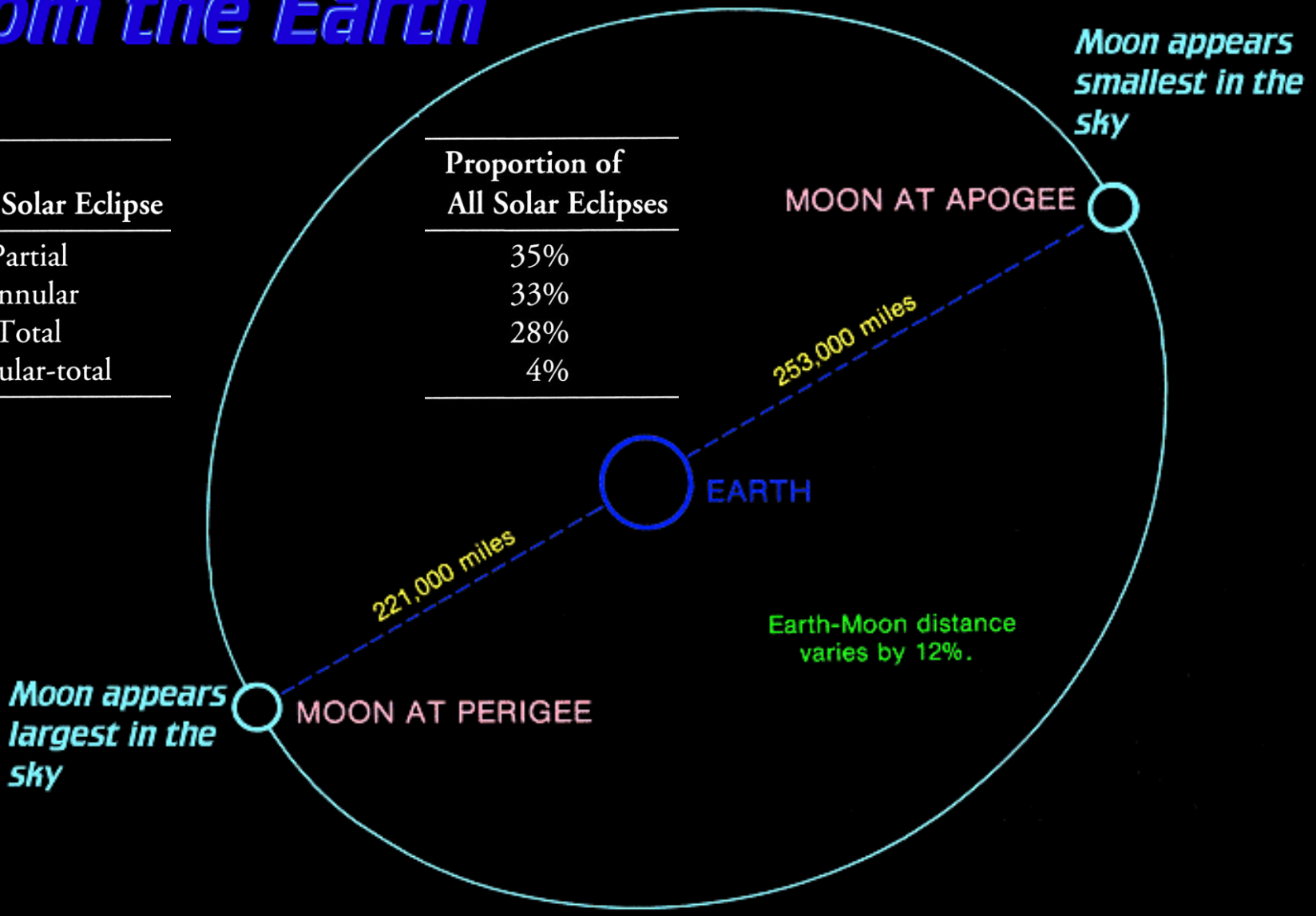


Daniel Fischer image

July 11, 2010--Janne Pyykko, El Calafate, Patagonia, Argentina,

Moon's Changing Distance from the Earth

Type of Solar Eclipse	Proportion of All Solar Eclipses
Partial	35%
Annular	33%
Total	28%
Annular-total	4%



from Bryan Brewer, Eclipse, Earth View, 1979, 1991

Change in the Angular Diameter of the Moon

Perigee Full Moon

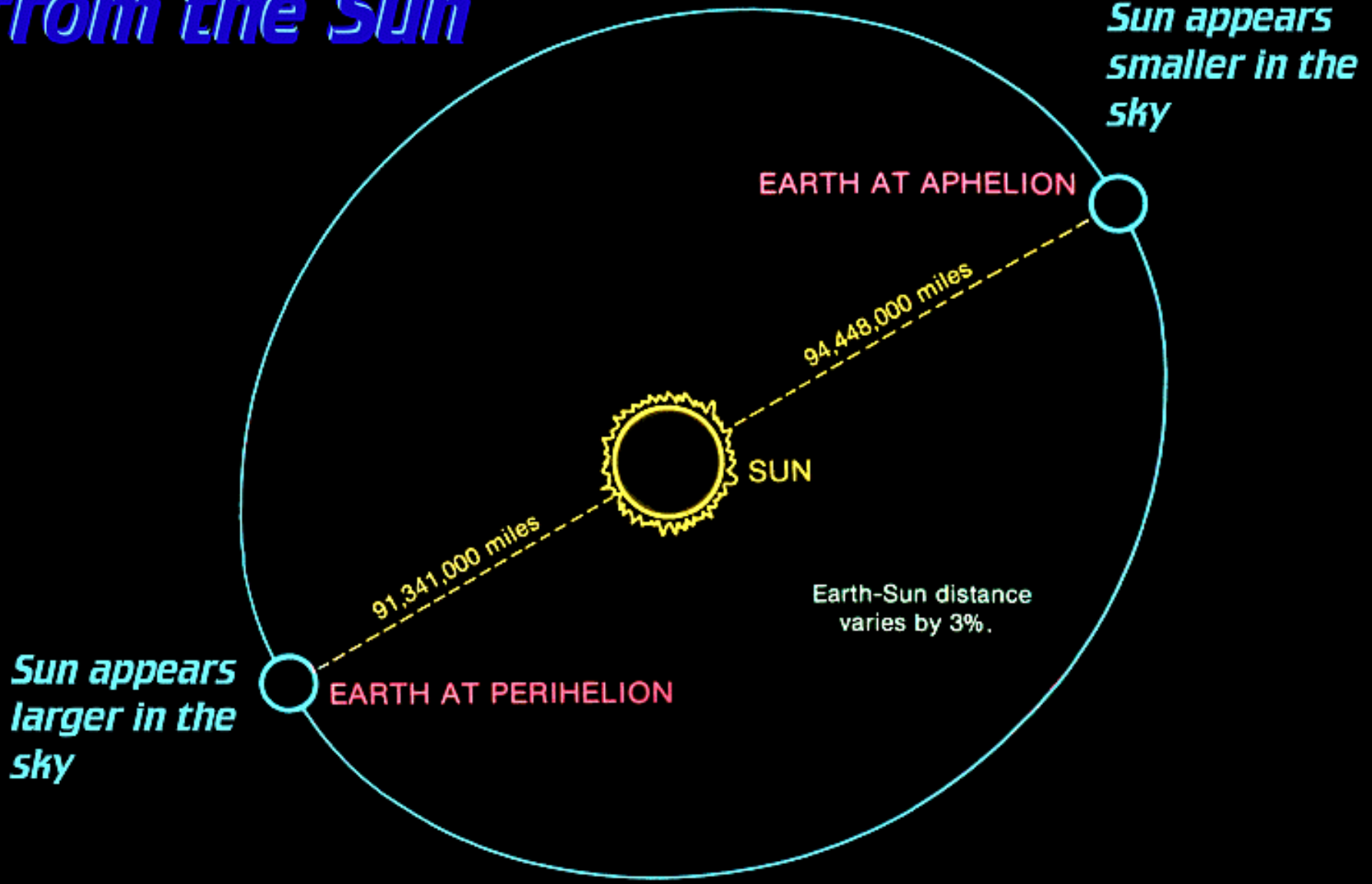
March 19, 2011
221,614 miles
33 min, 30 sec

Apogee Full Moon

November 28, 2012
252,459 miles
29 min, 24 sec

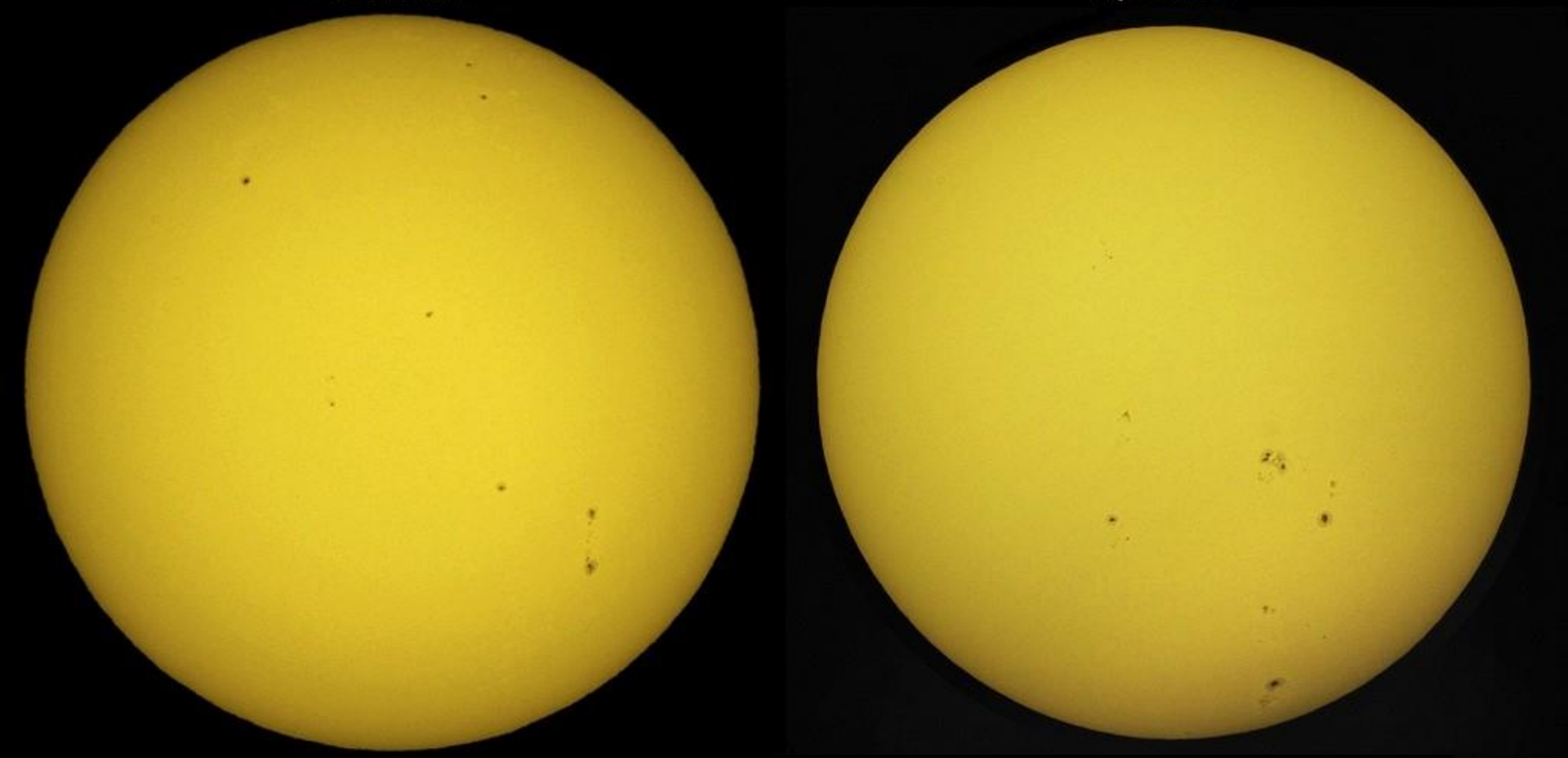
Gary A. Becker images

Earth's Changing Distance from the Sun



from Bryan Brewer, Eclipse, Earth View, 1979, p. 62

Change in the Angular Diameter of the Sun



January 3, 2013
91,330,000 miles
32 min, 32 sec

July 3, 2014
94,490,000 miles
31 min, 28 sec

Gary A. Becker images

Extreme Angular Diameters of the Sun and the Moon to Scale

2011-2014

Gary A. Becker images

Repetition of Eclipses

1. Moon is at a new or a full phase.

2. Moon is at or near a node.

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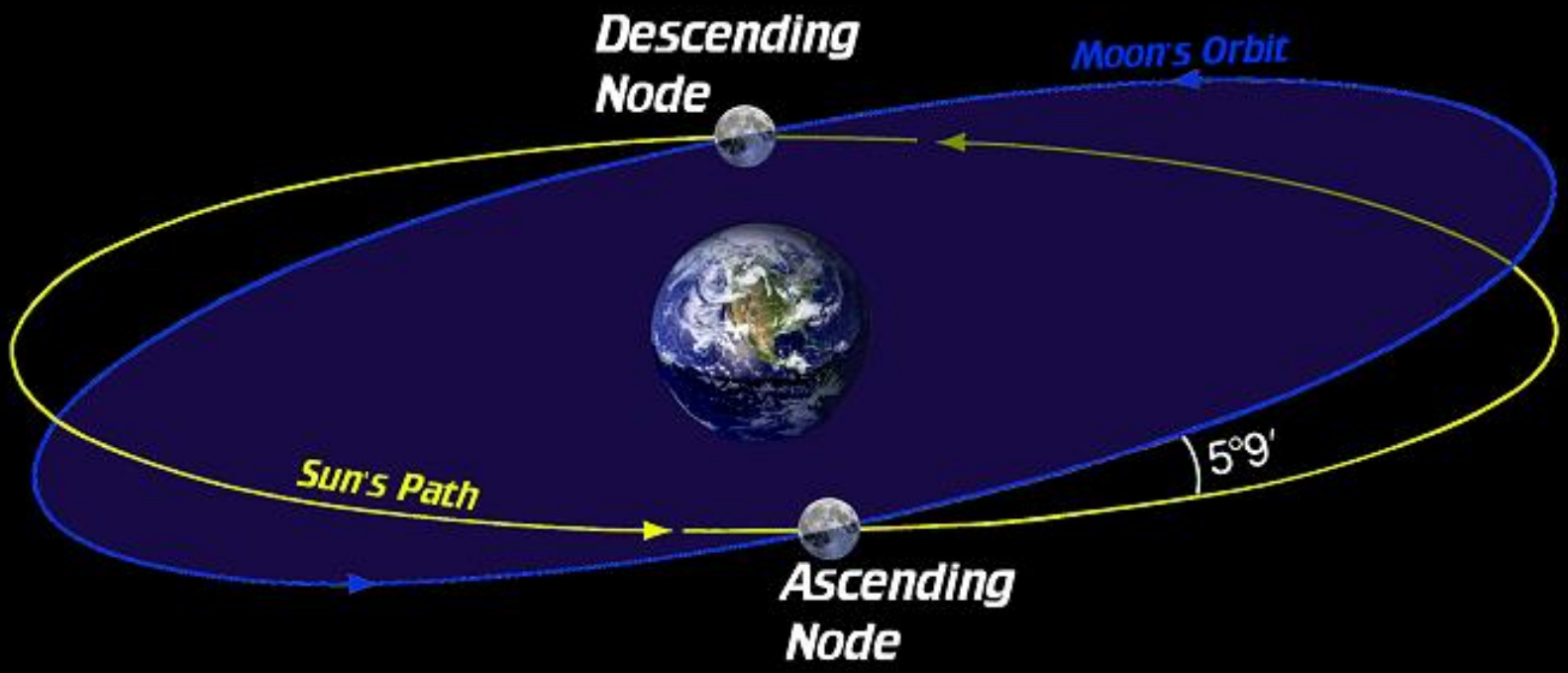
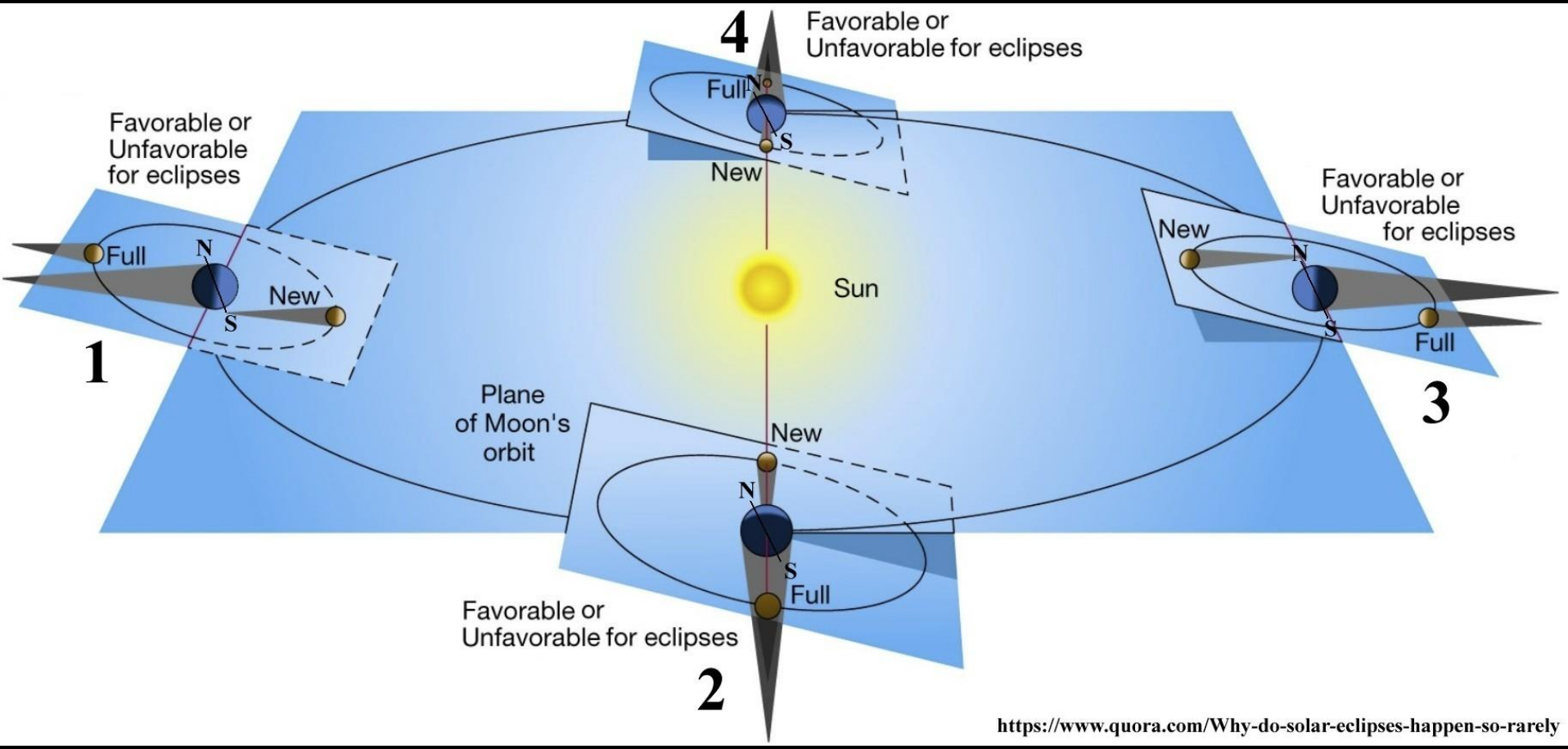
Inclination of the Moon's Orbit

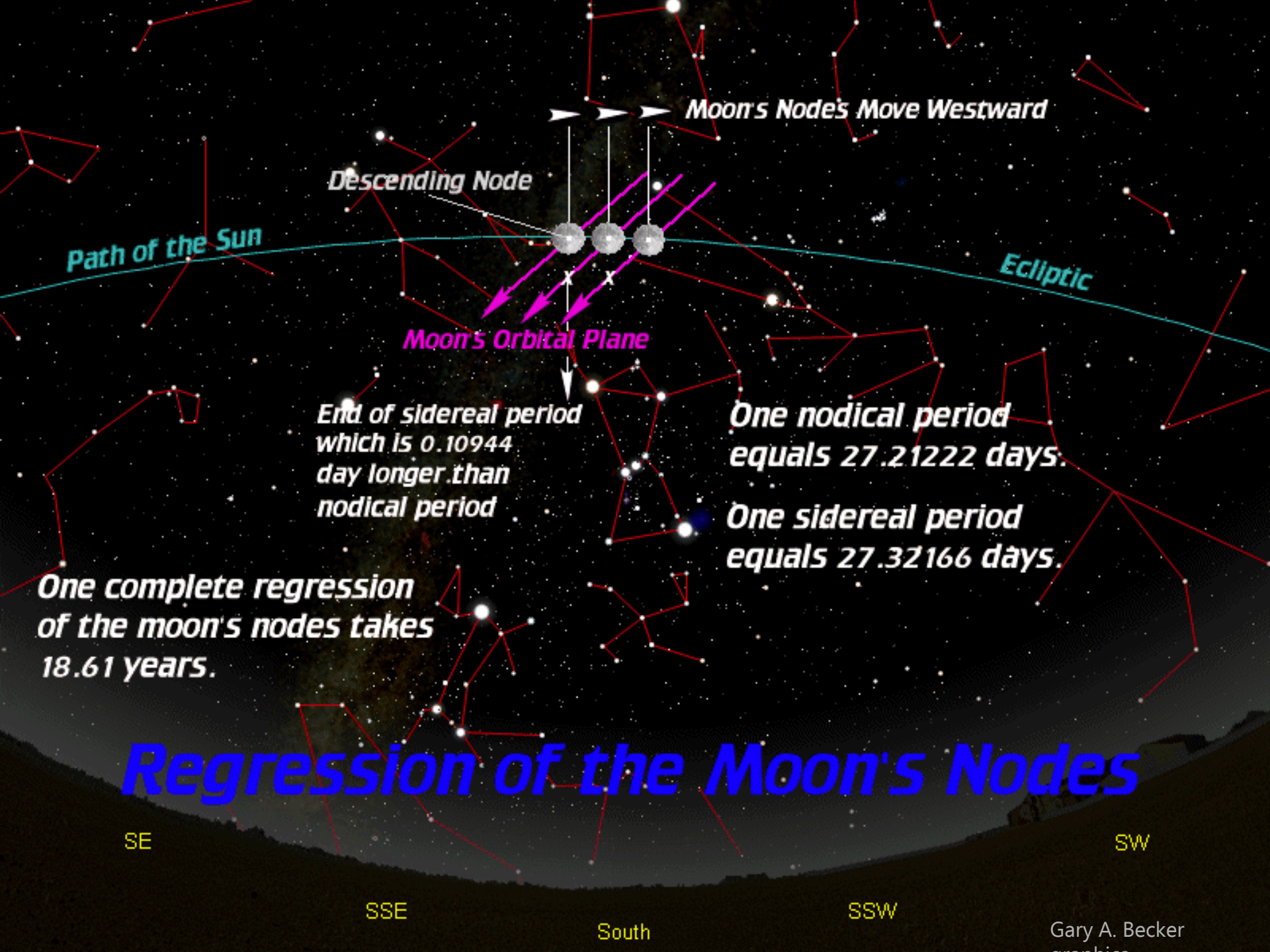


Adapted from Bryan Brewer, Eclipse, 1979

Importance of the Nodes in an Eclipse



https://www.quora.com/Why-do-solar-eclipses-happen-so-rarely


Moon's Nodes Move Westward
Descending Node
Path of the Sun
Ecliptic
Moon's Orbital Plane
End of sidereal period which is 0.10944 day longer than nodical period
One nodical period equals 27.21222 days.
One sidereal period equals 27.32166 days.
One complete regression of the moon's nodes takes 18.61 years.
Regression of the Moon's Nodes
SE
SW
SSE
SSW
South
Gary A. Becker

Repetition of Eclipses

SYNODIC MONTH = *29.53059 days*
(phase period)

NODICAL MONTH = *27.21222 days*
(two crossings of same node)

Gary A. Becker
graphics

Repetition of Eclipses

In order for the repetition of an eclipse to occur, the same number of days must be contained within integral numbers of synodic and nodical periods.

47 Synodic Months = 51 Nodical Months

1387.9377 days 1387.8232 days

3 years, 291 or 292 days

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Repetition of Similar Eclipses

1. The moon is new or full.
2. The moon is at or near a node.
3. The moon is at a similar distance from Earth.

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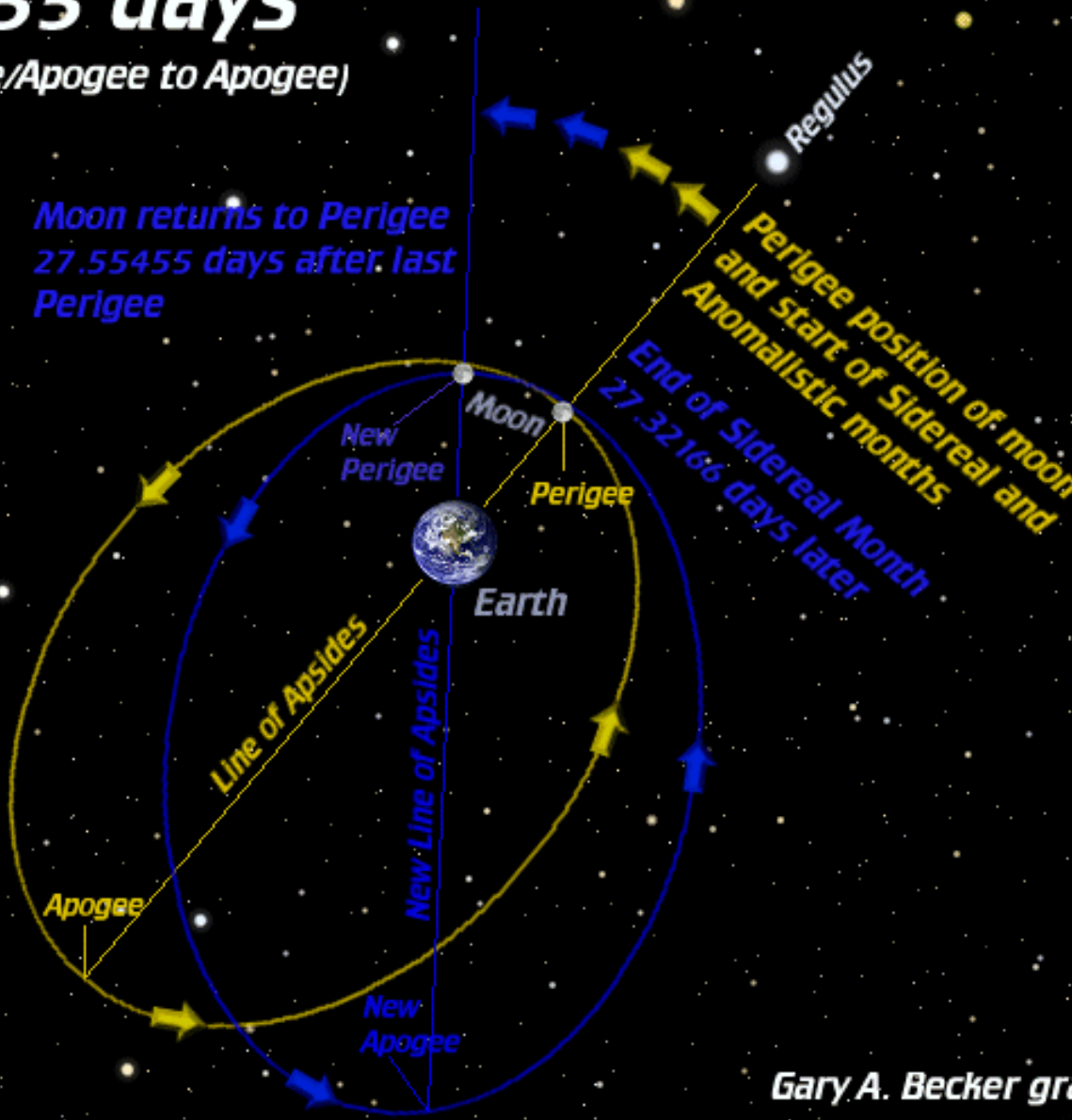
Anomalistic Month

27.55455 days

(Perigee to Perigee/Apogee to Apogee)



Drawing is exaggerated

Line of Apsides equals Major Axis

One complete revolution of the Line of Apsides takes 8.85 years to complete.

Gary A. Becker graphics

Predicting Similar Eclipses

SYNODIC MONTH = 29.53059 DAYS
(phase period)

NODICAL MONTH = 27.21222 DAYS
(two crossings of same node)

ANOMALISTIC M. = 27.55455 DAYS
(perigee to perigee period)

Gary A. Becker slide

What is the Saros?

223 syn. mon. = 6585.3216 days
(29.53059 d)

242 nod. mon. = 6585.3572 days
(27.21222 d)

239 anom. mon. = 6585.5375 days
(27.55455 d)

This known as the Saros and equals 18 years 10 or 11 days.

Gary A. Becker slide

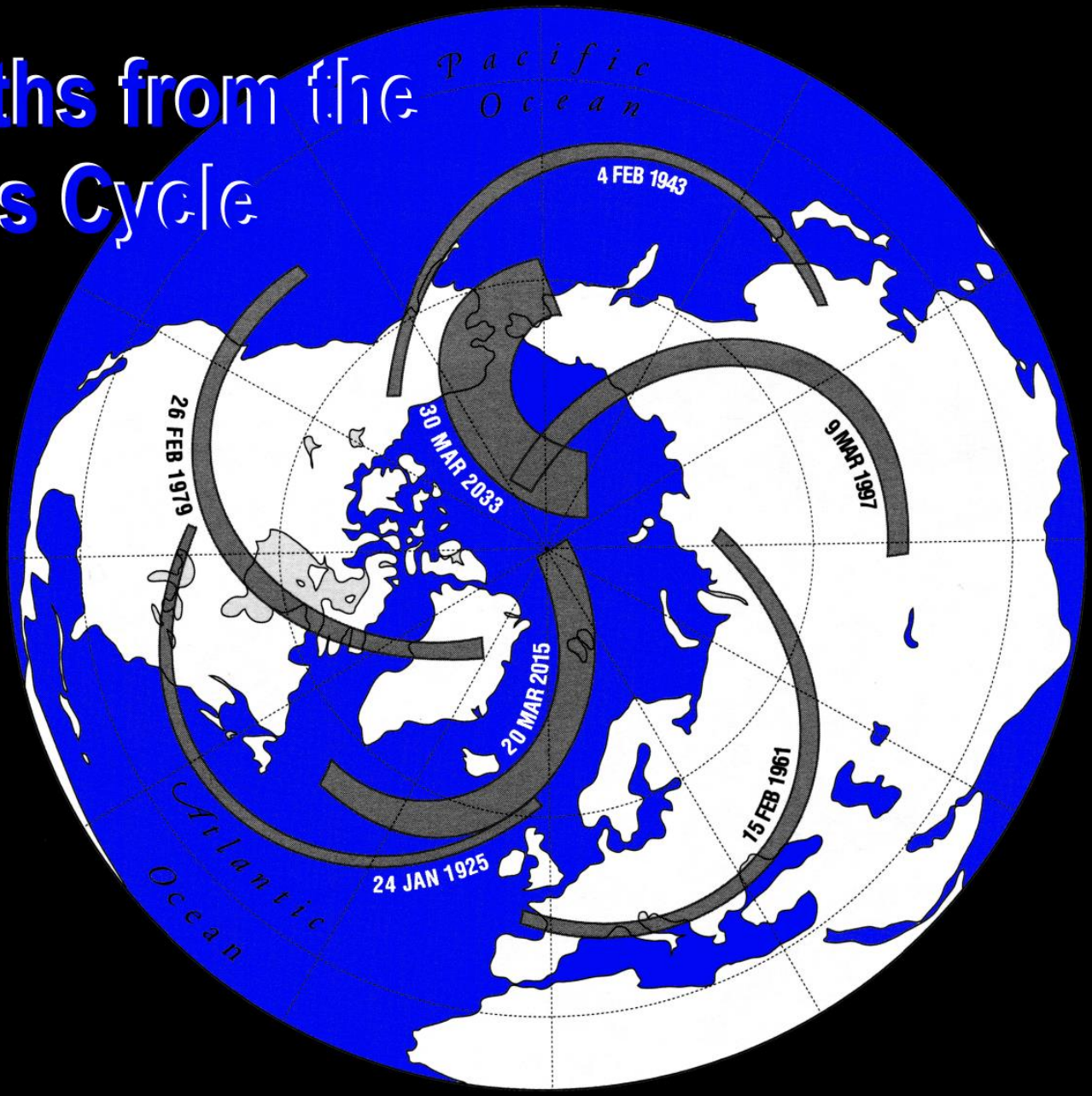
A Complete Saros Cycle

Date	Type	Date	Type
933 May 27	Partial	1582 June 20	Total
951 June 7	Partial	*1600 July 10	Total
969 June 17	Partial	1618 July 21	Total
987 June 28	Partial	1636 Aug. 1	Total
1005 July 9	Partial	1654 Aug. 12	Total
1023 July 20	Partial	1672 Aug. 22	Total
1041 July 30	Partial	1690 Sep. 3	Total
1059 Aug. 11	Annular	1708 Sep. 14	Total
1077 Aug. 21	Annular	1726 Sep. 25	Total
1095 Sep. 1	Annular	1744 Oct. 6	Total
1113 Sep. 11	Annular	1762 Oct. 17	Total
1131 Sep. 23	Annular	1780 Oct. 27	Total
1149 Oct. 3	Annular	1798 Nov. 8	Total
1167 Oct. 14	Annular	1816 Nov. 19	Total
1185 Oct. 25	Annular	1834 Nov. 30	Total
1203 Nov. 5	Annular	1852 Dec. 11	Total
1221 Nov. 15	Annular	1870 Dec. 22	Total
1239 Nov. 27	Annular	1889 Jan. 1	Total
1257 Dec. 7	Annular	1907 Jan. 14	Total
1275 Dec. 18	Annular	1925 Jan. 24	Total
1293 Dec. 29	Annular	1943 Feb. 2	Total
1312 Jan. 9	Annular	1961 Feb. 15	Total
1330 Jan. 19	Annular	1979 Feb. 26	Total
1348 Jan. 31	Annular	1997 Mar. 9	Total
1366 Feb. 10	Annular	2015 Mar. 20	Total
1384 Feb. 21	Annular	2033 Mar. 30	Total
1402 Mar. 4	Annular	2051 Apr. 11	Partial
1420 Mar. 14	Annular	2069 Apr. 21	Partial
1438 Mar. 25	Annular	2087 May 2	Partial
1456 Apr. 4	Annular	2105 May 14	Partial
1474 Apr. 16	Annular	2123 May 25	Partial
1492 Apr. 26	Annular	2141 June 4	Partial
1510 May 8	Annular-total	2159 June 16	Partial
1528 May 18	Annular-total	2177 June 26	Partial
1546 May 29	Annular-total	2195 July 7	Partial
1564 June 8	Total		

*Begin dates from Gregorian calendar

Bryan Brewer, Eclipse, 1979

Eclipse Paths from the Same Saros Cycle

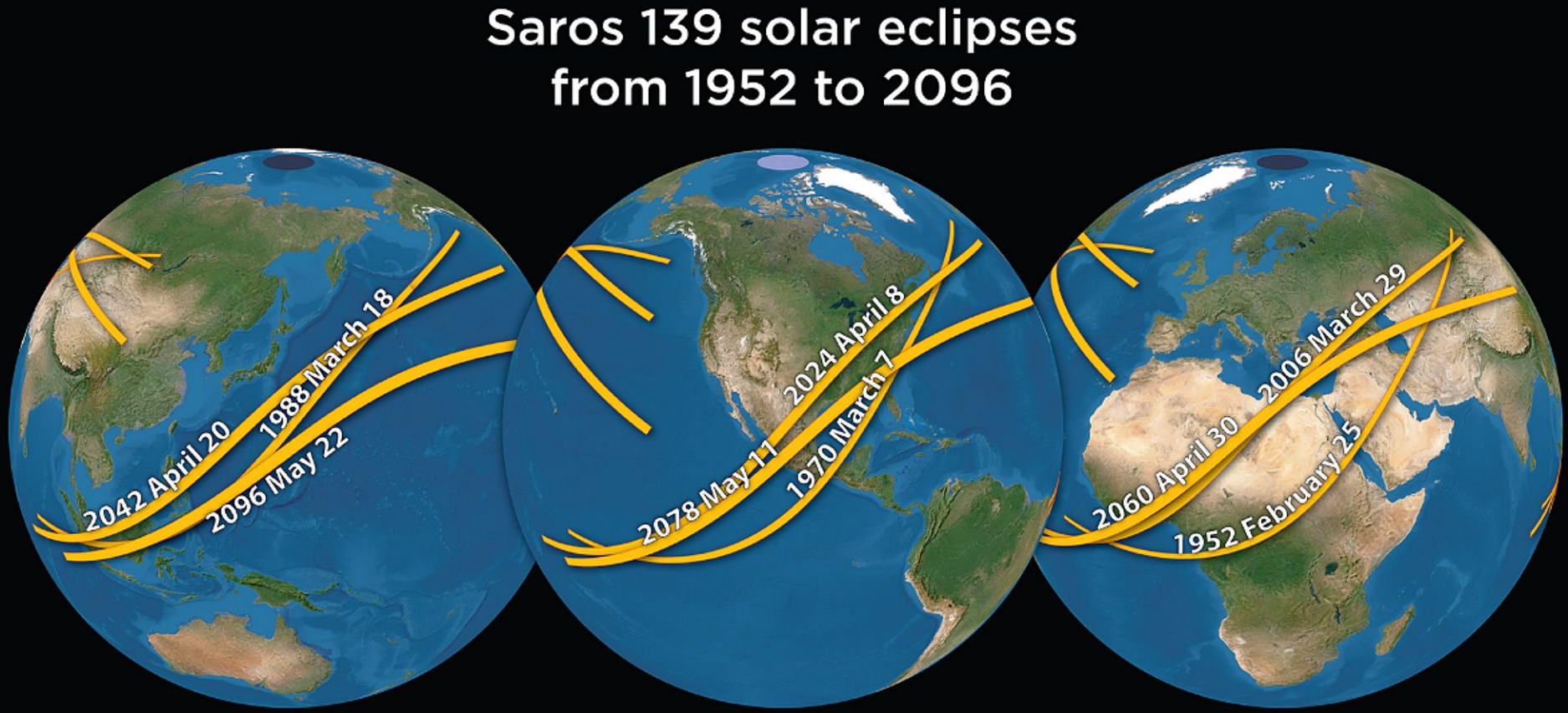


24 JAN 1925
4 FEB 1943
15 FEB 1961
26 FEB 1979
9 MAR 1997
20 MAR 2015
30 MAR 2033

Bryan Brewer, Eclipse, 1991

Note the Symmetry

The 1/3 (0.3216) day remainder for the **Synodic period** causes the next eclipse to shift by approximately 120 degrees west for each successive eclipse in the series

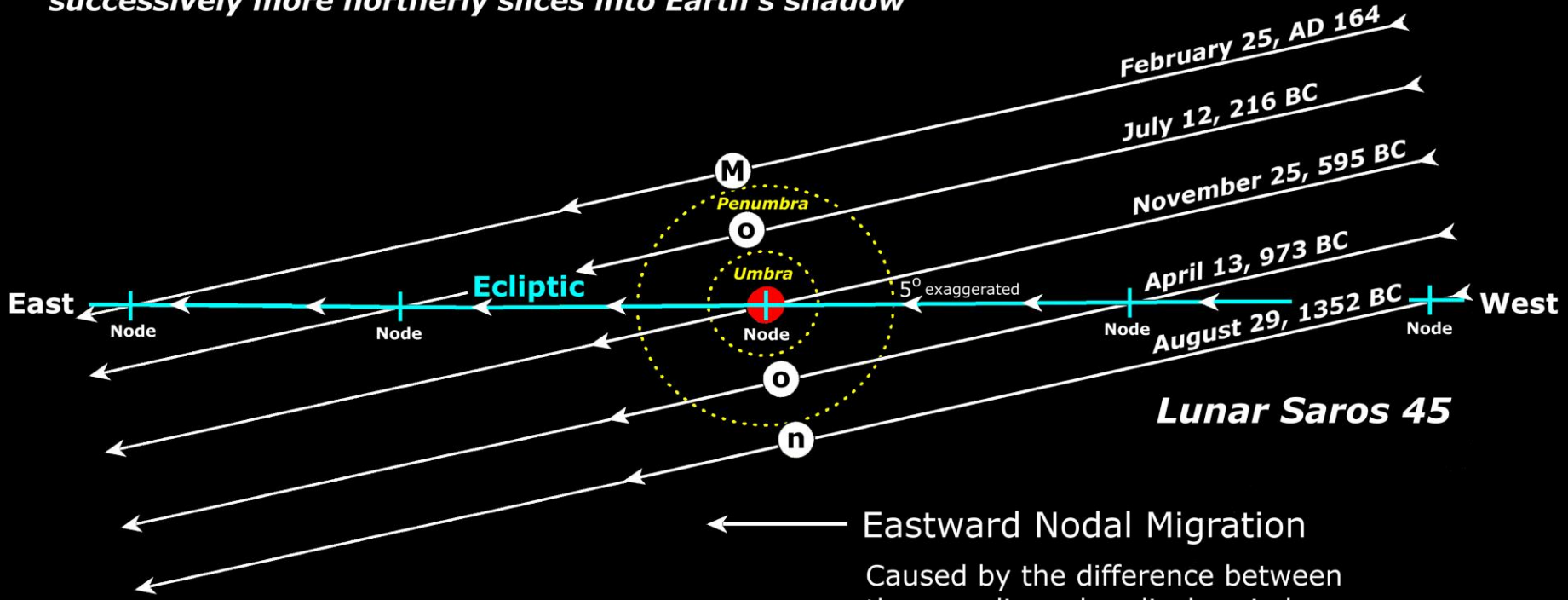


Eclipses on each Earth are separated by 54 years

GreatAmericanEclipse.com

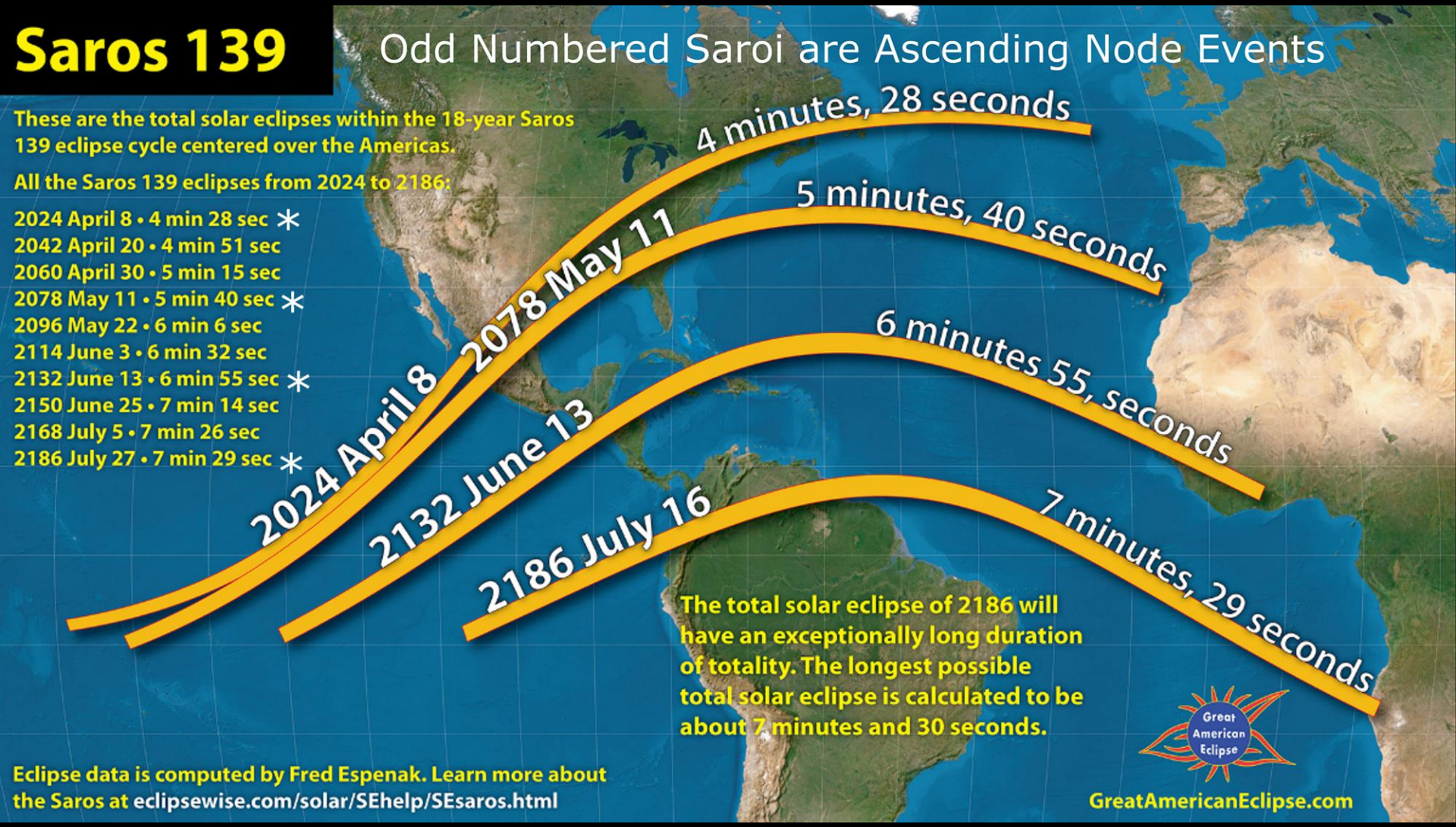
Eastward Drift of Lunar Nodes

The eastward migration of the node causes the Moon to cut successively more northerly slices into Earth's shadow



From *Sky and Telescope/Gary* A. Becker slide

Saros 139



These are the total solar eclipses within the 18-year Saros 139 eclipse cycle centered over the Americas.

All the Saros 139 eclipses from 2024 to 2186:

2024 April 8 • 4 min 28 sec ✳
2042 April 20 • 4 min 51 sec
2060 April 30 • 5 min 15 sec
2078 May 11 • 5 min 40 sec ✳
2096 May 22 • 6 min 6 sec
2114 June 3 • 6 min 32 sec
2132 June 13 • 6 min 55 sec ✳
2150 June 25 • 7 min 14 sec
2168 July 5 • 7 min 26 sec
2186 July 27 • 7 min 29 sec ✳

Eclipse data is computed by Fred Espenak. Learn more about the Saros at eclipsewise.com/solar/SEhelp/SEsaros.html

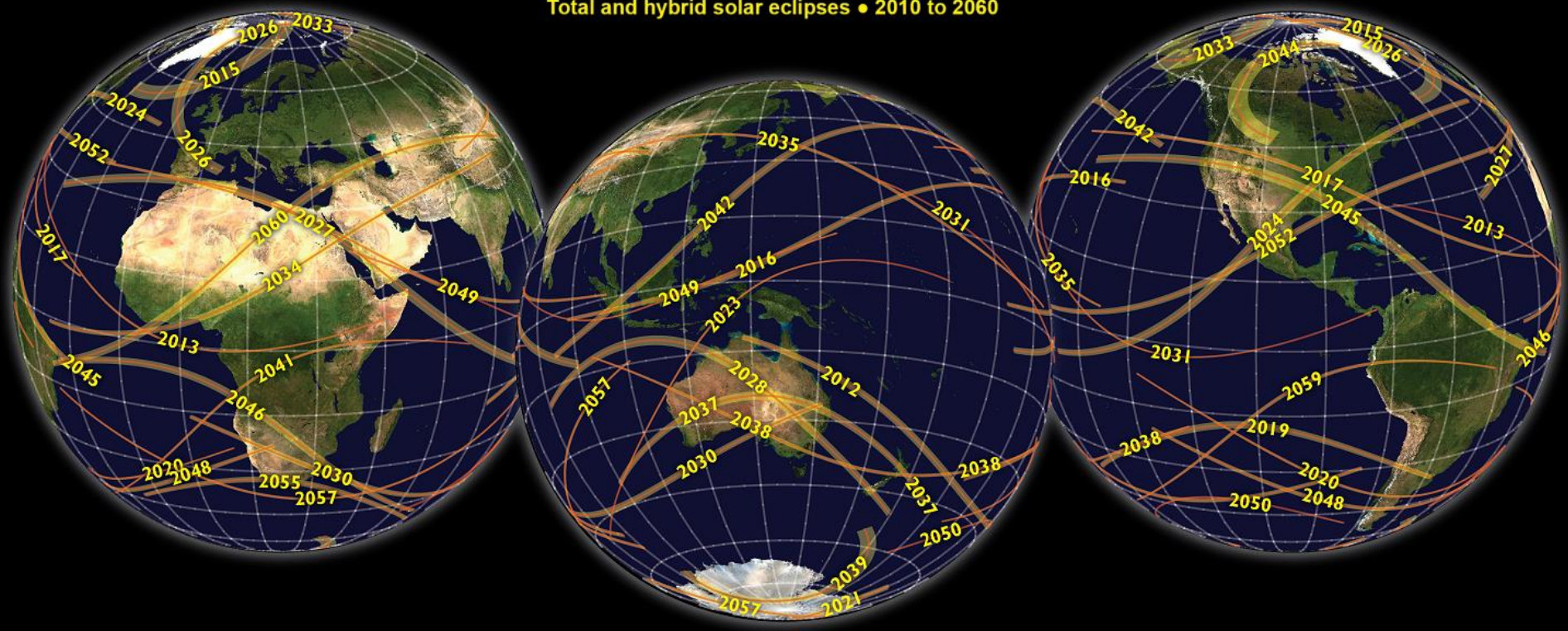
Frequecy of Total Solar Eclipses at One Location

Location	Dates of Consecutive Total Eclipses	Years in Interval
London	Oct. 29, 878 A.D. — Apr. 22, 1715 A.D.	837
Jerusalem	Sep. 30, 1131 B.C. — July 4, 336 B.C.	795
Great Pyramid of Egypt	Apr. 1, 2471 B.C. — June 29, 2159 B.C.	312
Stonehenge	May 8, 1169 B.C. — May 7, 1066 B.C.	103
Yellowstone National Park	July 29, 1878 A.D. — Jan. 1, 1889 A.D.	11
Tomb of Tutankhamun	May 31, 957 B.C. — May 22, 948 B.C.	9
Lake Okechobee, Florida	Aug. 19, 2259 A.D. — Dec. 22, 2261 A.D.	2½
Southern New Guinea	June 11, 1983 A.D. — Nov. 22, 1984 A.D.	1½

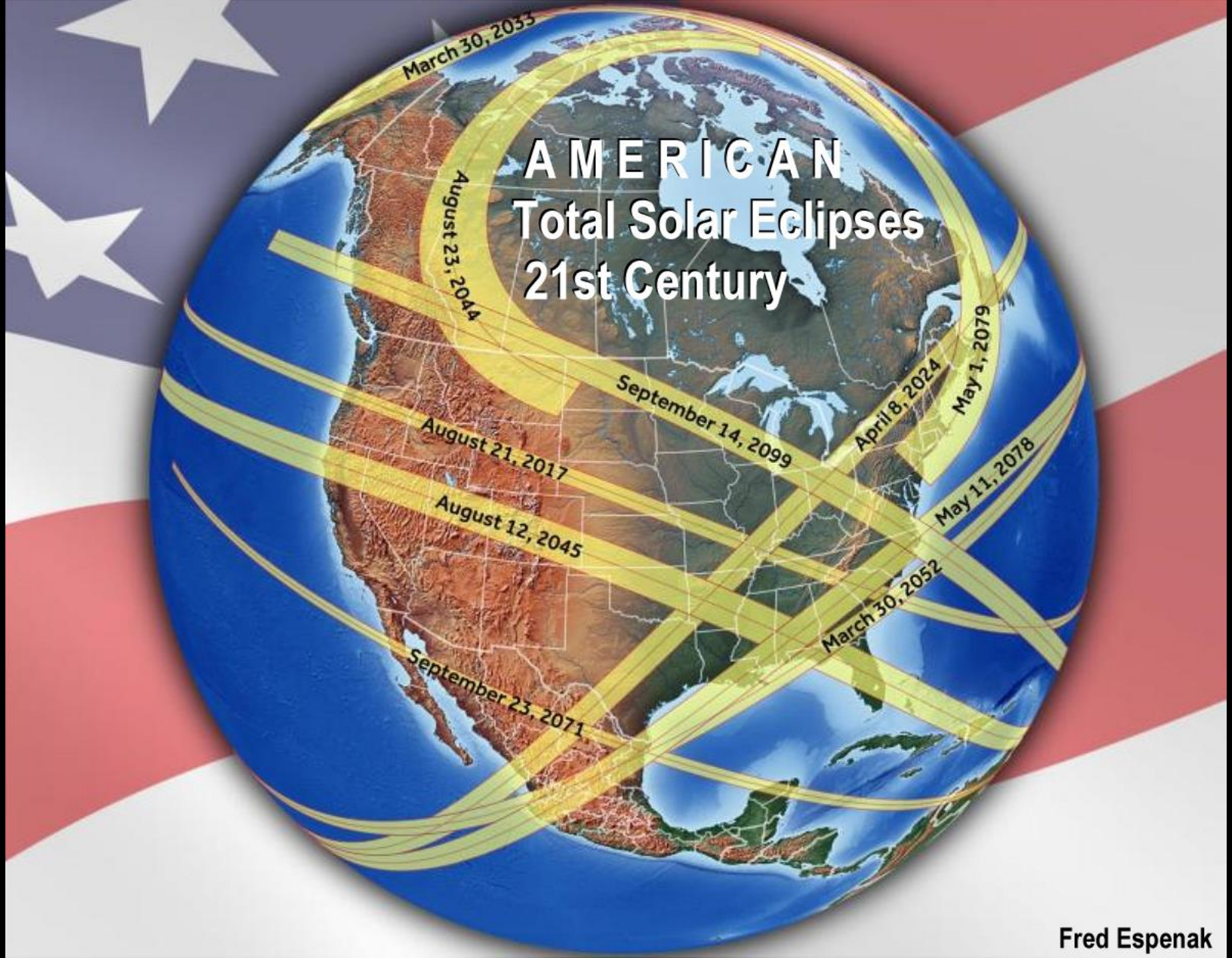
Bryan Brewer, Eclipse, 1979

Fifty years of solar eclipses

Total and hybrid solar eclipses • 2010 to 2060



Map by Michael Zeiler, December 2010, www.eclipse-maps.com
Paths of solar eclipses by Xavier Jubier, xjubier.free.fr


AMERICAN
Total Solar Eclipses
21st Century
March 30, 2033
August 23, 2044
September 14, 2099
April 8, 2024
May 1, 2079
August 21, 2017
August 12, 2045
May 11, 2078
March 30, 2052
September 23, 2071
Fred Espenak

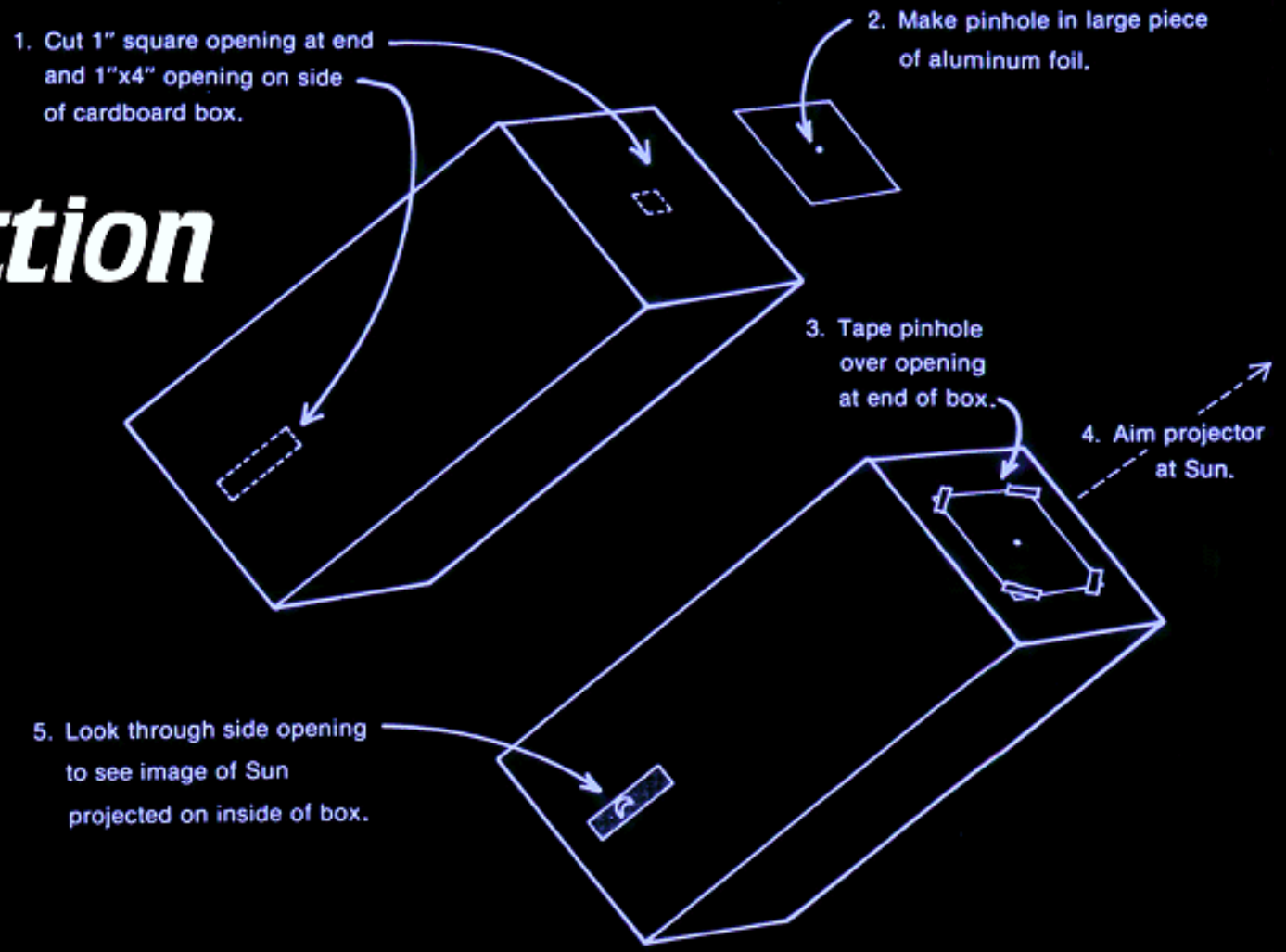
Solar Max
1991

Solar Min
2009

Internet/Peter K. Detterline slide

Peter K. Detterline image

Solar Projection Box



CAUTION: Never look through the pinhole directly at the Sun.

from Bryan Brewer, Eclipse, Earth View, 1979, p. 82

May 10, 1994,
Canutillo, Texas
Penny
Crisscrossed Fingers
Gary A. Becker image

Putting on the Ritz!

Ritz-Internet/Aruba, Gary A. Becker

May 10, 1994,
Canutillo, Texas

Annularity/Adam R. Jones

Let the leaves of a tree do all the work.

Gary A. Becker image/others-Internet

May 10, 1994,
Canutillo, Texas

Gary A. Becker image-insert, Adam R. Jones

Colander Head, Pete

Dean Bauer image

July 22, 2009-South China Sea

Peter K. Detterline image

May 10, 1994,
Canutillo, Texas
Gary A. Becker image

May 10, 1994,
Canutillo, Texas
Gary A. Becker image

Get Your Eclipse Glasses Now!

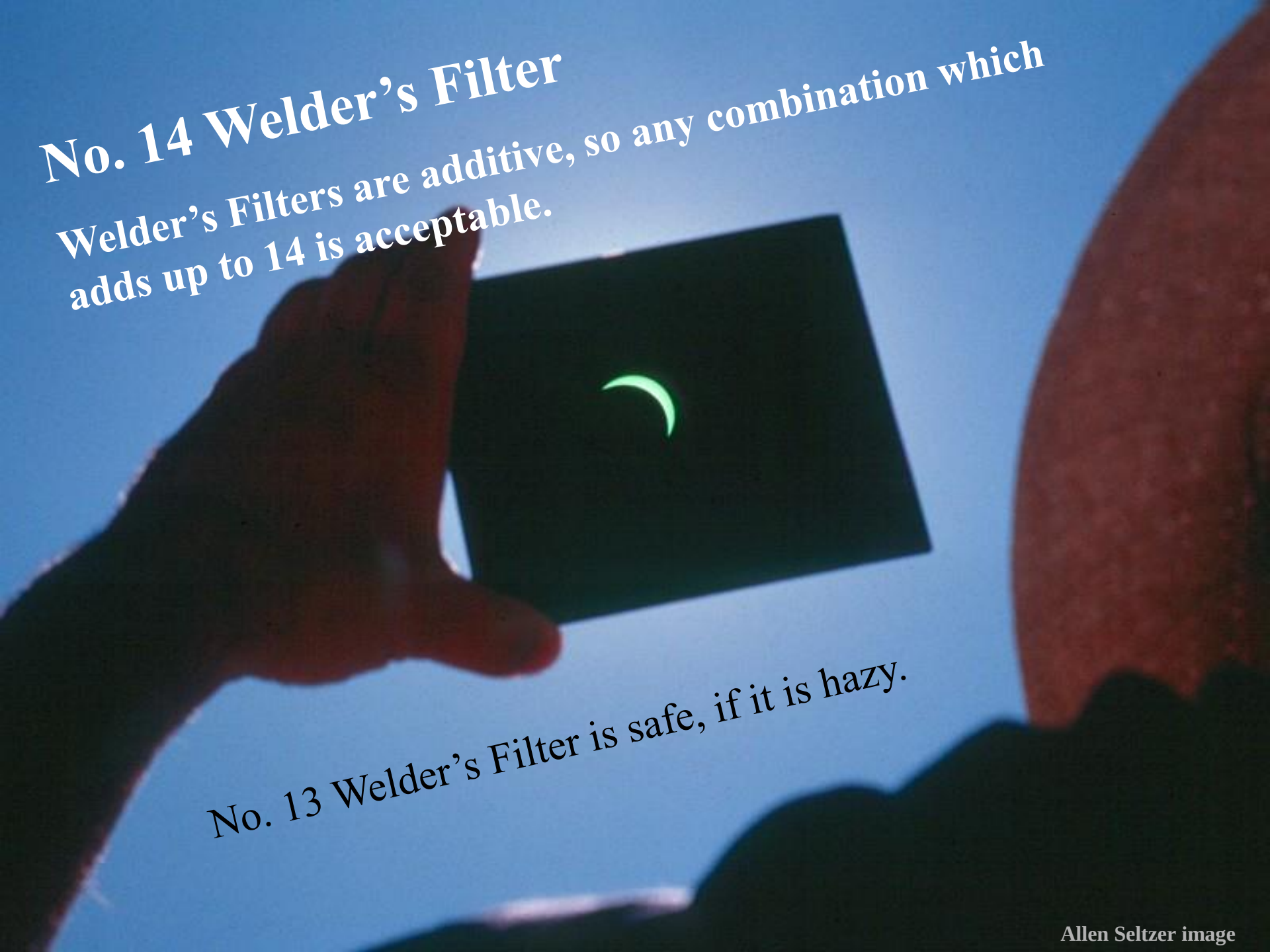
Gary A. Becker Slide

Gary A. Becker images

Eclipse Filters/Glasses are Very Safe

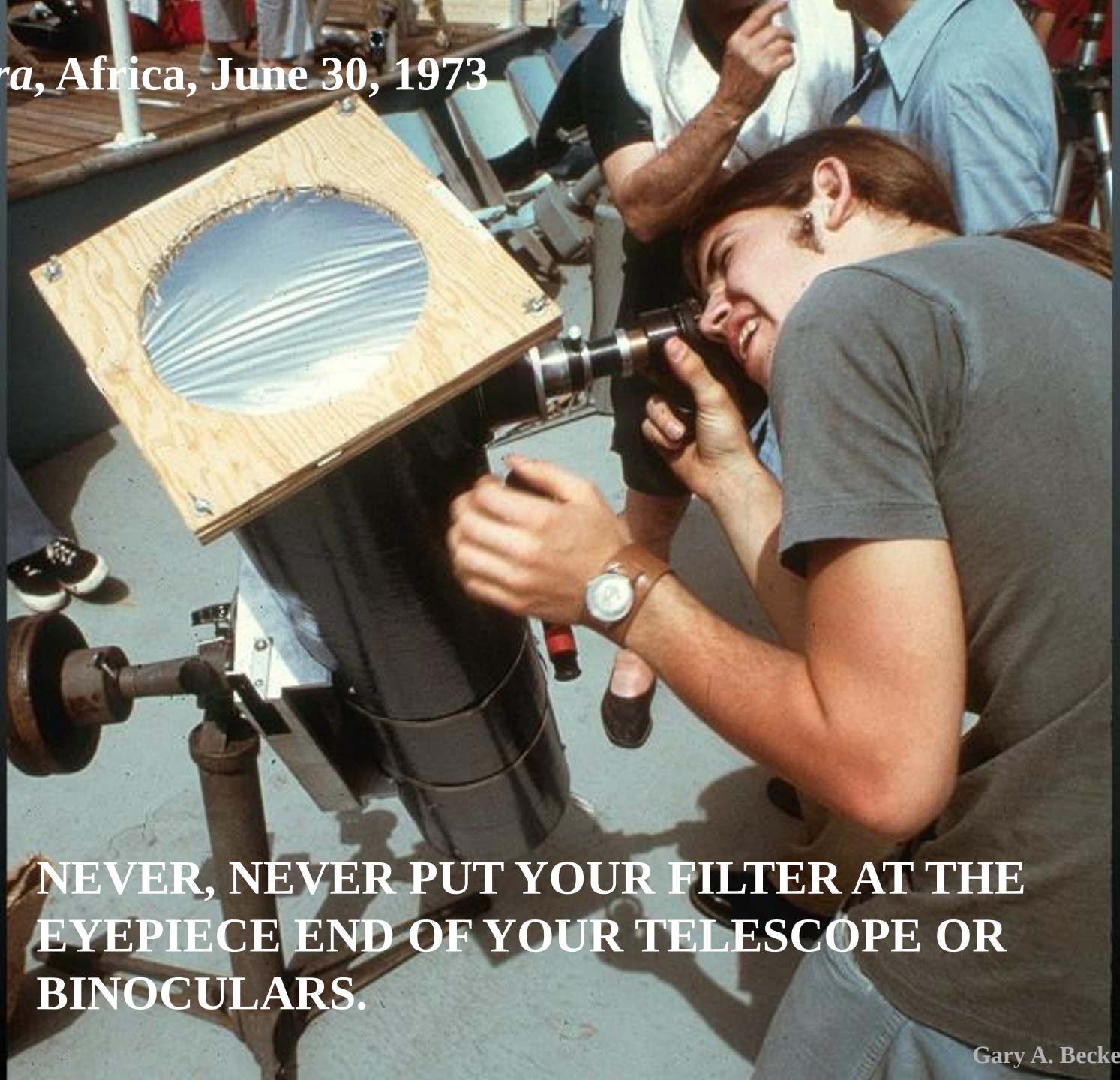
Purchase them from an American distributor such as Rainbow Symphony or Paper Optics.

Peter K. Detterline image


No. 14 Welder's Filter
Welder's Filters are additive, so any combination which adds up to 14 is acceptable.
No. 13 Welder's Filter is safe, if it is hazy.
Allen Seltzer image

May 10, 1994,
Canutillo, Texas
Aluminized Mylar
Gary A. Becker image

Canberra, Africa, June 30, 1973



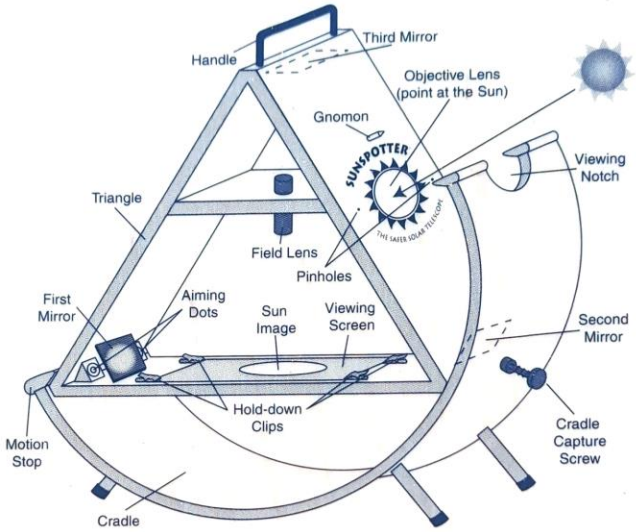
NEVER, NEVER PUT YOUR FILTER AT THE EYEPIECE END OF YOUR TELESCOPE OR BINOCULARS.

Gary A. Becker image

May 10, 1994,
Canutillo, Texas
Allen Seltzer image

SUNSPOTTER®

THE SAFER SOLAR TELESCOPE

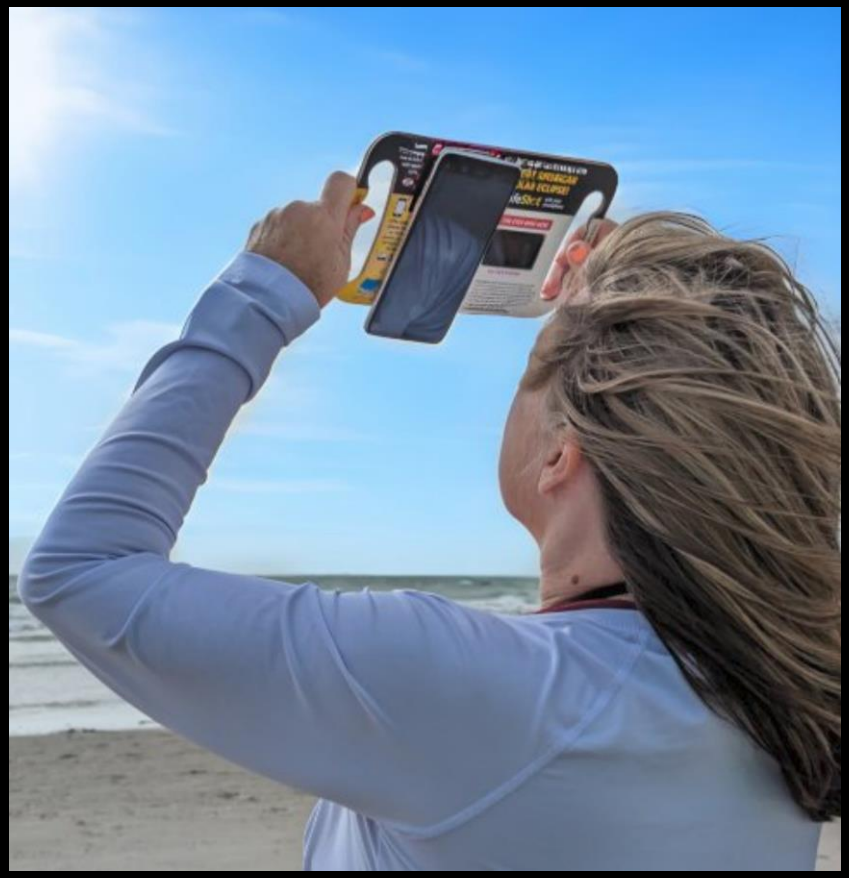


INSTRUCTIONS FOR USE

1. To use your Sunspotter, unlatch the triangle from the cradle.
2. Aim the objective lens at the Sun by moving the cradle side to side and tilting the triangle up and down within the cradle.
3. When the Sunspotter is aligned, the shadow of the gnomon will disappear.
4. Adjust so that the light from the pinhole falls upon the aiming dot. An image of the Sun will appear on the viewing screen.
5. If the sun is low in the sky, orient the triangle so that the objective lens side is facing away from the viewing notch of the cradle.
6. If the sun is high in the sky, orient the triangle so that the objective lens side is facing above the viewing notch.

Gary A. Becker images

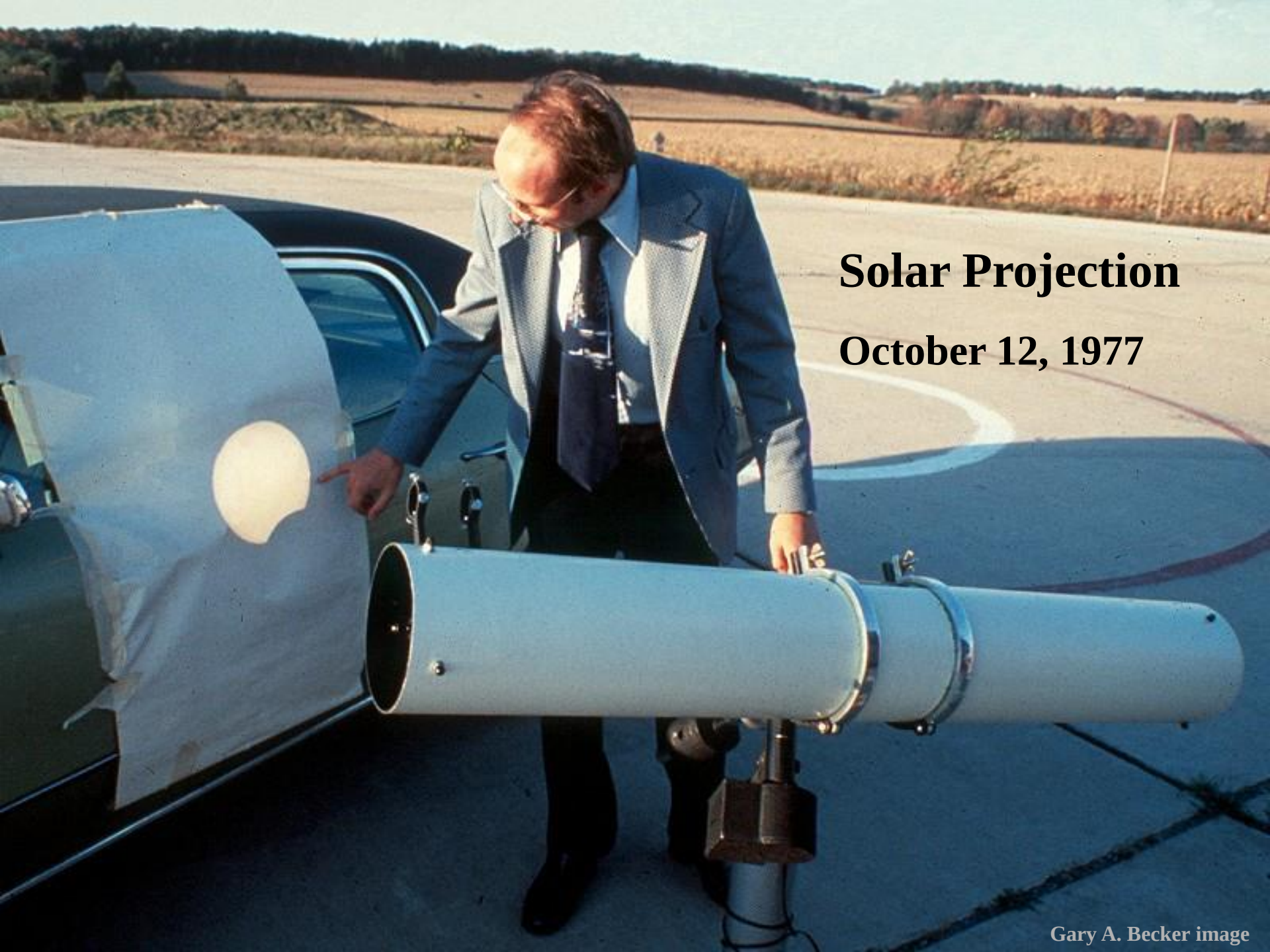
SafeShot



SOLAR SNAP: A work still in progress, but the app is free for experimentation. Attach a solar filter to your smartphone lenses.

Internet images

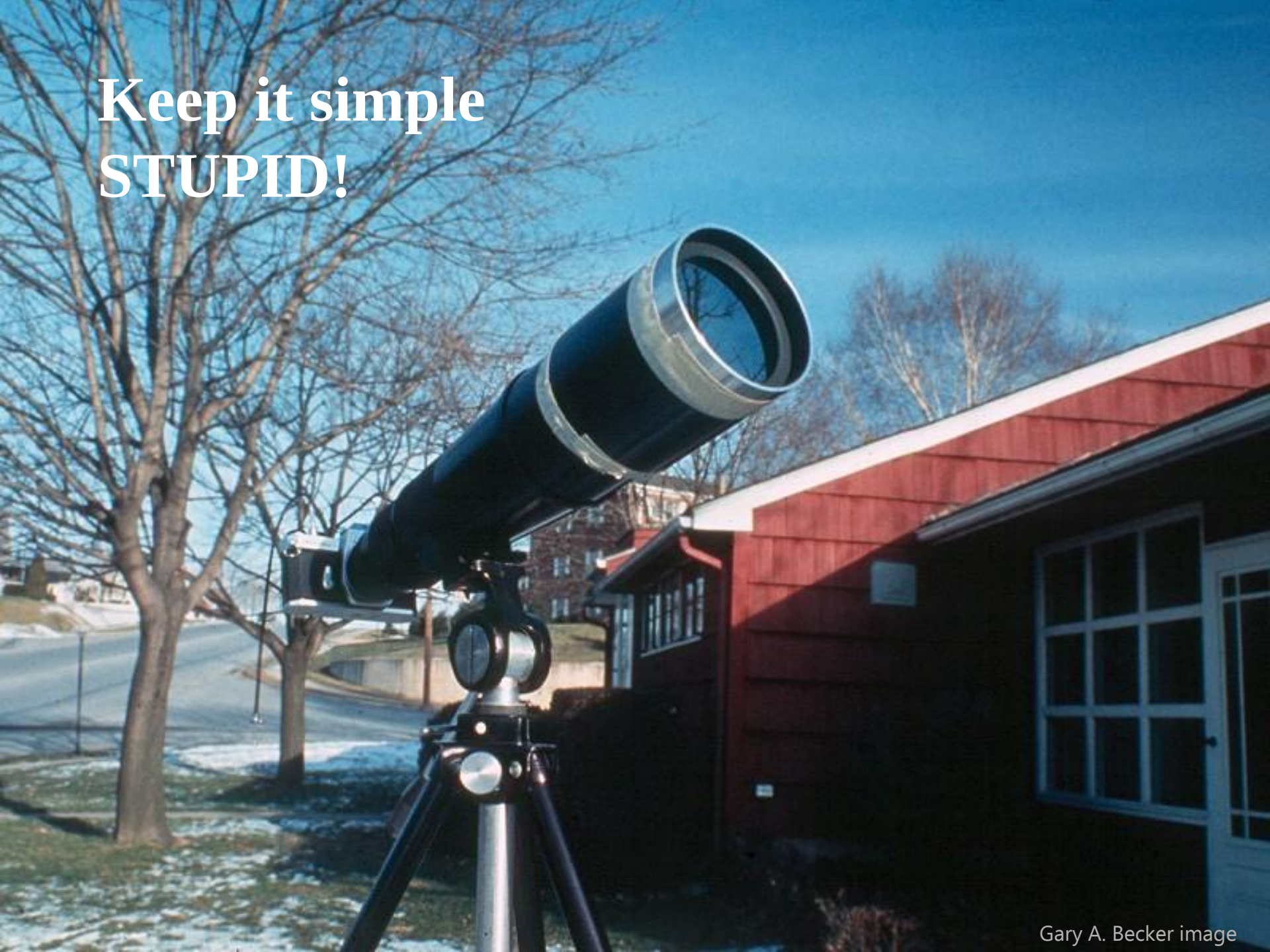
Gary A. Becker images


Solar Projection
October 12, 1977
Gary A. Becker image

May 10, 1994,
Canutillo, Texas
Gary A. Becker image

Gary A. Becker image

Keep it simple STUPID!



Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

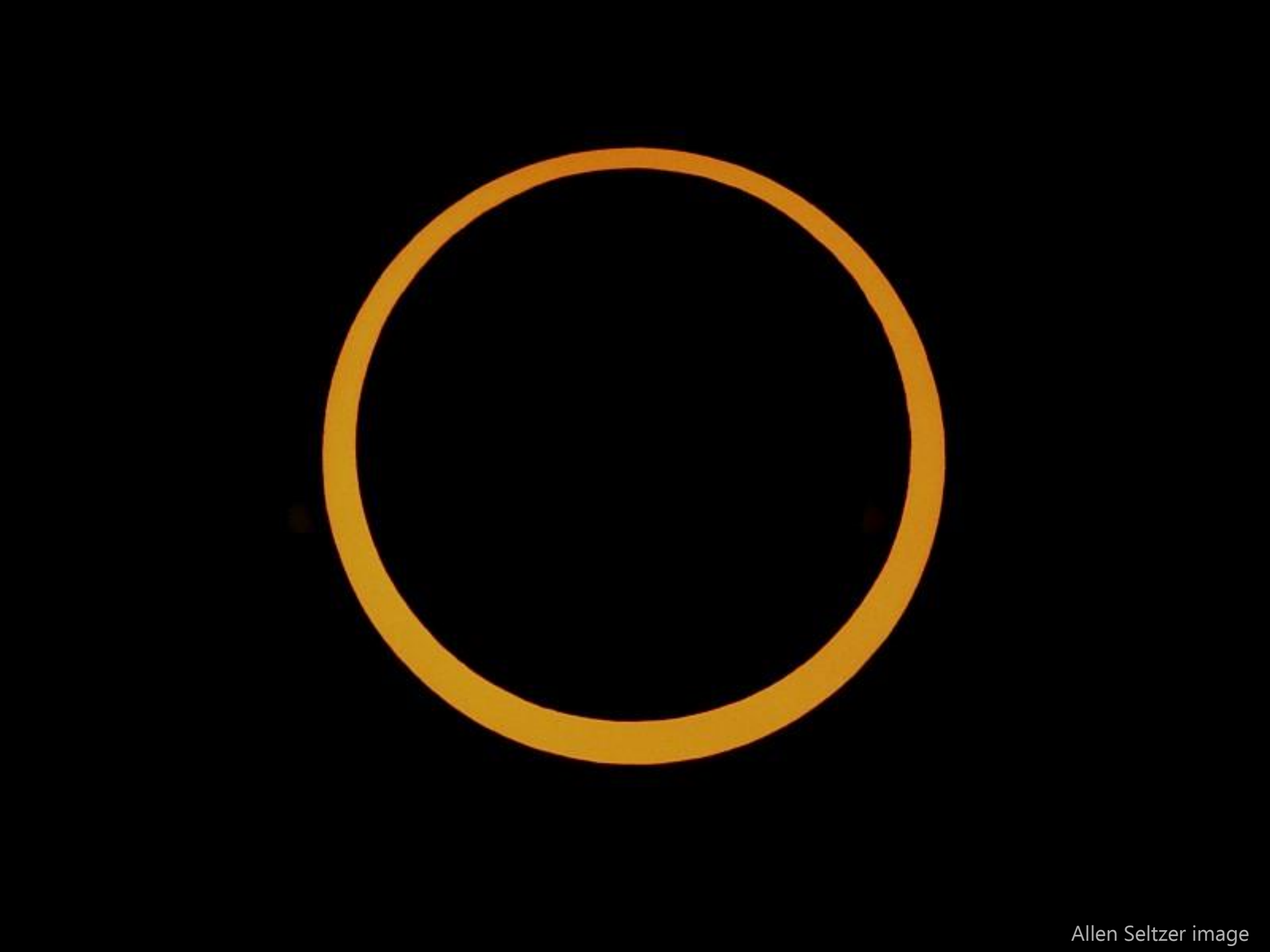
Gary A. Becker image

Gary A. Becker image

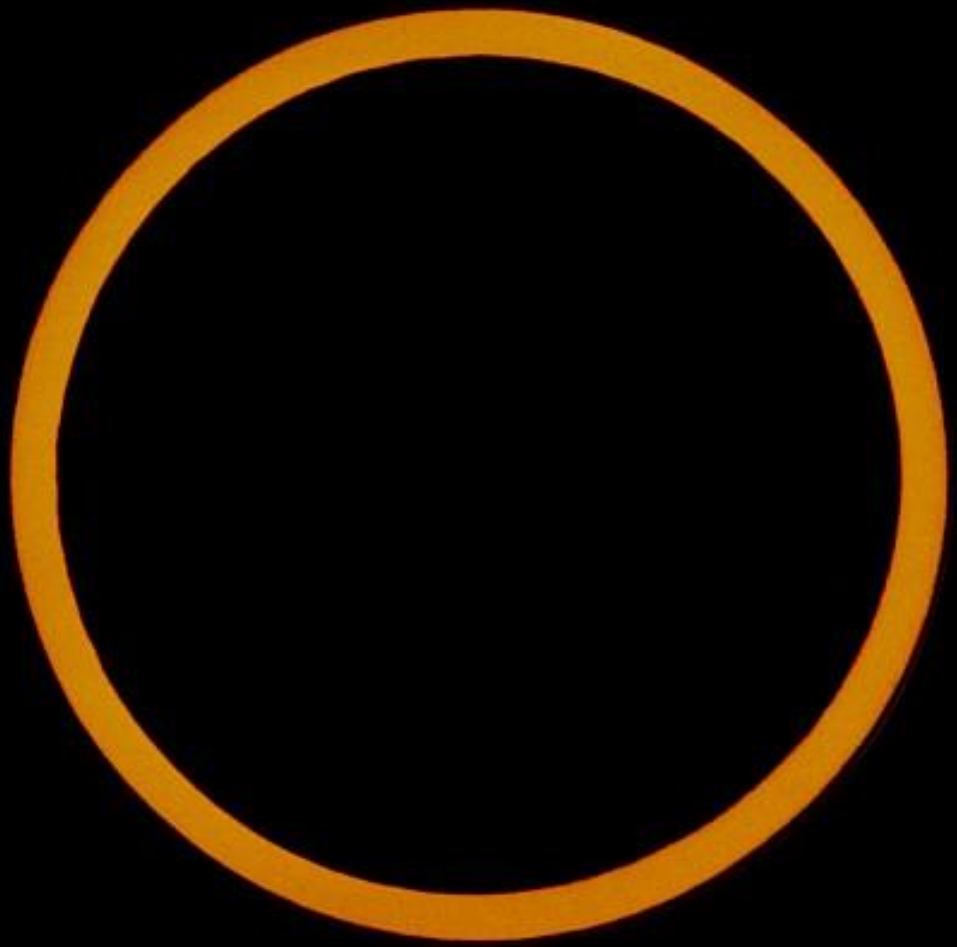
Allen Seltzer image

Allen Seltzer image

Allen Seltzer image



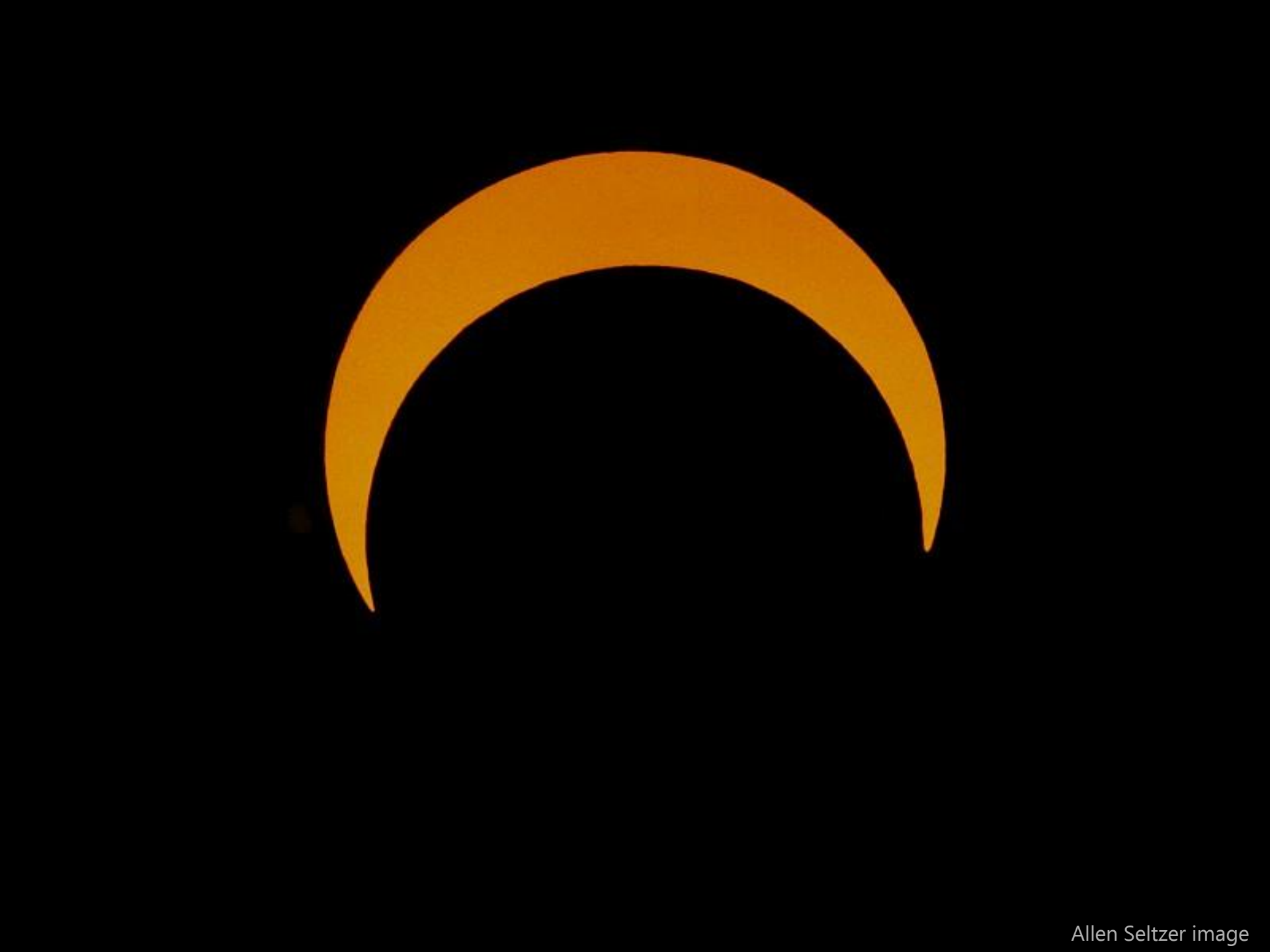
Allen Seltzer image



Allen Seltzer image

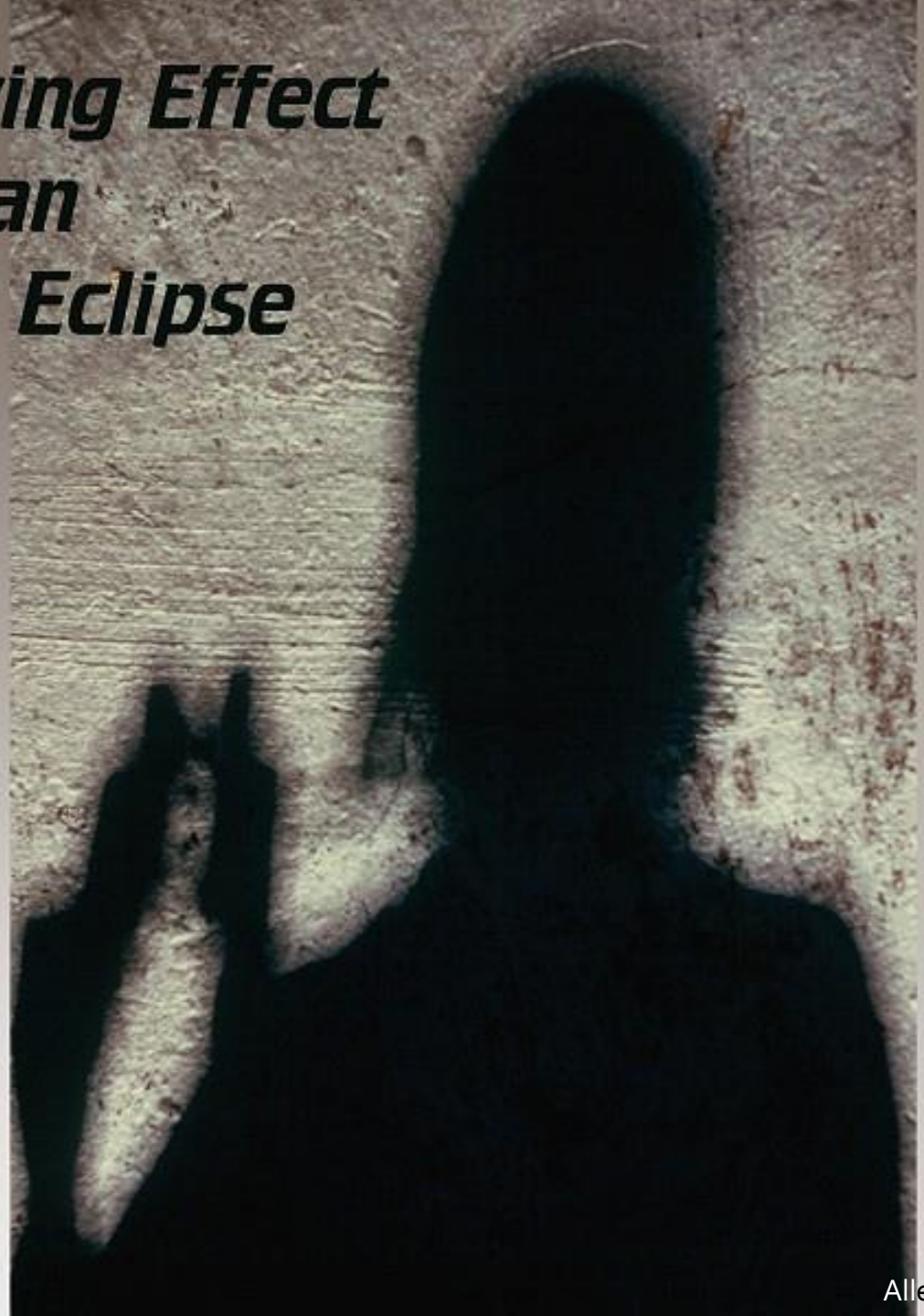
Allen Seltzer image

Allen Seltzer image



Allen Seltzer image

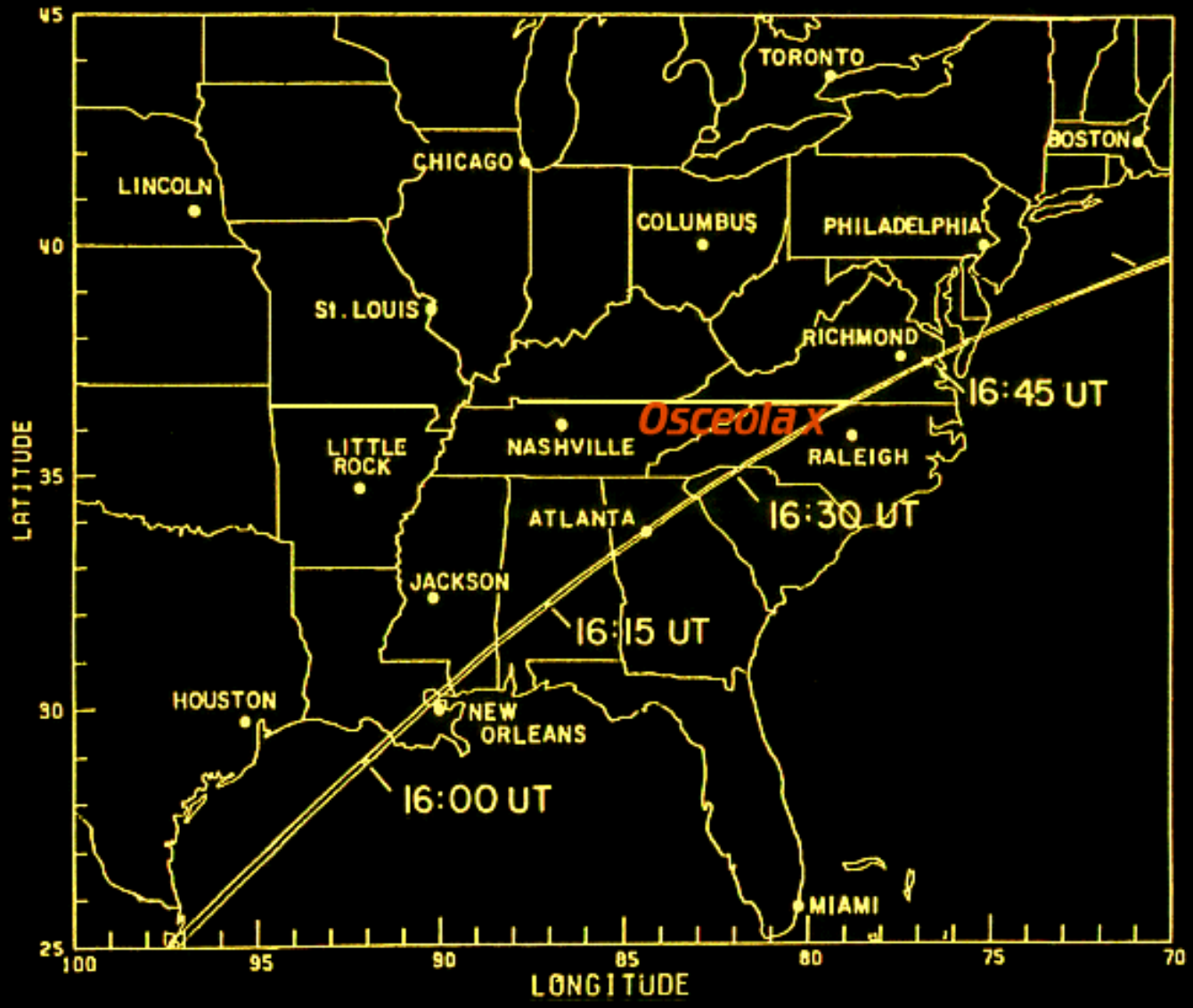
Shadowing Effect During an Annular Eclipse



Allen Seltzer image

Allen Seltzer image

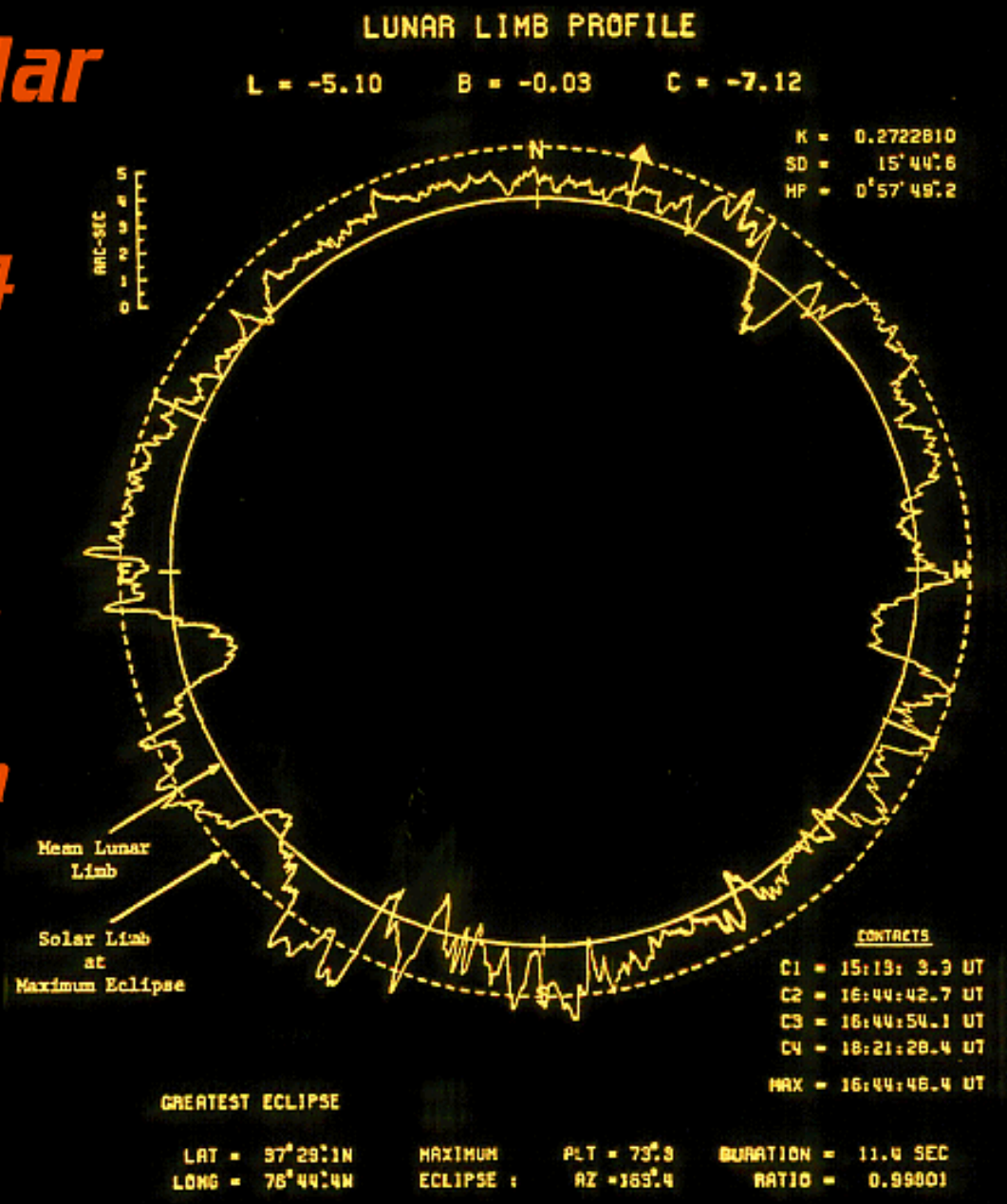
Annular Eclipse–May 30, 1984



US Naval Observatory

Broken Annular Eclipse May 30, 1984

Difference in angular diameter between the sun and the moon



US Naval Observatory

Gary A. Becker image

Gary A. Becker image

Charles Tackus image

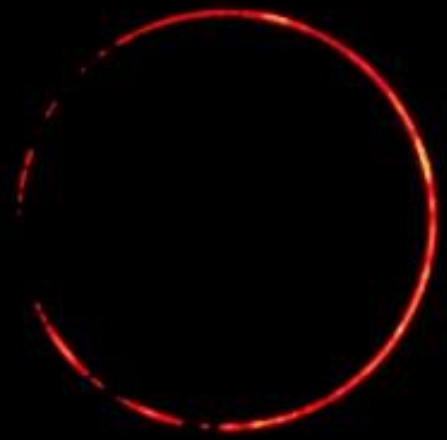
Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image



Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

20 minutes before broken annularity

Gary A. Becker image

5 minutes before broken annularity

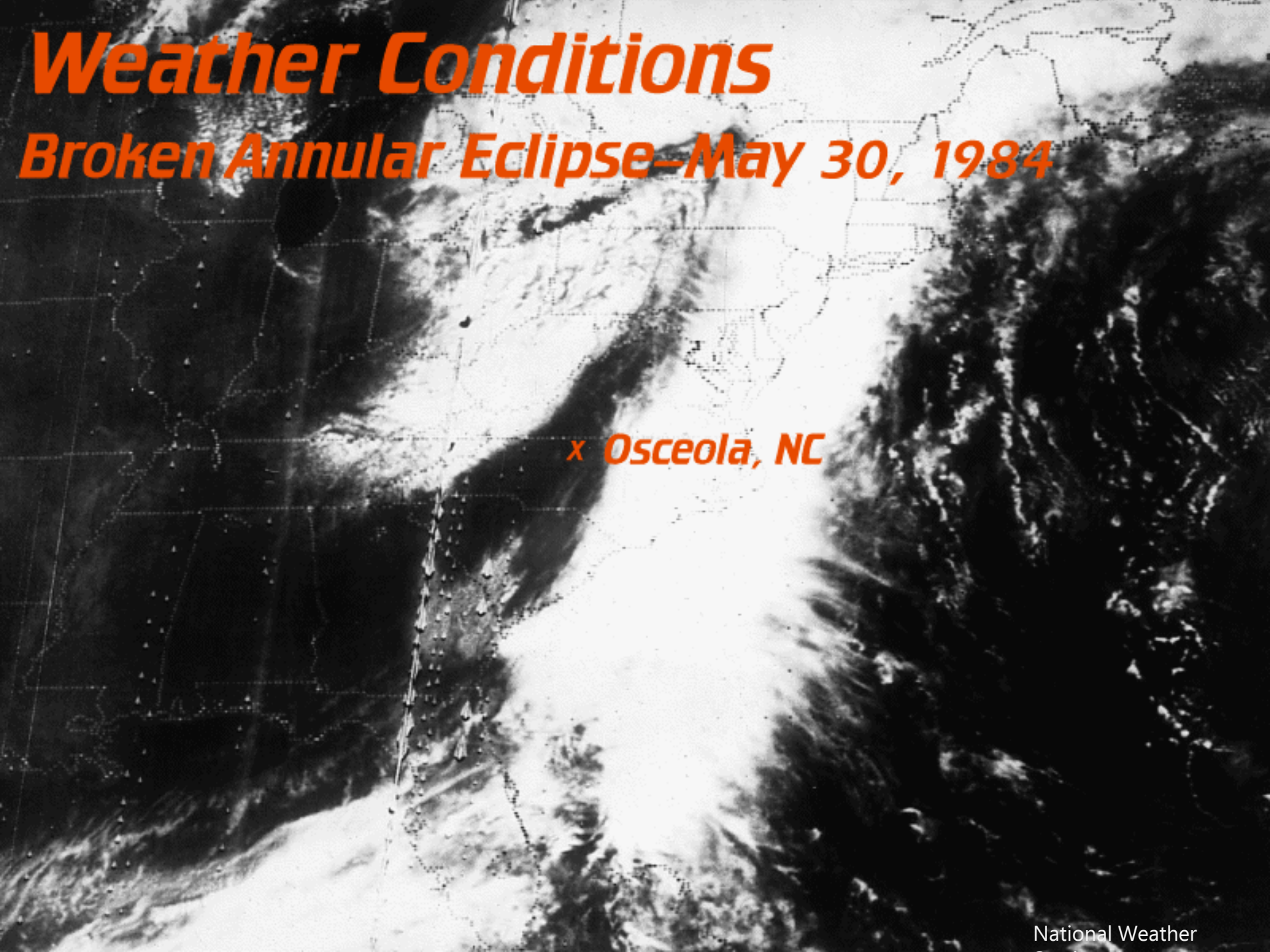
Gary A. Becker image

1 minute before broken annularity

Gary A. Becker image

Weather Conditions

Broken Annular Eclipse–May 30, 1984



National Weather

Annular Eclipse of May 20, 2012

Chaco Culture National Historical Park
Nageezi, New Mexico

Gary A. Becker image

Jesse Leayman image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

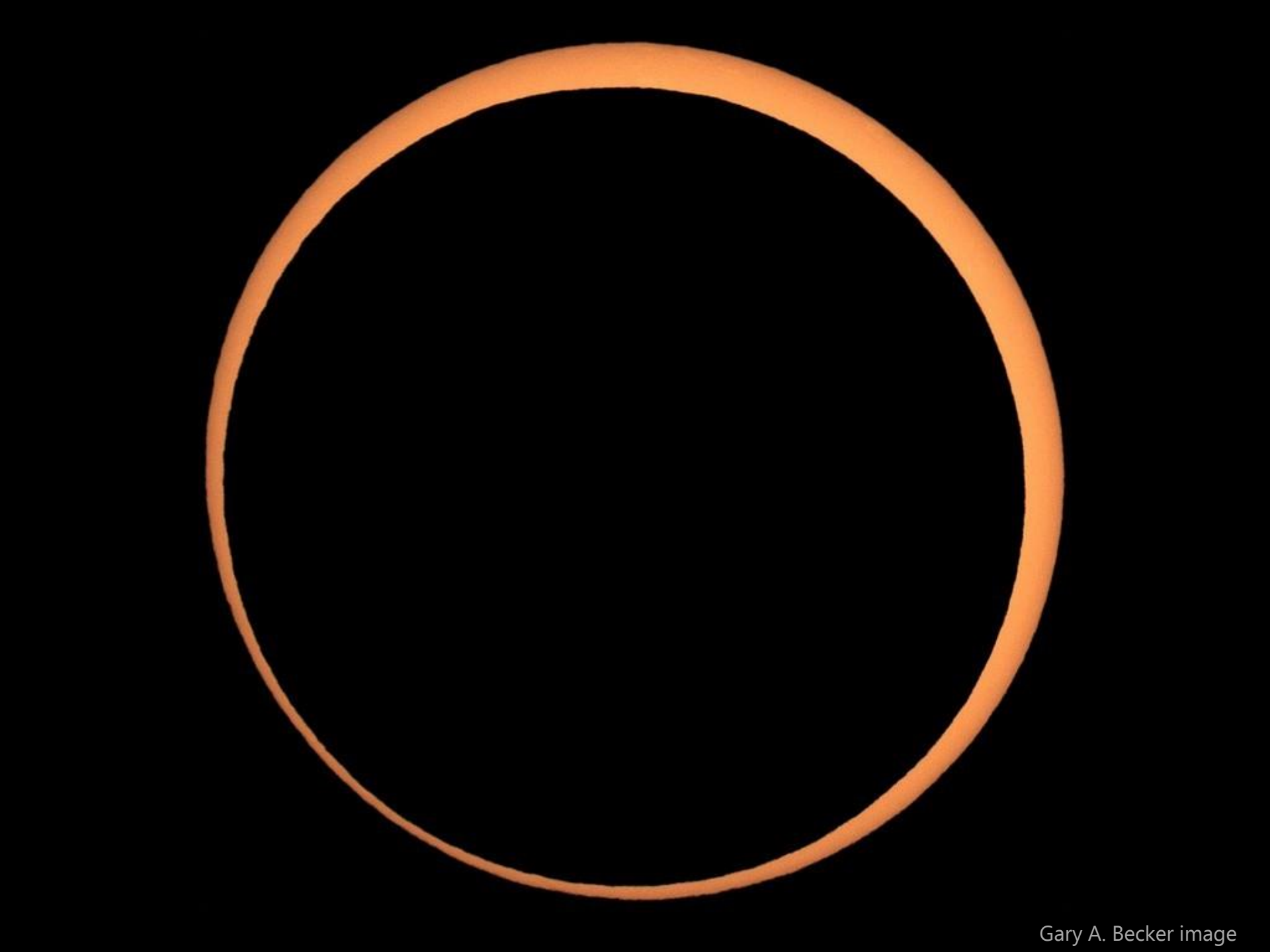
Gary A. Becker image

Gary A. Becker image

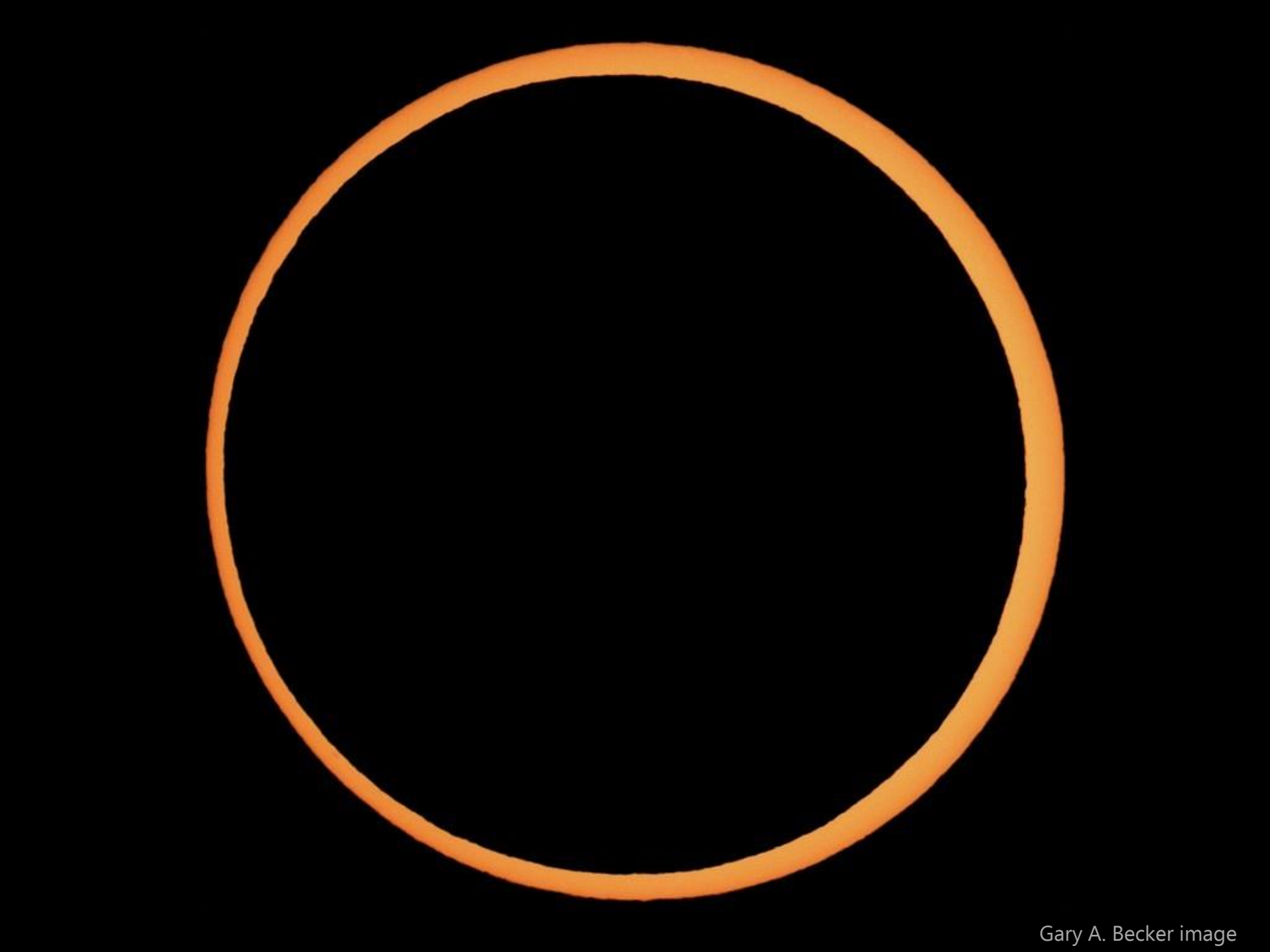
Gary A. Becker image

Gary A. Becker image

Gary A. Becker image



Gary A. Becker image



Gary A. Becker image

Gary A. Becker image

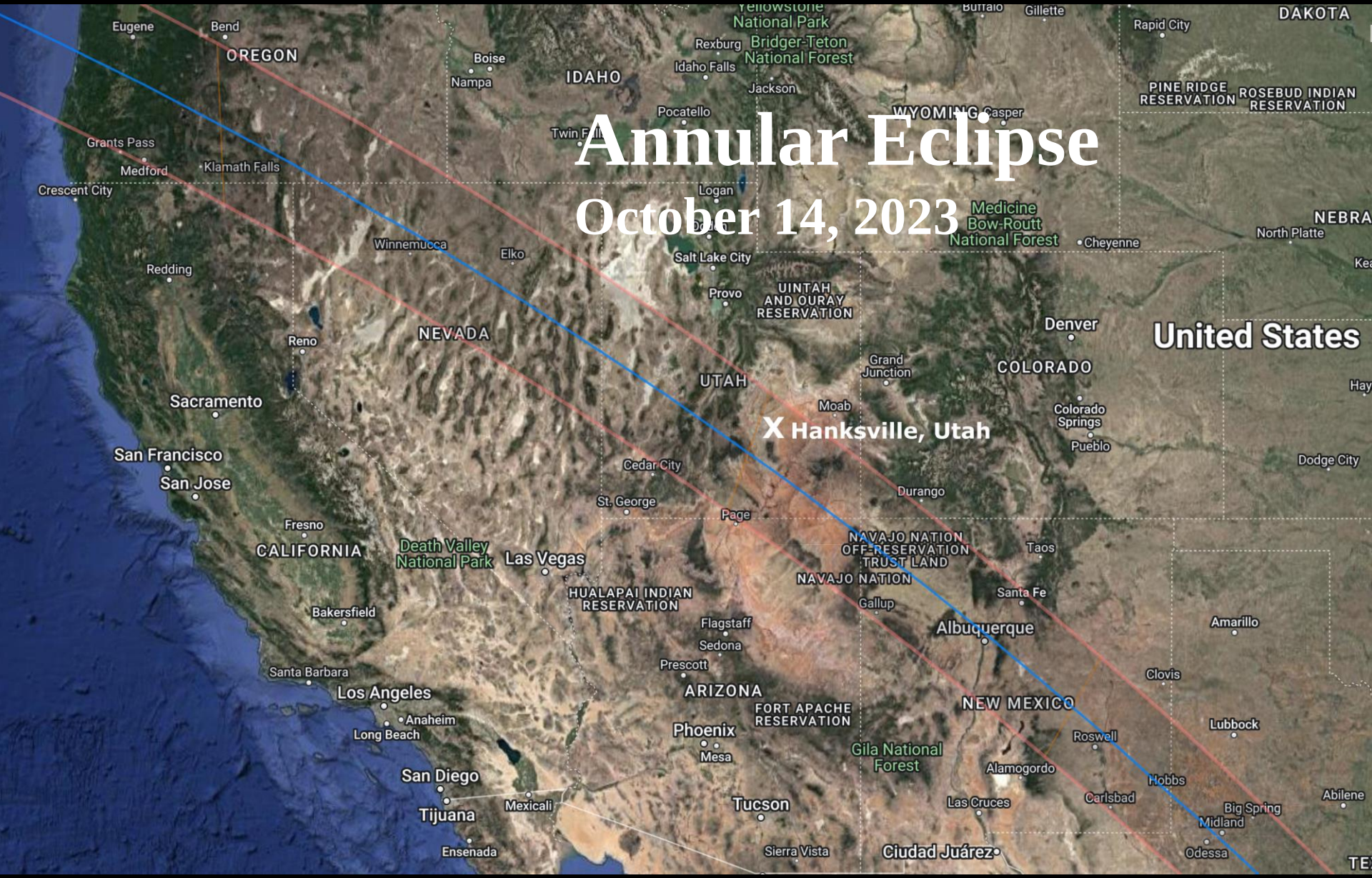
Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image


Annular Eclipse
October 14, 2023
X Hanksville, Utah
United States
Eugene
Bend
OREGON
Boise
Nampa
IDAHO
Yellowstone National Park
Rexburg
Bridger-Teton National Forest
Idaho Falls
Jackson
Buffalo
Gillette
Rapid City
DAKOTA
PINE RIDGE RESERVATION
ROSEBUD INDIAN RESERVATION
Pocatello
Twin Falls
WYOMING
Casper
Grants Pass
Medford
Klamath Falls
Crescent City
Logan
Medicine Bow-Routt National Forest
Cheyenne
North Platte
NEBRA
Winnemucca
Elko
Salt Lake City
Redding
Provo
UINTAH AND OURAY RESERVATION
Denver
Reno
NEVADA
Grand Junction
COLORADO
UTAH
Sacramento
Moab
Colorado Springs
Pueblo
San Francisco
San Jose
Cedar City
Dodge City
Durango
St. George
Page
Fresno
CALIFORNIA
Death Valley National Park
Las Vegas
NAVAJO NATION OFF-RESERVATION TRUST LAND
Taos
NAVAJO NATION
HUALAPAI INDIAN RESERVATION
Santa Fe
Gallup
Bakersfield
Flagstaff
Albuquerque
Amarillo
Sedona
Prescott
Santa Barbara
Clovis
Los Angeles
ARIZONA
NEW MEXICO
Anaheim
Long Beach
FORT APACHE RESERVATION
Lubbock
Phoenix
Roswell
Mesa
Gila National Forest
Alamogordo
San Diego
Hobbs
Tucson
Las Cruces
Carlsbad
Abilene
Mexicali
Tijuana
Big Spring
Midland
Ensenada
Sierra Vista
Ciudad Juárez
Odessa

Gary A. Becker image

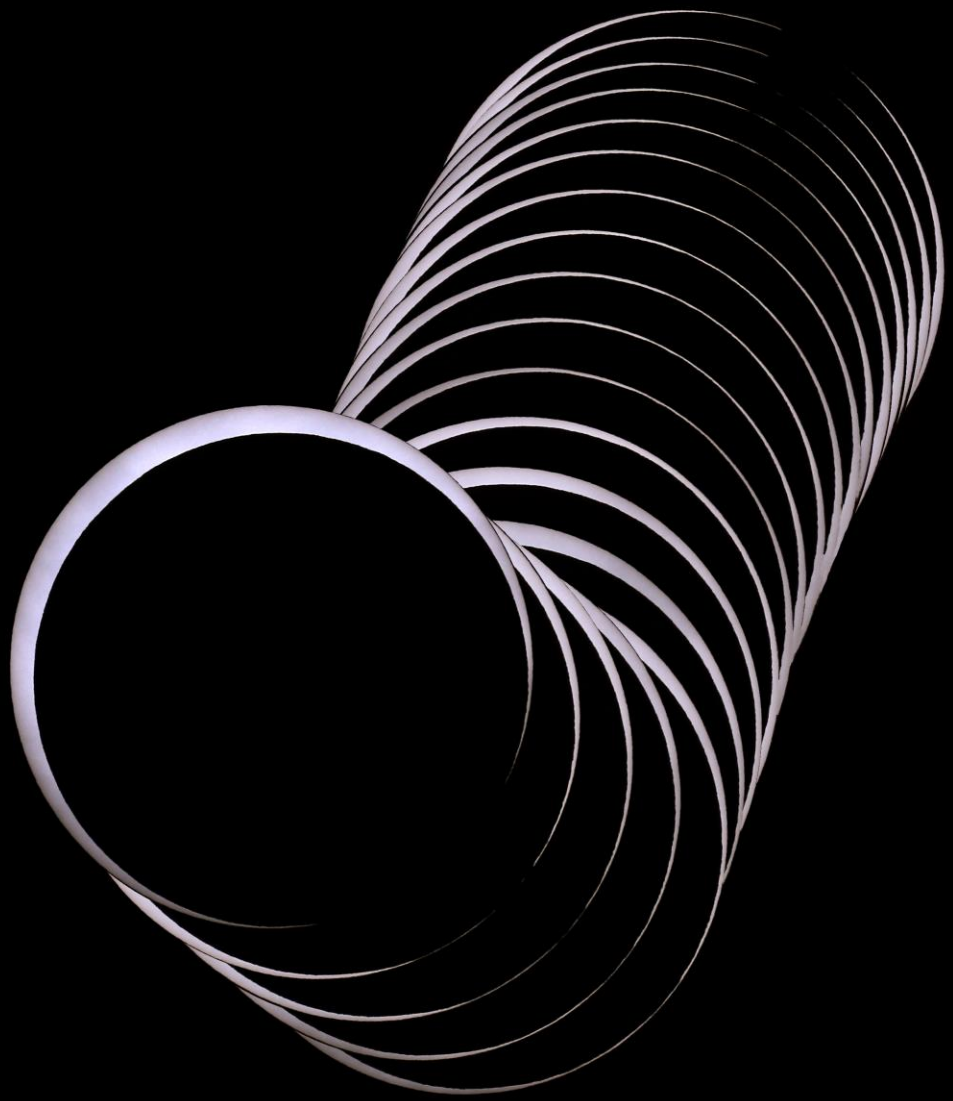
Dust Storm

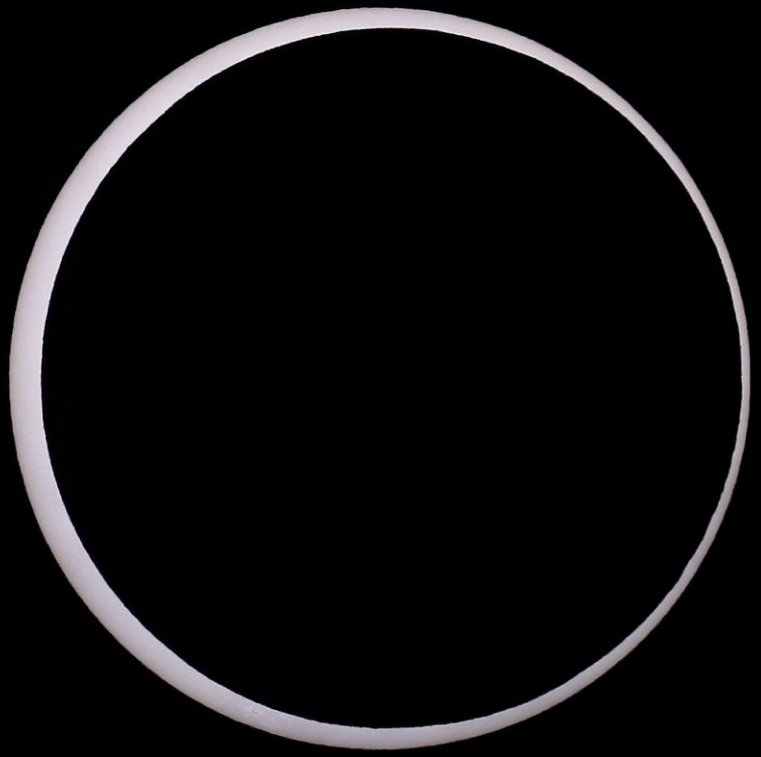
Gary A. Becker images

Goal: Capture Baily's Beads

Capturing Baily's Beads

Annular Eclipse, October 14, 2023
MDRS, Hanksville, Utah





Gary A. Becker images

Baily's Beads

1.43 seconds
between frames

Gary A. Becker images

Peter K. Detterline image

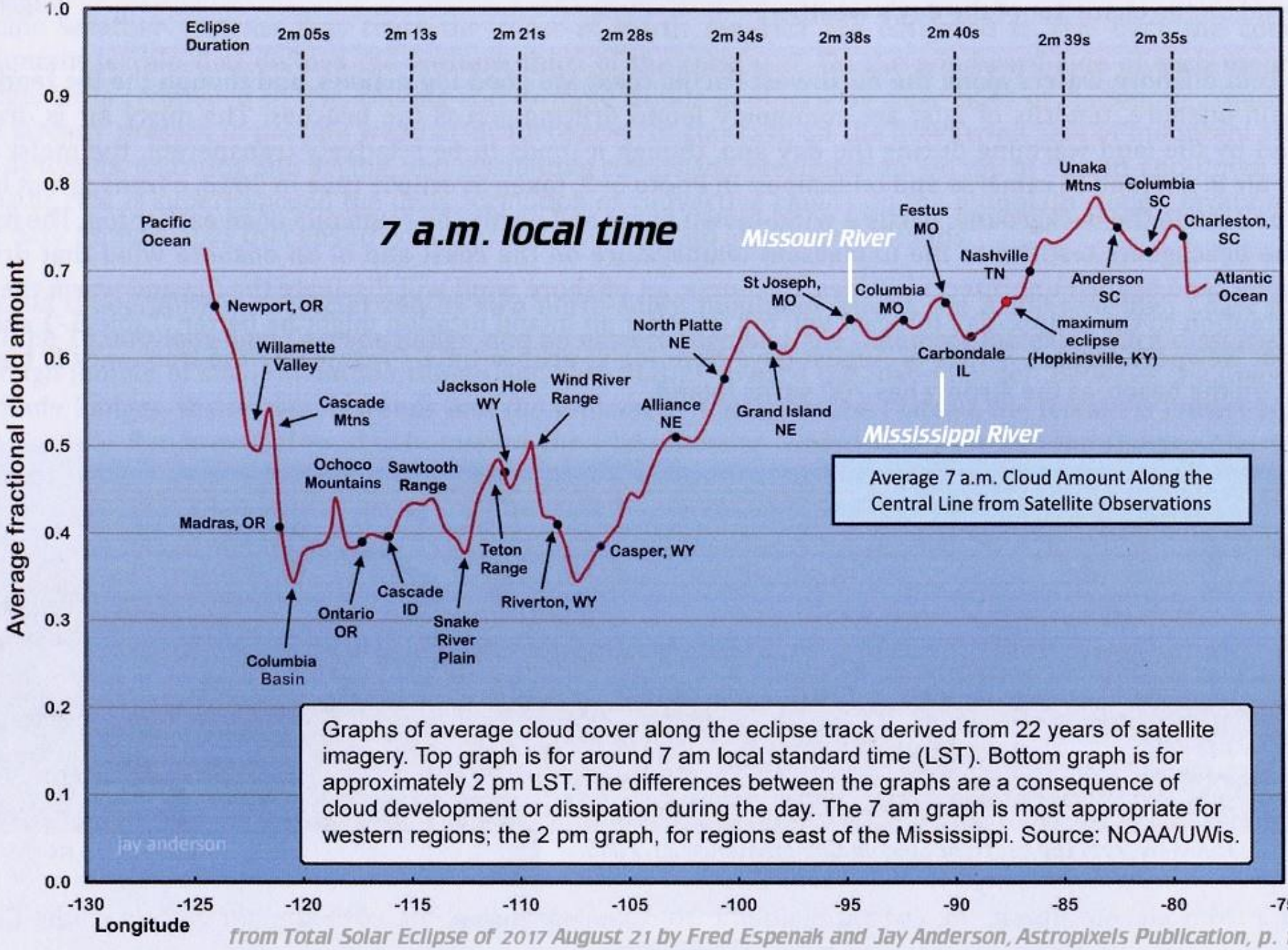
Greatest Duration: The position on the earth's surface where totality lasts the longest (2 min 40.2 sec.).

Greatest Eclipse: The moment when the moon's shadow passes closest to the center of the earth.

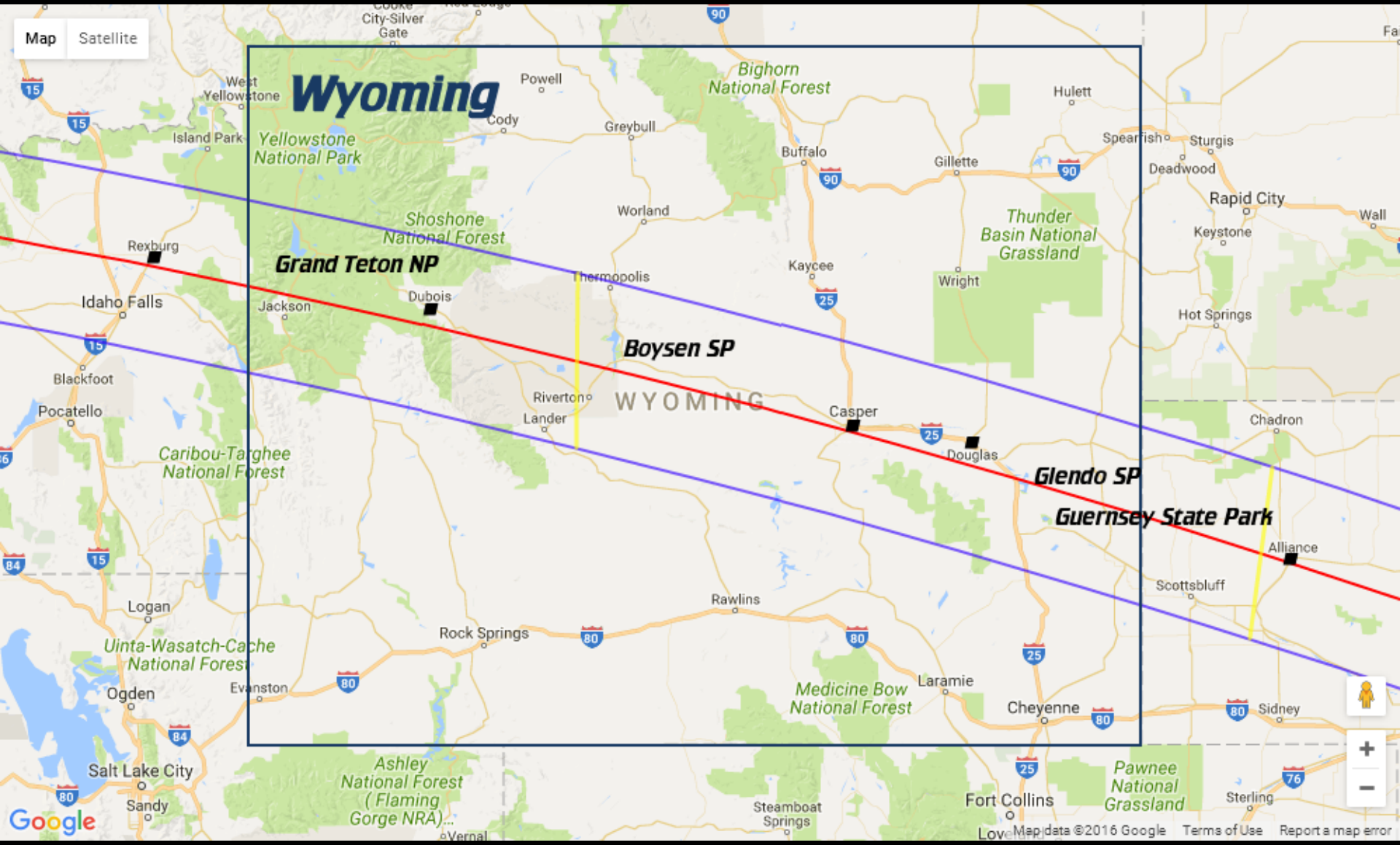
https://eclipse.gsfc.nasa.gov

Peter K. Detterline image

Graph of Average Cloud Cover Along the Eclipse Path

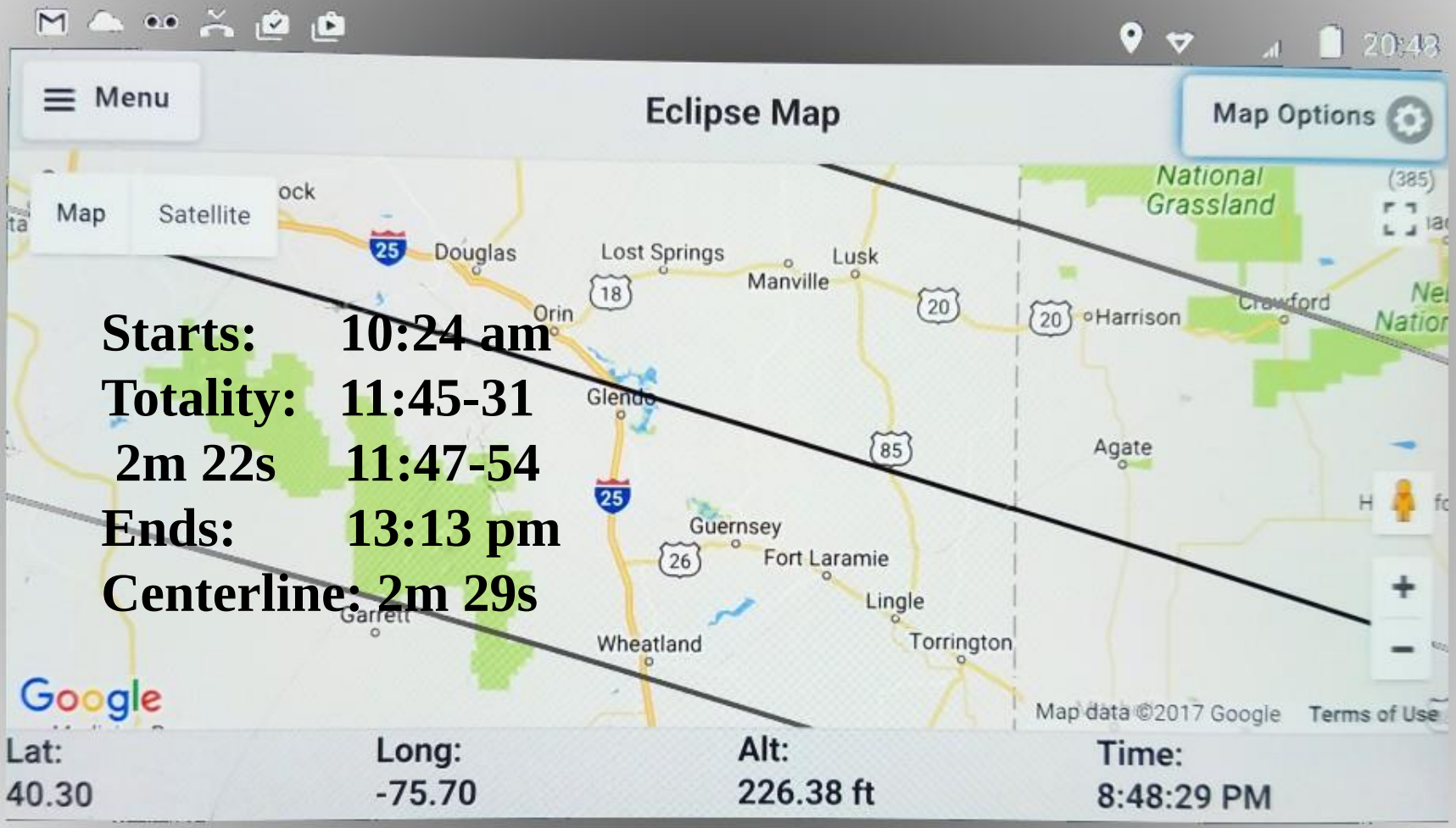


Graphs of average cloud cover along the eclipse track derived from 22 years of satellite imagery. Top graph is for around 7 am local standard time (LST). Bottom graph is for approximately 2 pm LST. The differences between the graphs are a consequence of cloud development or dissipation during the day. The 7 am graph is most appropriate for western regions; the 2 pm graph, for regions east of the Mississippi. Source: NOAA/UWis.


Map
Satellite
Wyoming
Grand Teton NP
Boysen SP
Glendo SP
Guernsey State Park
WYOMING
Yellowstone National Park
Shoshone National Forest
Bighorn National Forest
Thunder Basin National Grassland
Caribou-Targhee National Forest
Uinta-Wasatch-Cache National Forest
Medicine Bow National Forest
Ashley National Forest (Flaming Gorge NRA)...
Pawnee National Grassland
Rexburg
Idaho Falls
Blackfoot
Pocatello
Jackson
Dubois
Thermopolis
Worland
Cody
Powell
Greybull
Buffalo
Gillette
Hulett
Spearfish
Sturgis
Deadwood
Rapid City
Wall
Keystone
Hot Springs
Kaycee
Wright
Riverton
Lander
Casper
Douglas
Chadron
Alliance
Scottsbluff
Rawlins
Rock Springs
Laramie
Cheyenne
Sidney
Fort Collins
Sterling
Steamboat Springs
Logan
Ogden
Evanston
Salt Lake City
Sandy
Google
Map data ©2016 Google
Terms of Use
Report a map error

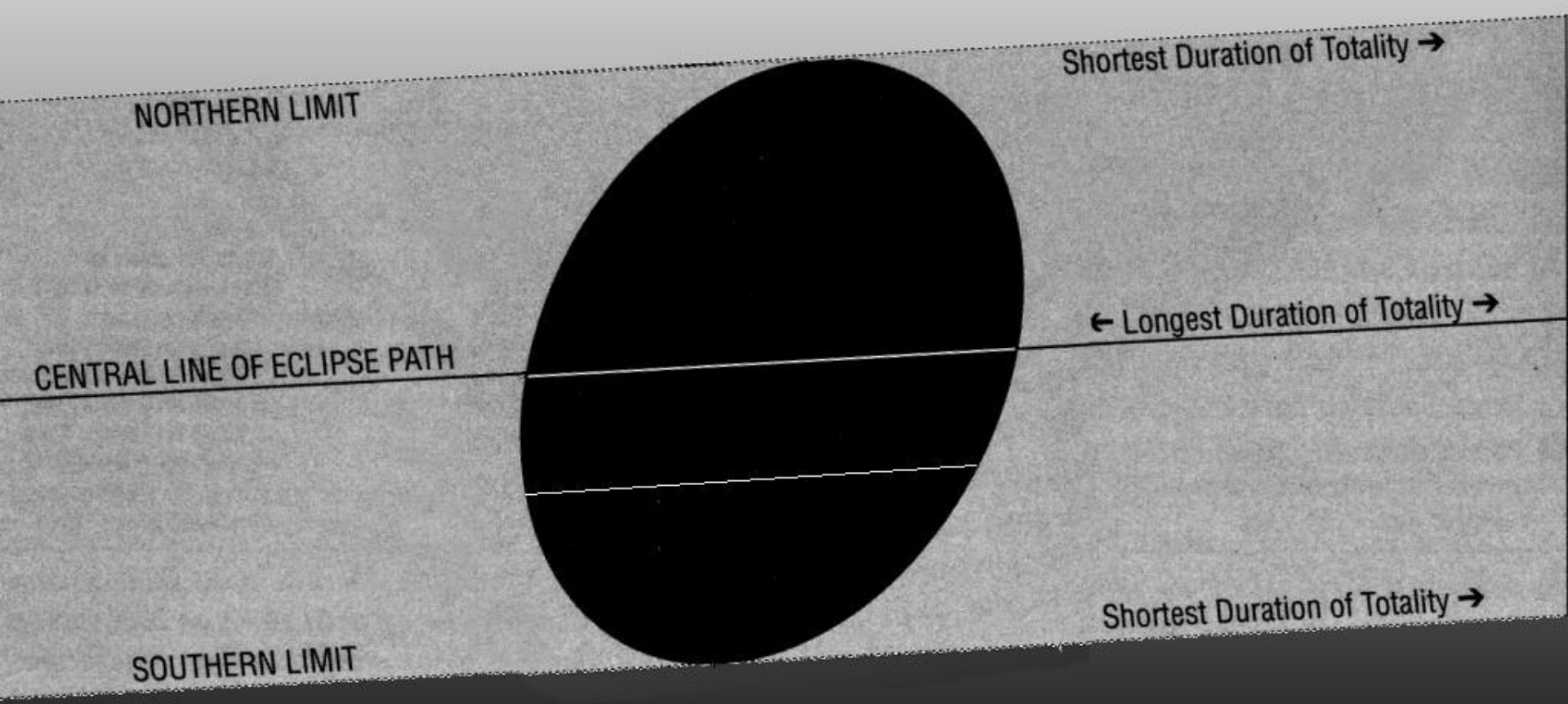
Eclipse Chaser Detailed Map

Guernsey State Park, Wyoming



Eclipse Explorer Application/Gary A. Becker slide

Distance from Centerline not Overly Important!



from Eclipse by Bryan Brewer, Earth View, Inc., p. 76

Umbra Shapes

Border of Oregon and Idaho

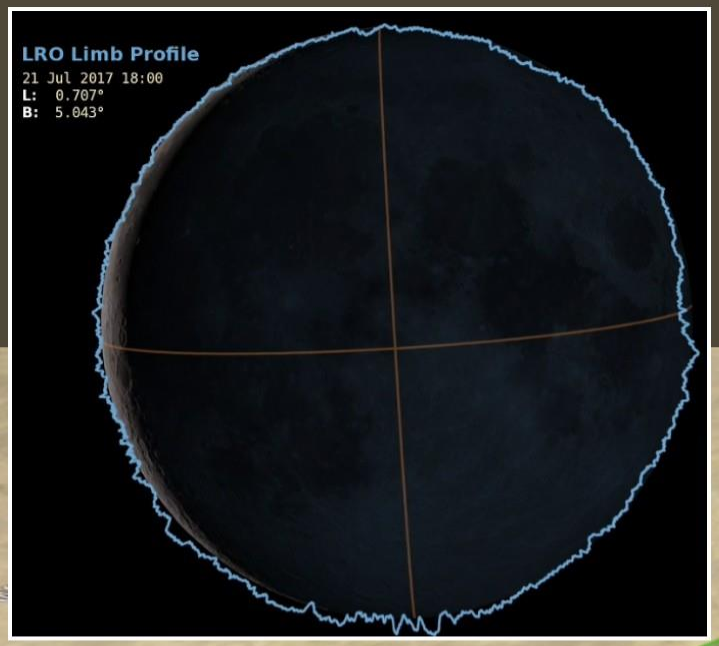
Smooth Limb

True Limb

True Limb + Earth Elevation

	Monday, August 21, 2017
Time	11:26:25 a.m. MDT
Center	44°22'28"N, 116°56'18"W, 899m
Duration	2m 10.6s
Sun Alt, Az	45.2°, 125.2°
Moon L, B, C	5.20°, -0.16°, 21.87°
Moon Distance	367399.7 km

NASA data sets visualizer, Ernie Wright

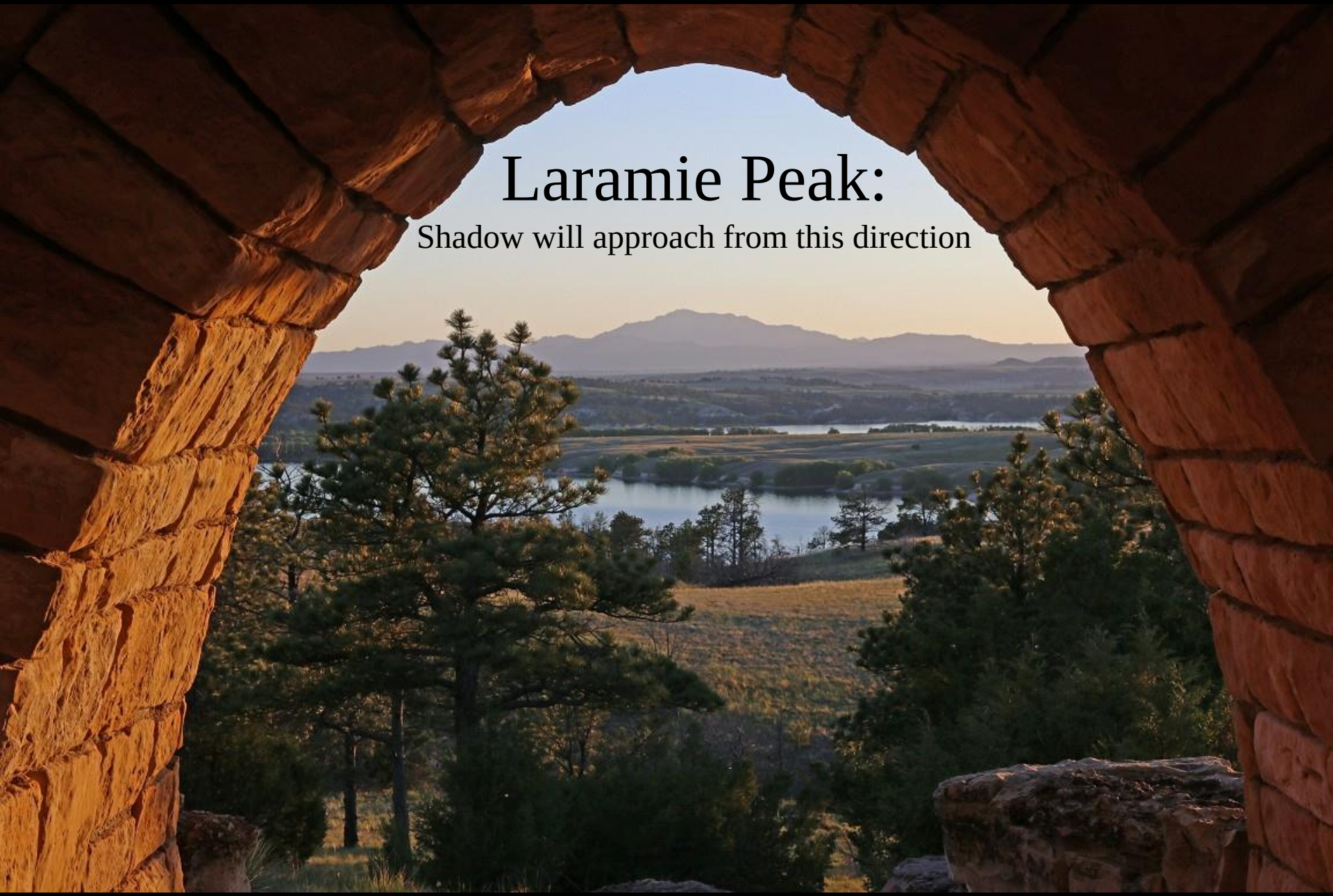


True Shape of Umbra

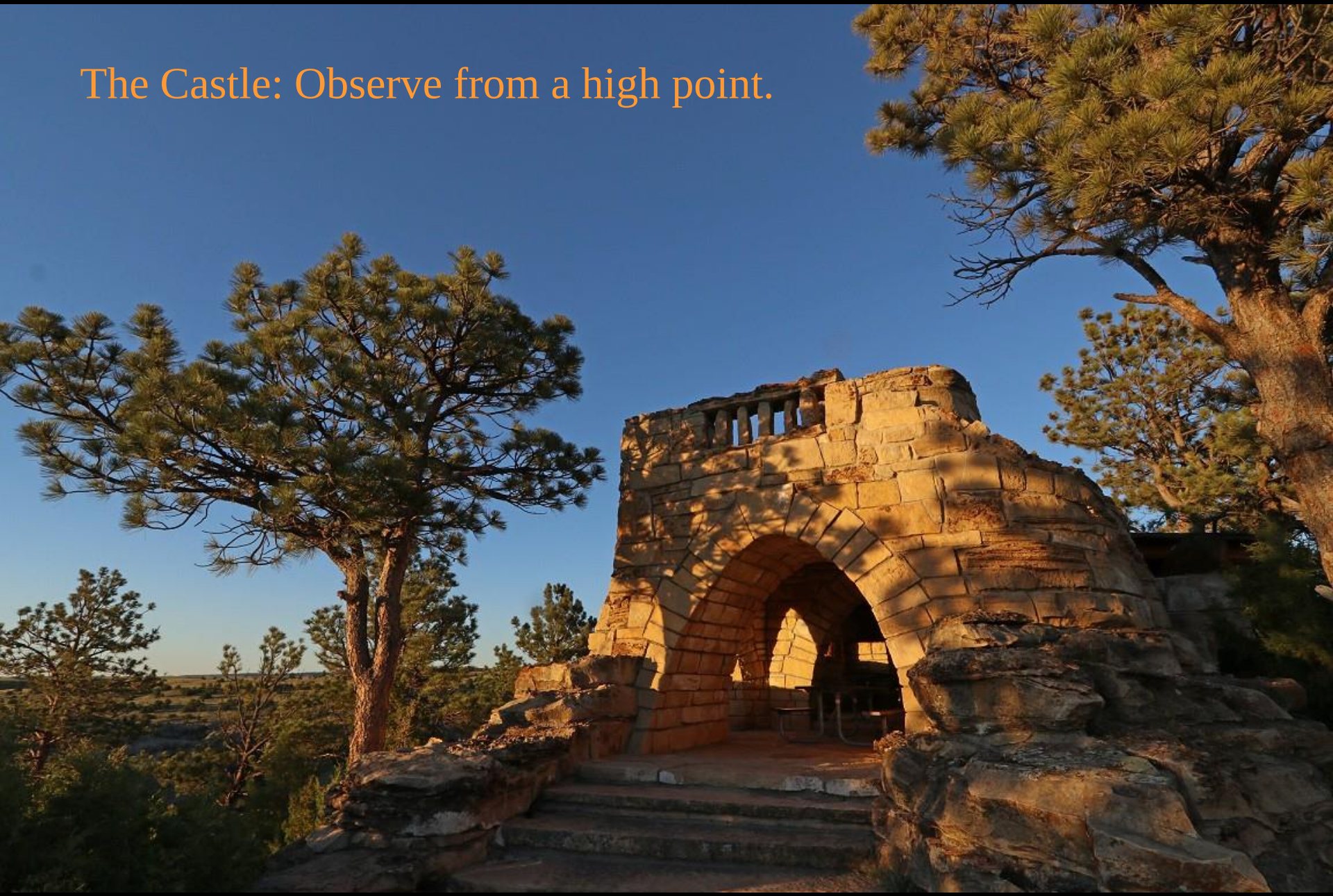
Limb profile of moon
Topography of Earth

The duration Guernsey, WY was in the moon's shadow was nearly the same as the centerline.

NASA data sets visualizer, Ernie Wright



Gary A. Becker image



Gary A. Becker image

Guernsey Reservoir in the direction of the departing shadow!

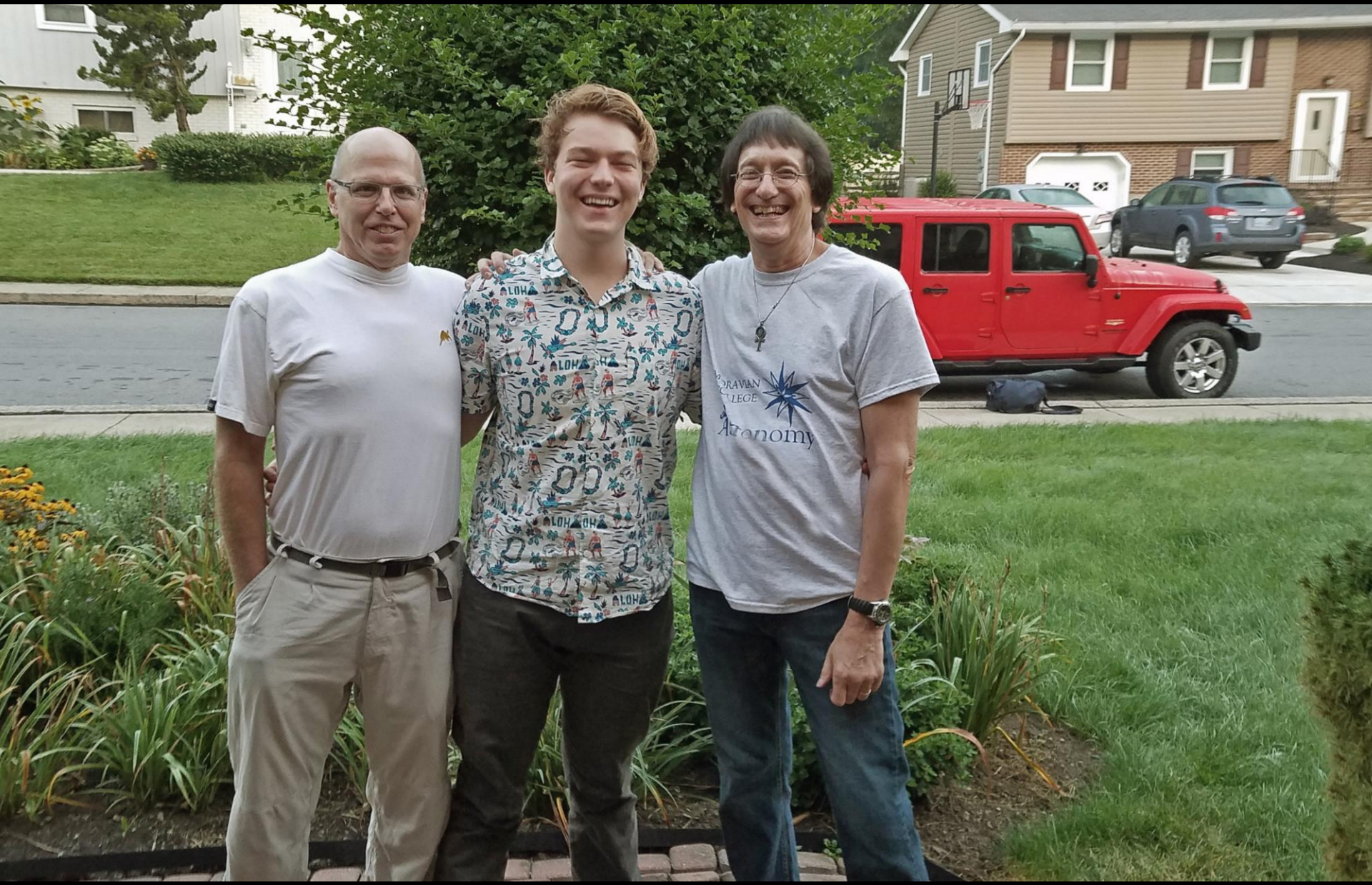
Gary A. Becker image

Why orange near the edge of the shadow?

Gary A. Becker image

A Cactus Attacked Us: Watch out for these guys!

Gary A. Becker image



Susan B. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

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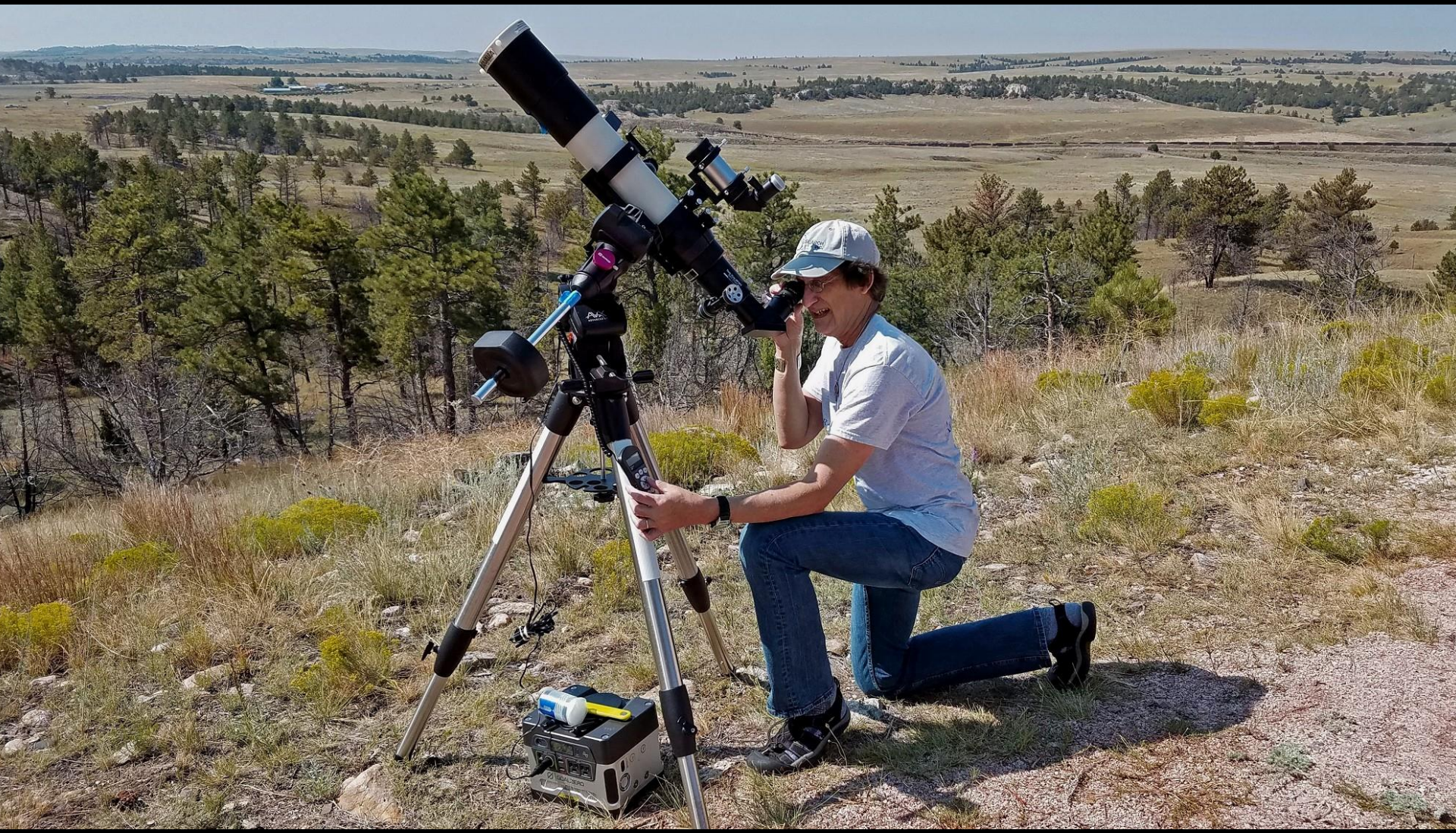
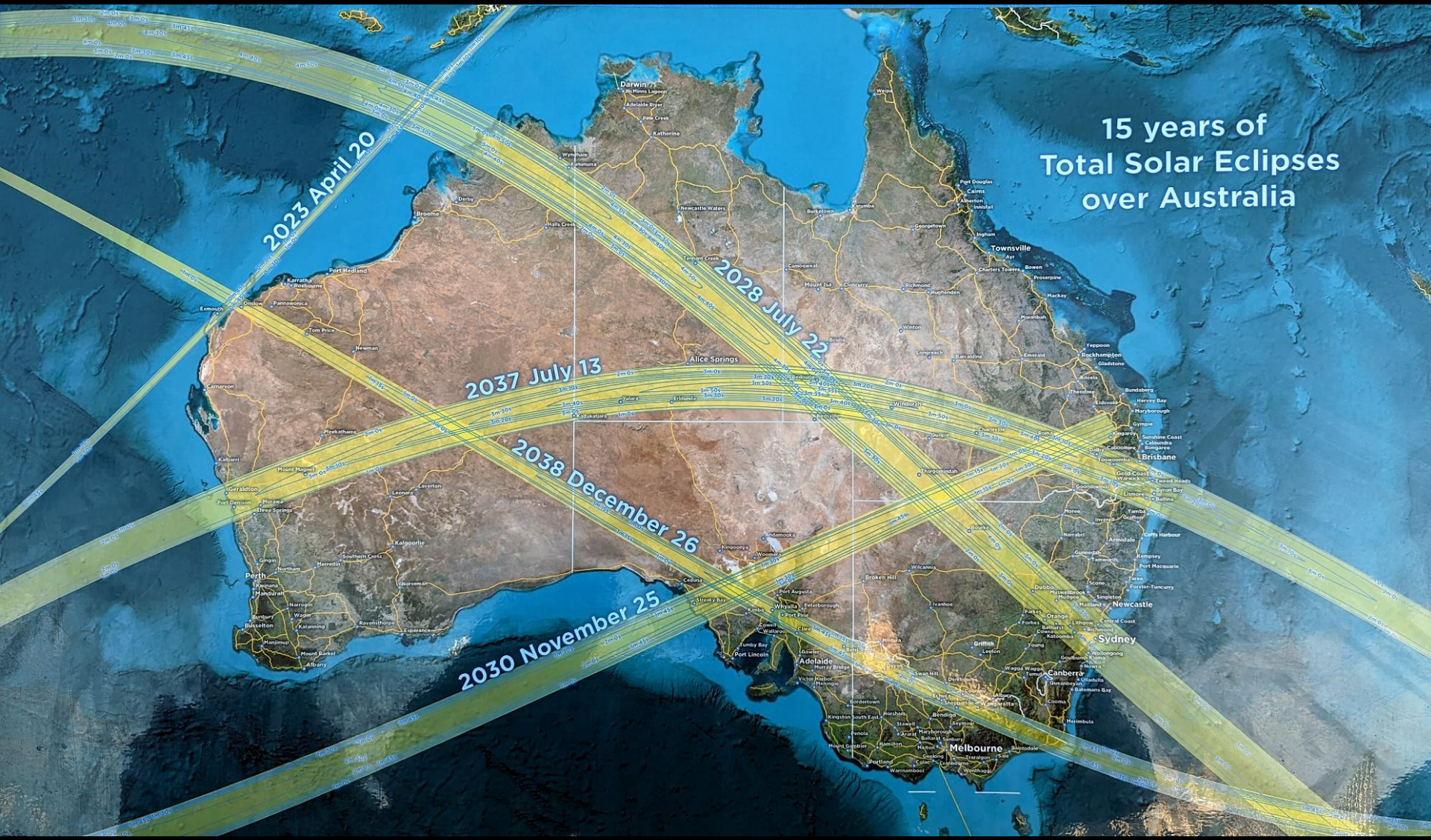
Gary A. Becker image

Gary A. Becker images



Peter K. Detterline image



GreatAmericanEclipse.com

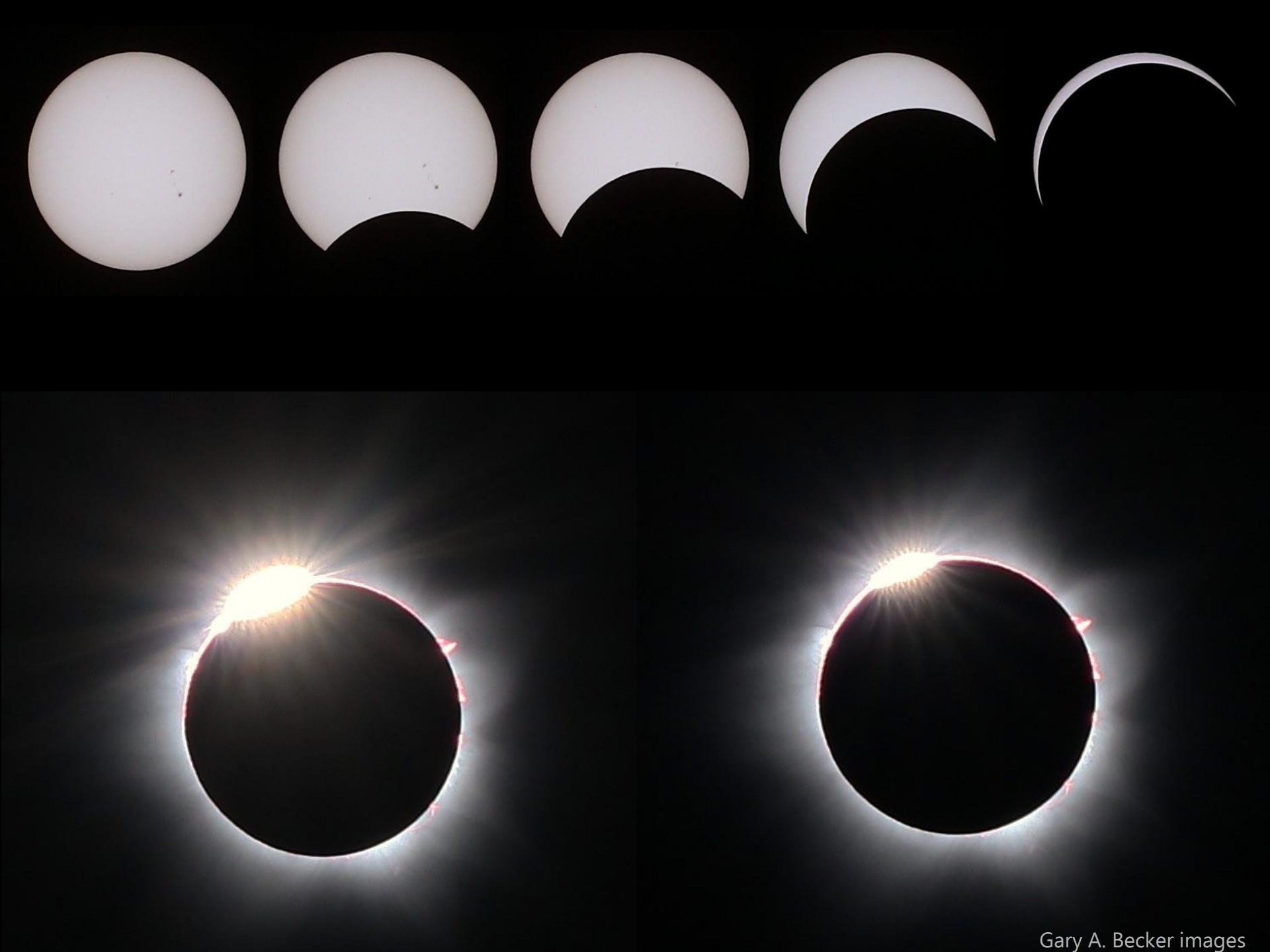
North West Coast

Australian Hybrid Eclipse

April 20, 2023

Goal: Capture the Ingress Diamond Ring

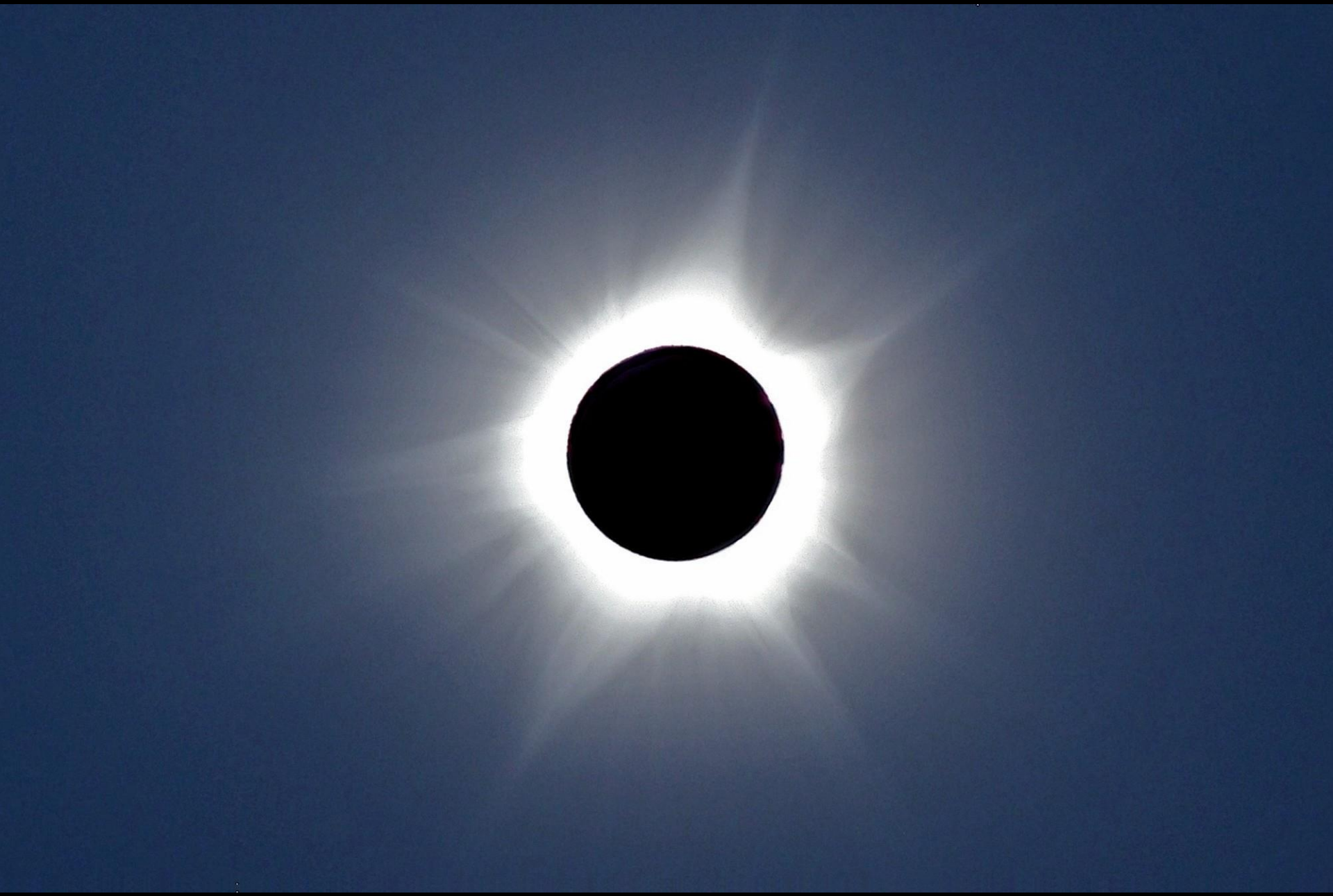
Gary A. Becker images



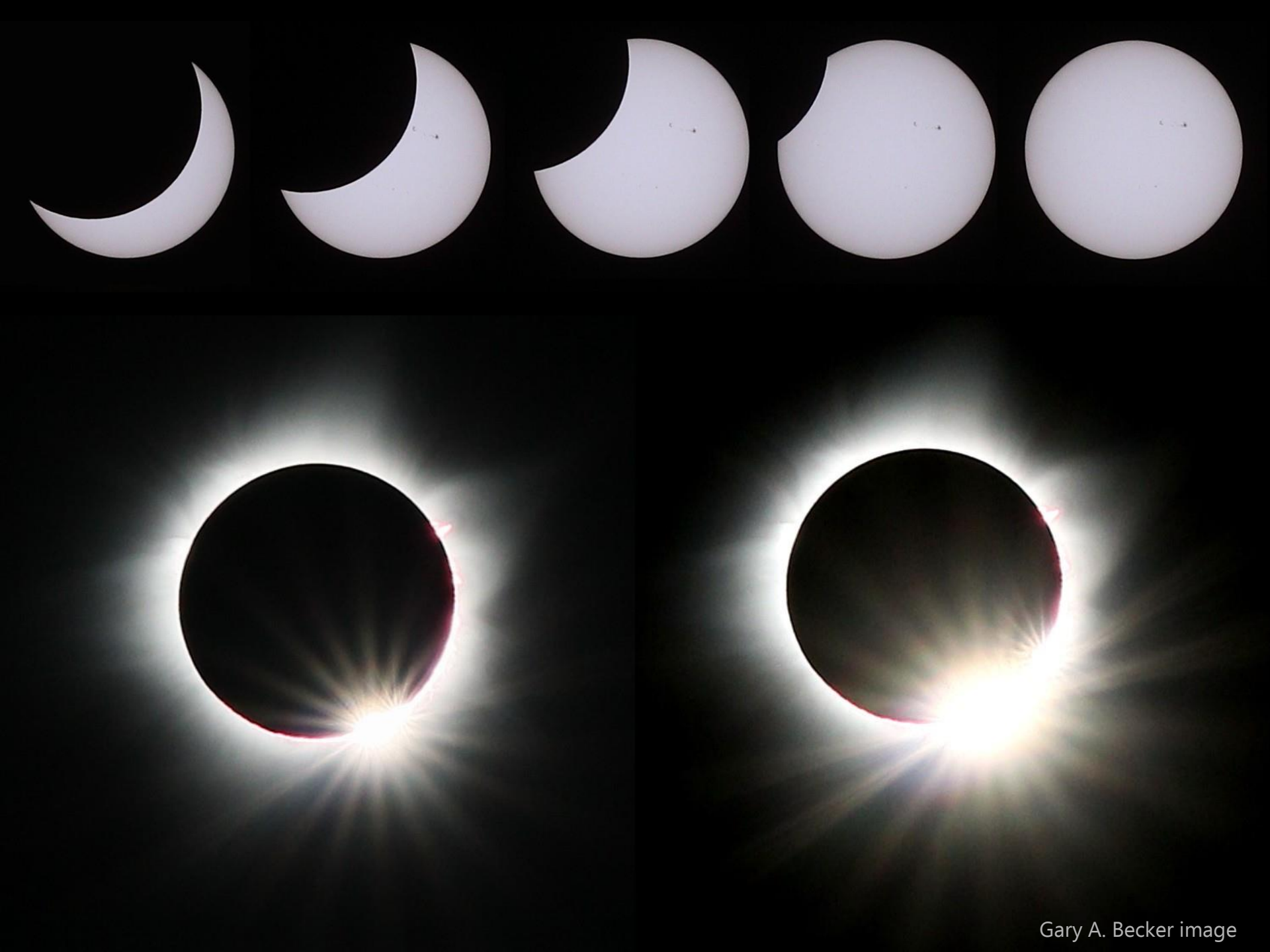
Gary A. Becker images

Gary A. Becker image

Gary A. Becker image



Gary A. Becker image



Gary A. Becker image

Aruba
February 26, 1998
United States
Mexico
Cuba
Puerto Rico
Guatemala
Nicaragua
Costa Rica
Panama
Venezuela
Colombia
Ecuador
Peru
Bolivia
Brazil
Guyana
Suriname
French Guiana
Caribbean Sea
Gulf of Mexico
Gulf of California
North Atlantic Ocean
San Francisco
Los Angeles
San Diego
Las Vegas
Dallas
Houston
San Antonio
Monterrey
Guadalajara
Mexico City
Miami
Havana
Santo Domingo
Caracas
Medellín
Bogotá
Cali
Quito
Lima
La Paz
Manaus
Brasília
Goiânia
Belo Horizonte
Natal
Washington
New York
NEVADA
UTAH
COLORADO
KANSAS
MISSOURI
INDIANA
OHIO
WEST VIRGINIA
VIRGINIA
KENTUCKY
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
LOUISIANA
TEXAS
OKLAHOMA
NEW MEXICO
ARIZONA
CALIFORNIA
FLORIDA
STATE OF RORAIMA
STATE OF AMAPÁ
STATE OF AMAZONAS
STATE OF PARÁ
STATE OF MARANHÃO
STATE OF CEARÁ
STATE OF PIAUÍ
STATE OF PARAÍBA
STATE OF ACRE
STATE OF RONDÔNIA
STATE OF TOCANTINS
STATE OF MATO GROSSO
STATE OF BAHIA
STATE OF SERGIPE
STATE OF ALAGOAS
STATE OF MINAS GERAIS
STATE OF ESPÍRITO SANTO
STATE OF MATO GROSSO

Google Map

Total Solar Eclipse
February 26, 1998
Sun Princess
P&O
Gary A. Becker image

Island of Grenada

Gary A. Becker image

Earl A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

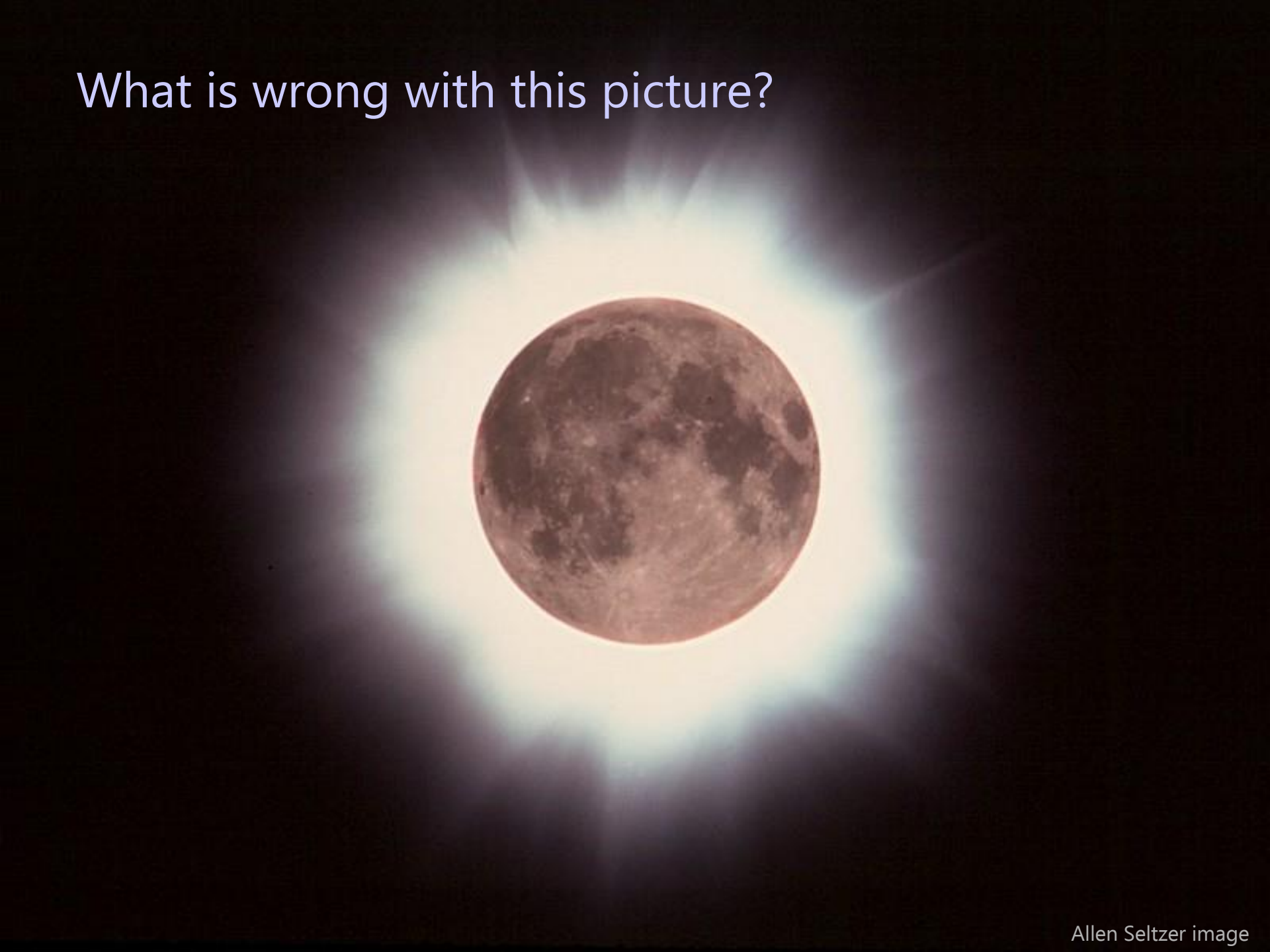
Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

Gary A. Becker image

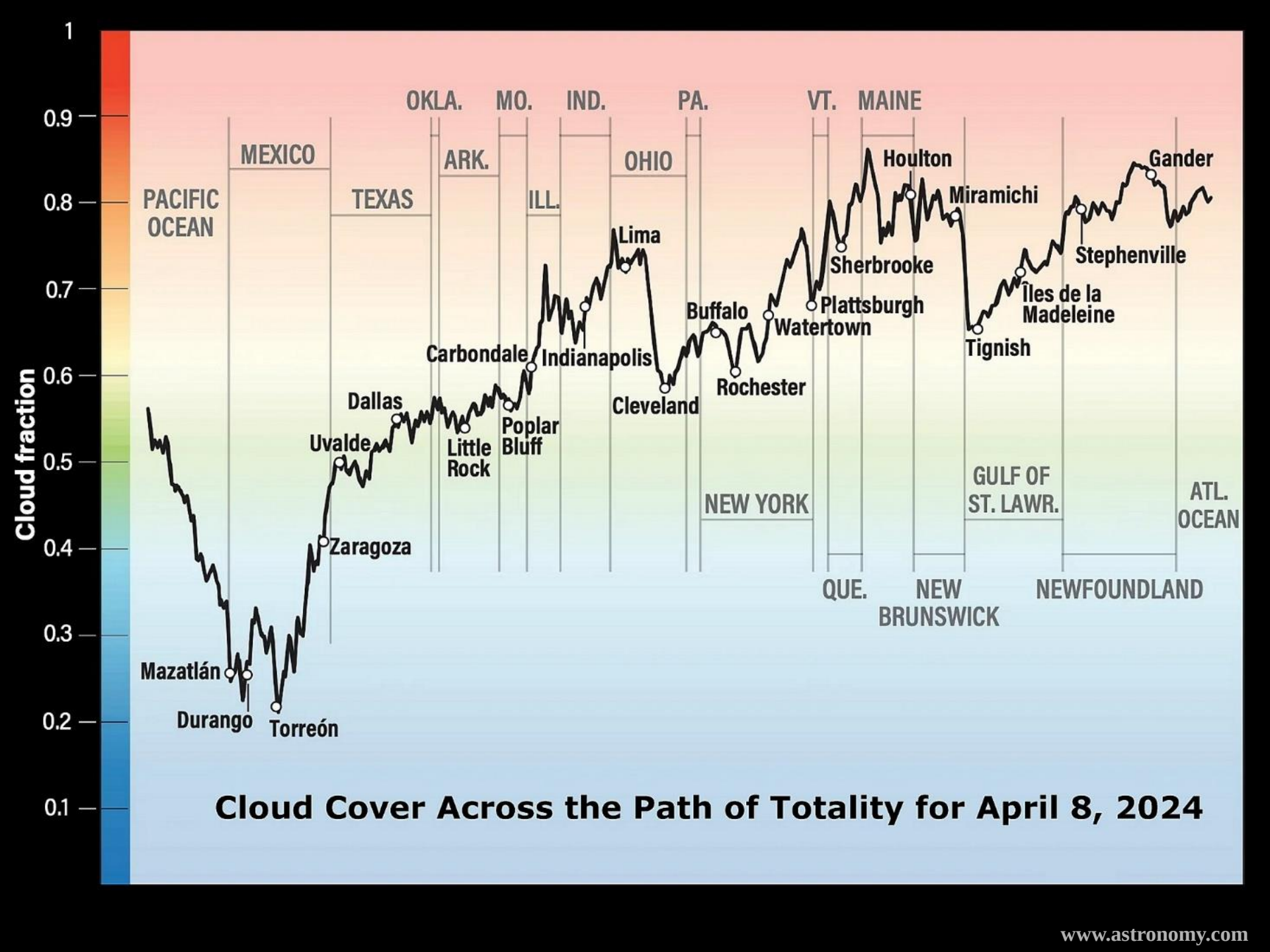
What is wrong with this picture?



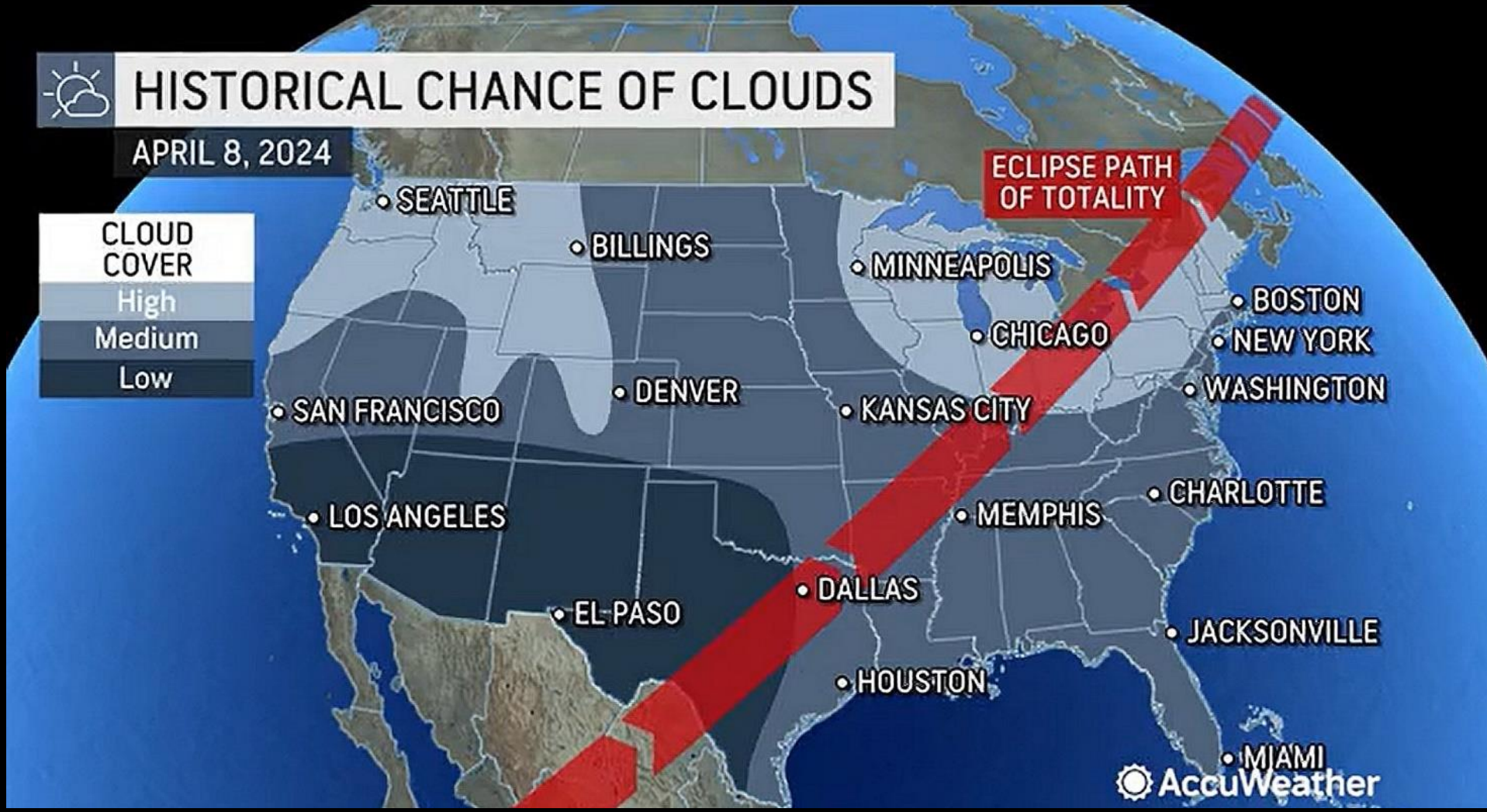
Allen Seltzer image

Last US Eclipse Until 2044

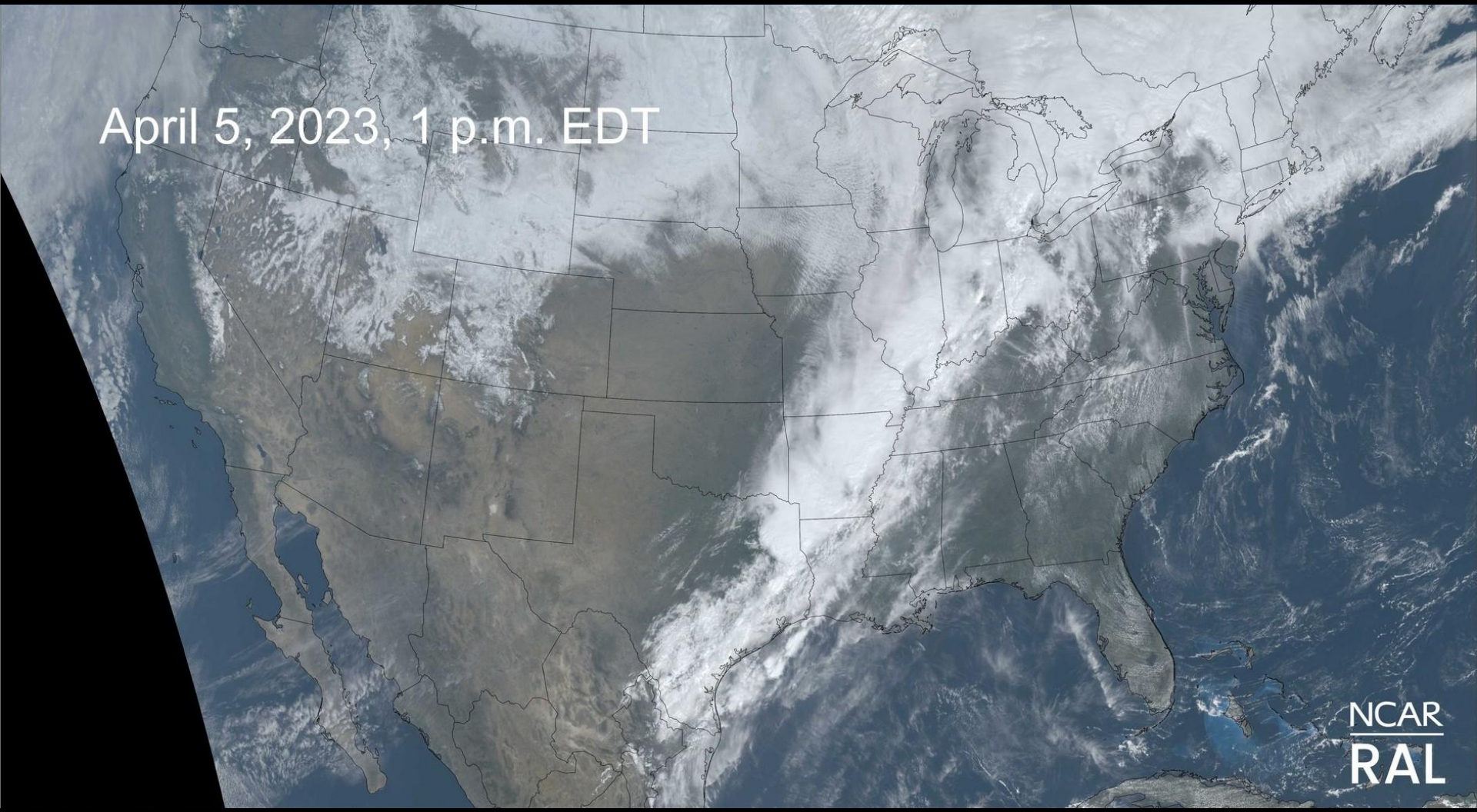
https://eclipse.gsfc.nasa.gov

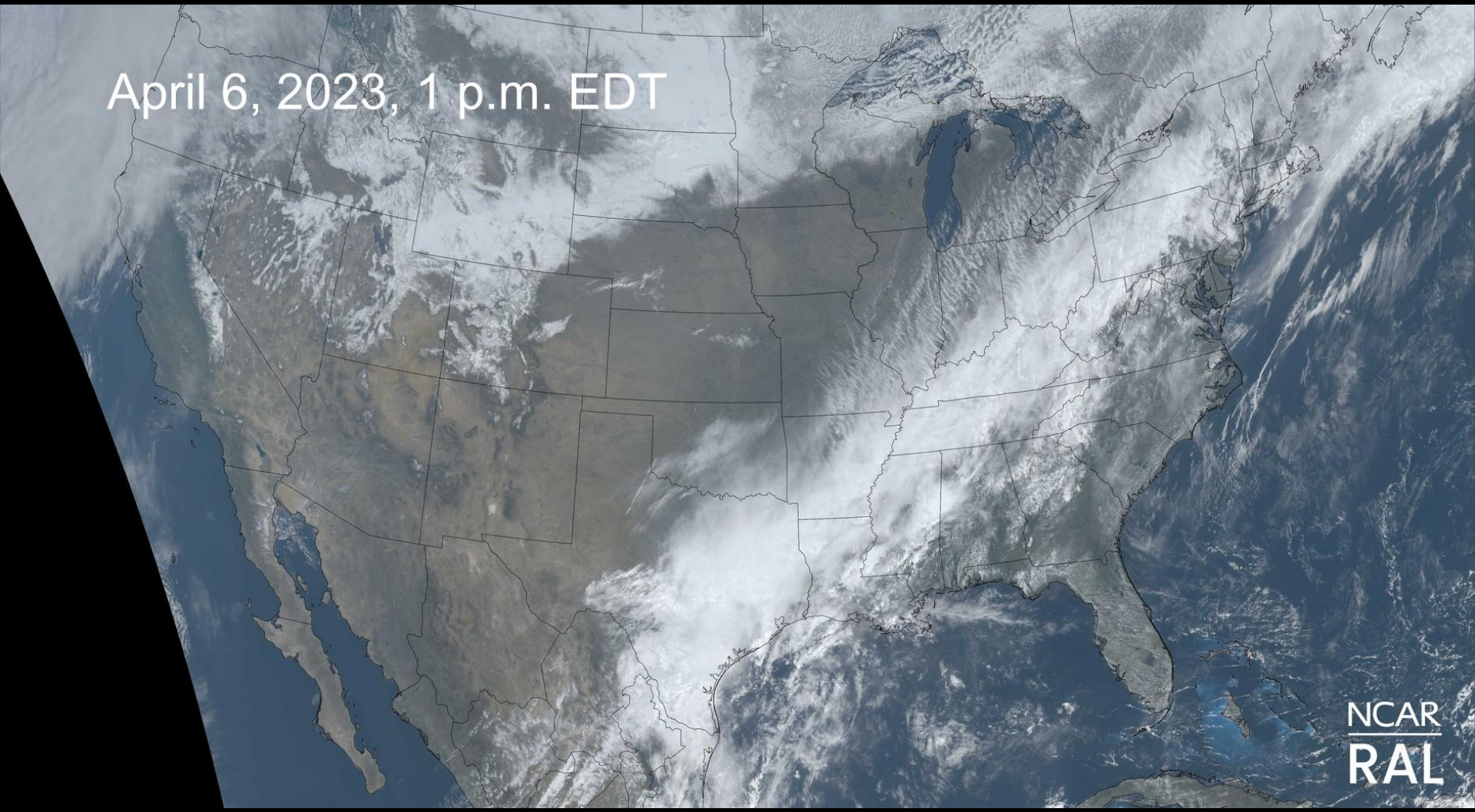


www.astronomy.com

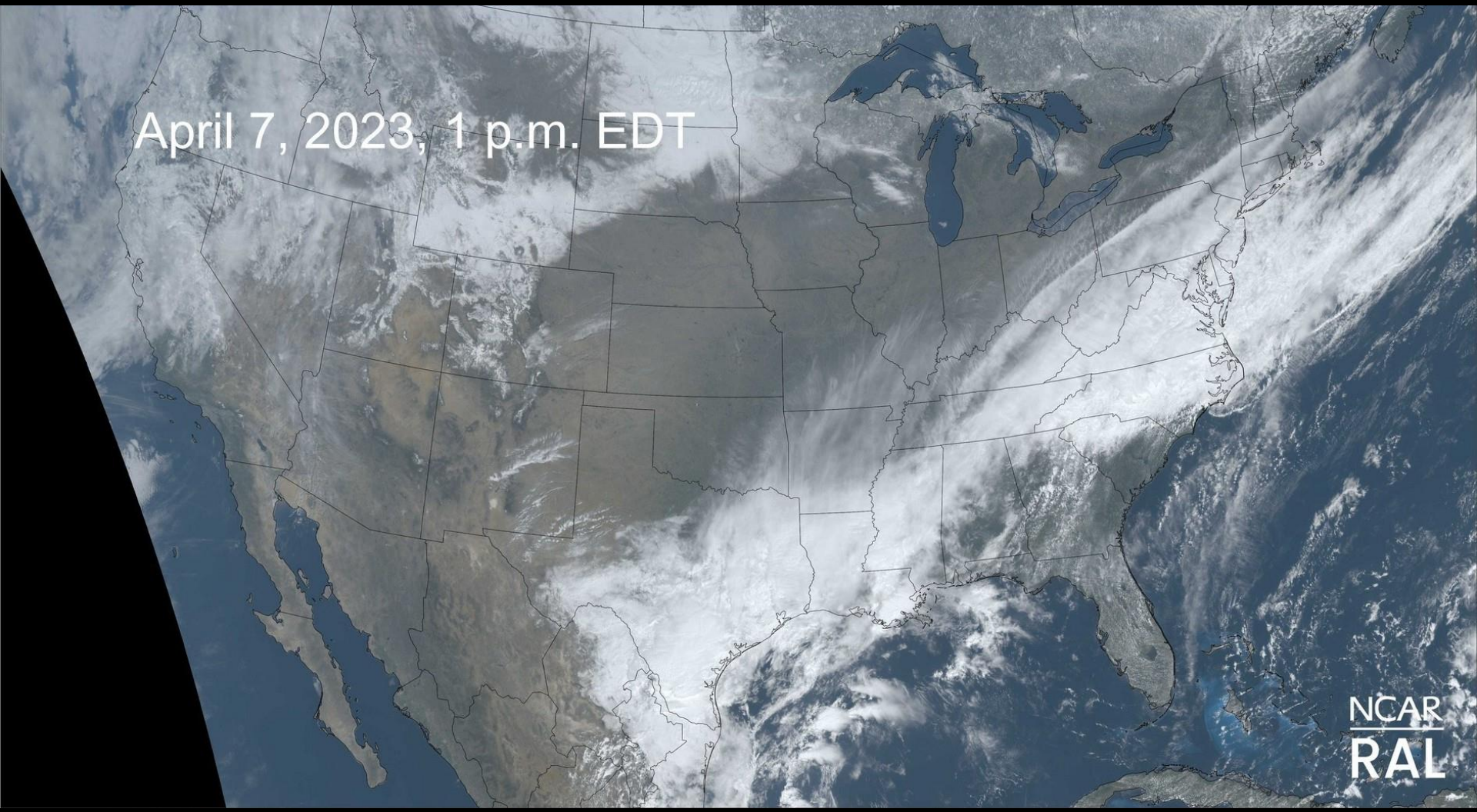


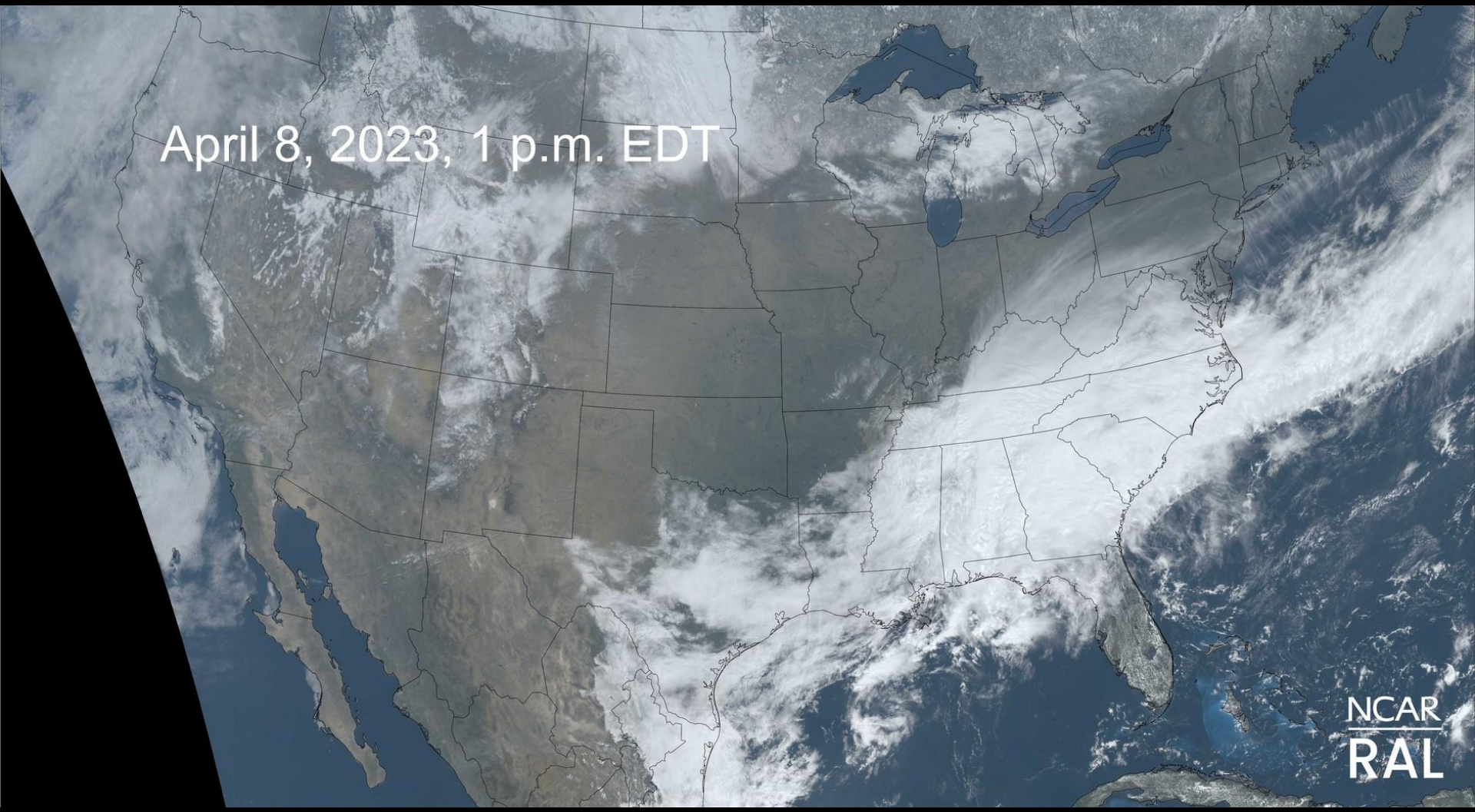
www.accuweather.com


April 5, 2023, 1 p.m. EDT
NCAR
RAL

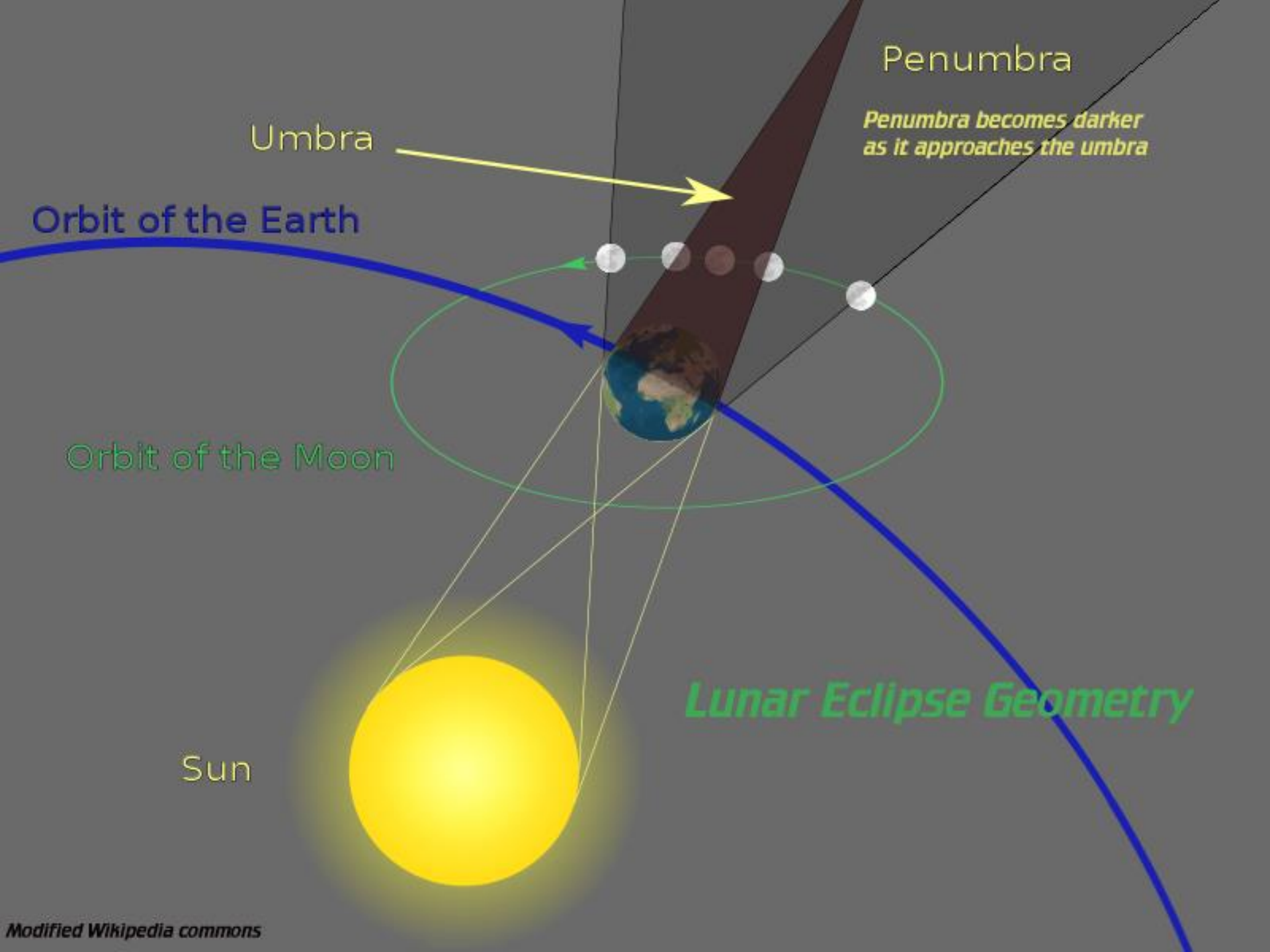


National Center for Atmospheric Research


April 7, 2023, 1 p.m. EDT
NCAR
RAL


April 8, 2023, 1 p.m. EDT
NCAR
RAL

Lunar Eclipses


Penumbra
Penumbra becomes darker as it approaches the umbra
Umbra
Orbit of the Earth
Orbit of the Moon
Lunar Eclipse Geometry
Sun
Modified Wikipedia commons

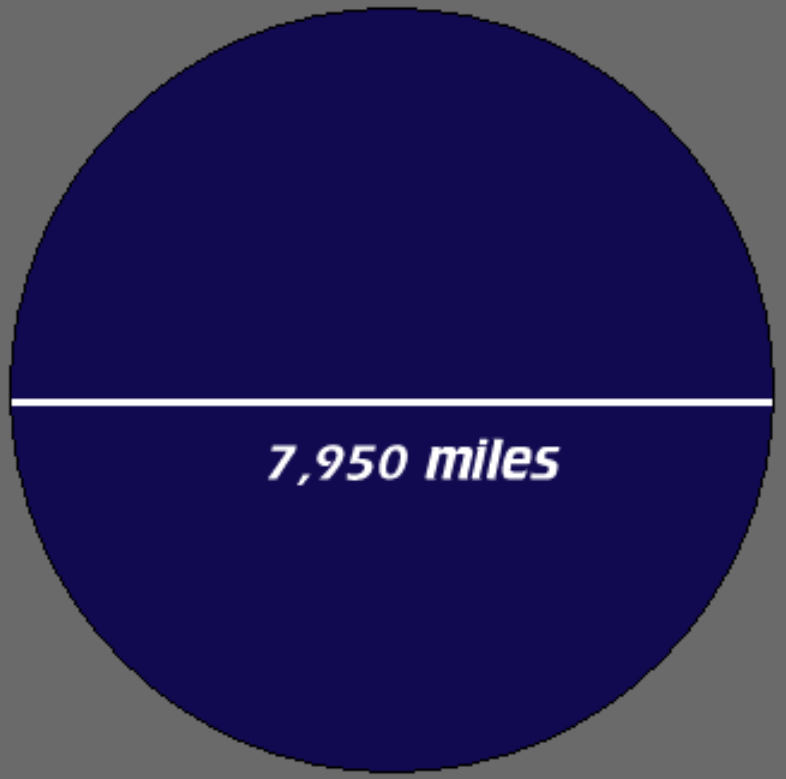
Target areas for total lunar/central solar eclipses

Which type is more common?

Total Lunar Eclipse

Diameter of Earth's shadow at the moon's average distance from Earth.

Central Solar Eclipse

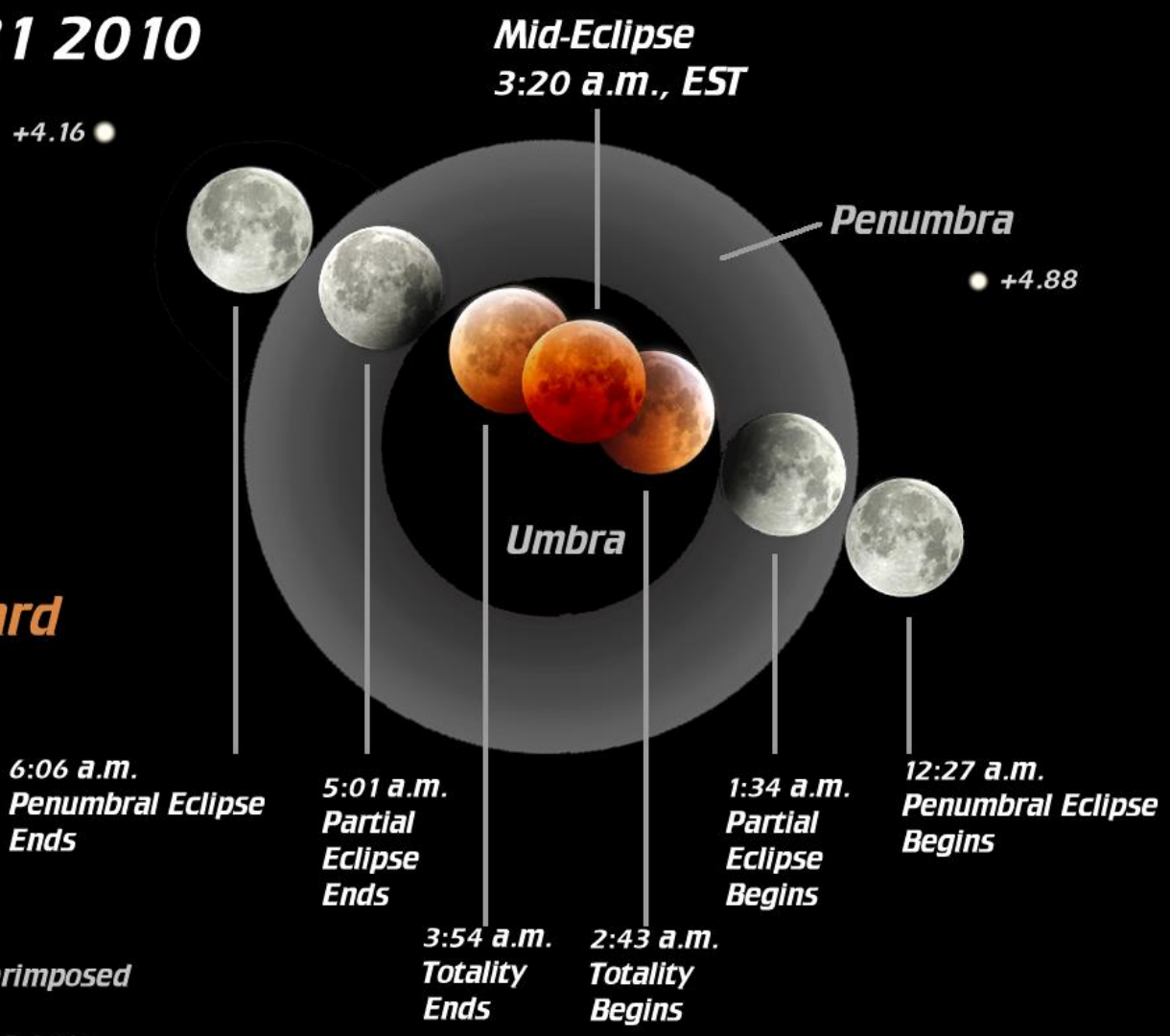


Diameter of Earth

Gary A. Becker slide

Winter Solstice Total Lunar Eclipse

December 21 2010

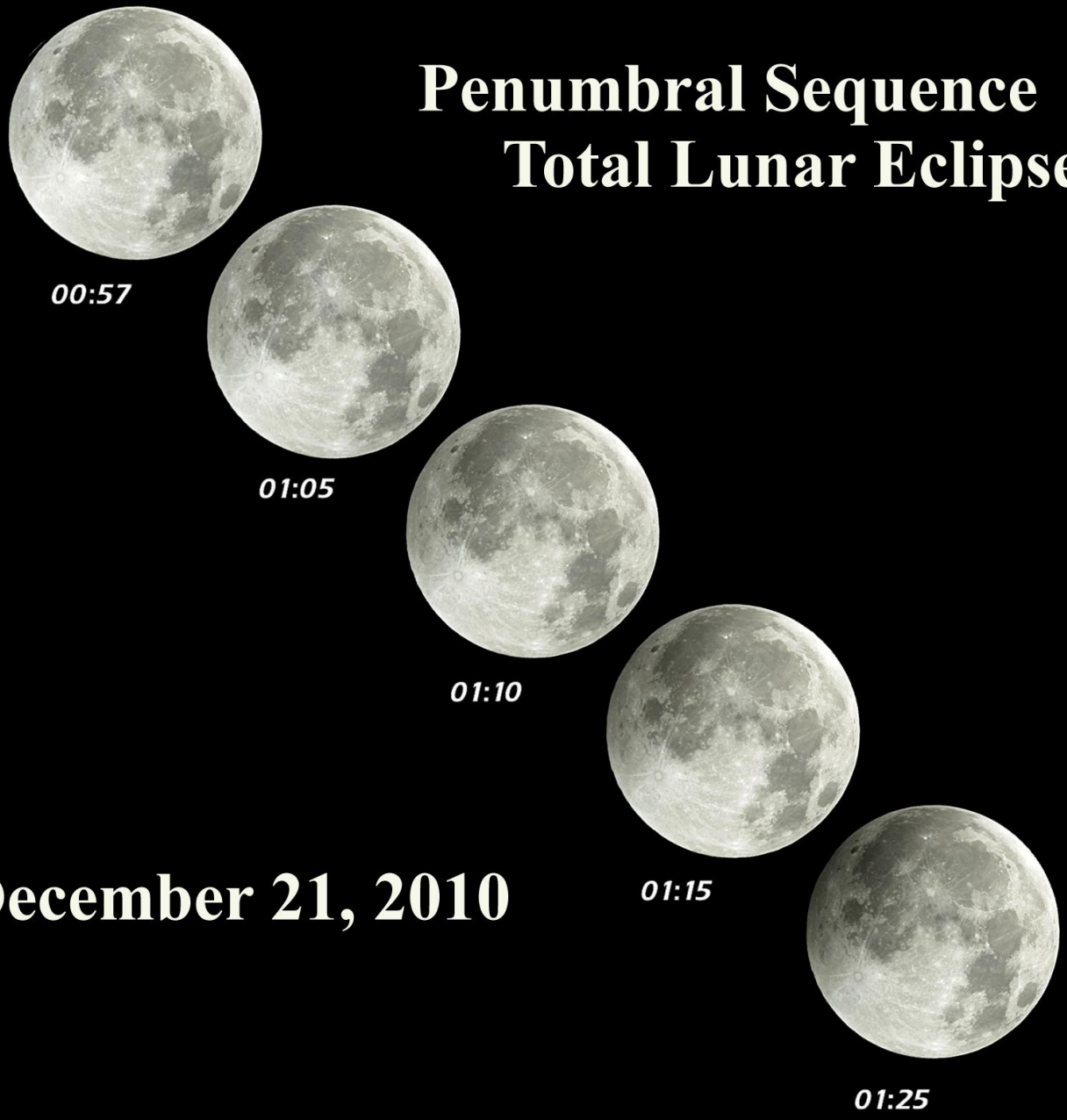


All Times are Eastern Standard

Gary A. Becker images superimposed over a computer generated cross section of the Winter Solstice Total Lunar Eclipse, December 21, 2010

Gary A. Becker slide

Penumbral Sequence
Total Lunar Eclipse



December 21, 2010

Gary A. Becker images

Gary A. Becker image

Total Lunar Eclipse-December 21, 2010

Gary A. Becker images

Gary A. Becker image

Total Lunar Eclipse-December 21, 2010

Gary A. Becker images

Winter Solstice Total Lunar Eclipse

December 21, 2010

Can you see the outline of Earth's shadow?

Gary A. Becker images

Winter Solstice Total Lunar Eclipse

December 21, 2010

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September 27, 2015, Total

Coopersburg, Pennsylvania

November 19, 2021, Deep Partial

Coopersburg, Pennsylvania

May 16, 2022, Total

Western Pennsylvania

Gary A. Becker image

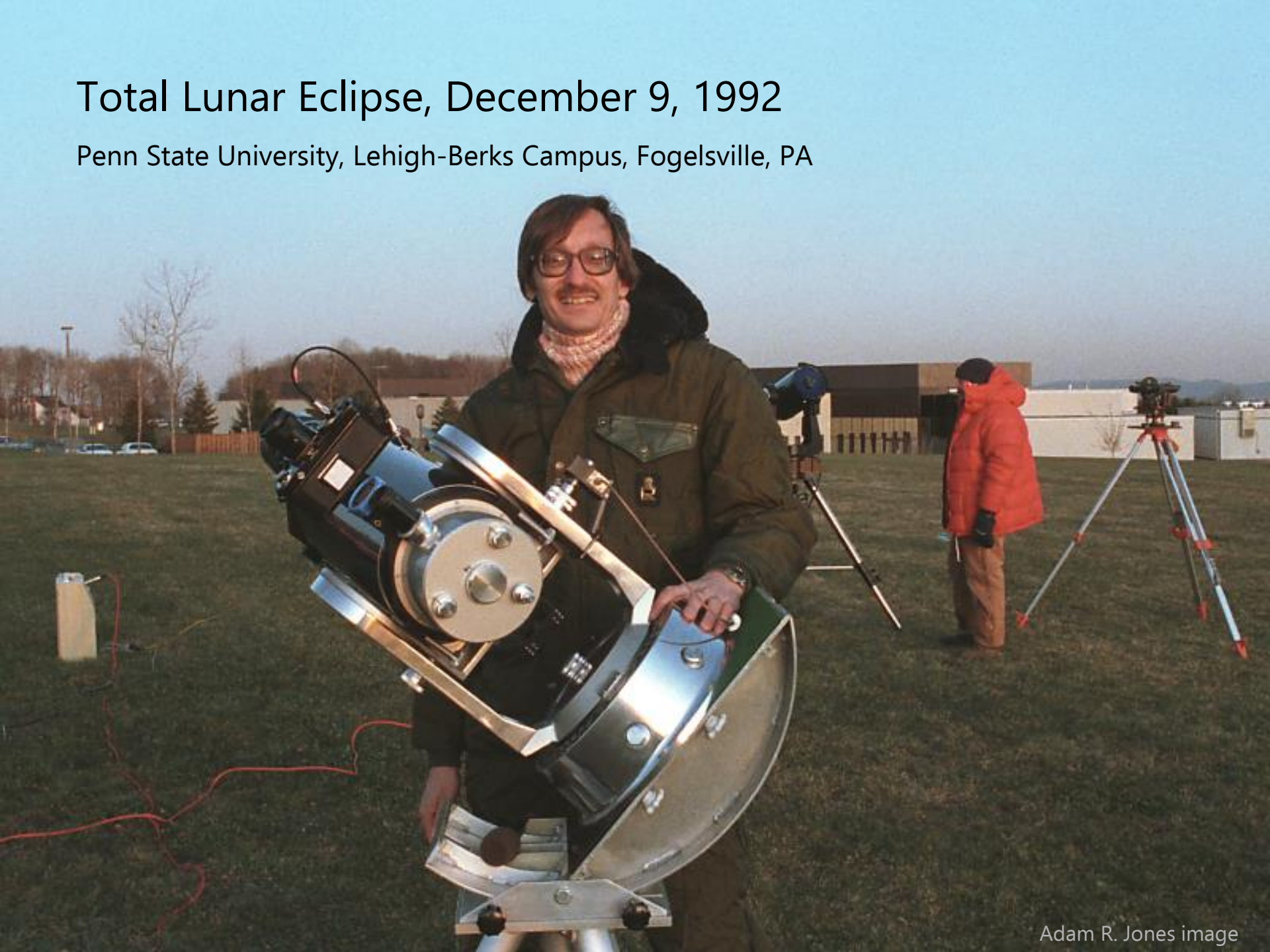
November 8, 2022, Total

Sky Deck, Moravian University

Gary A. Becker image

Total Lunar Eclipse, December 9, 1992

Penn State University, Lehigh-Berks Campus, Fogelsville, PA



Adam R. Jones image

Gary A. Becker image

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