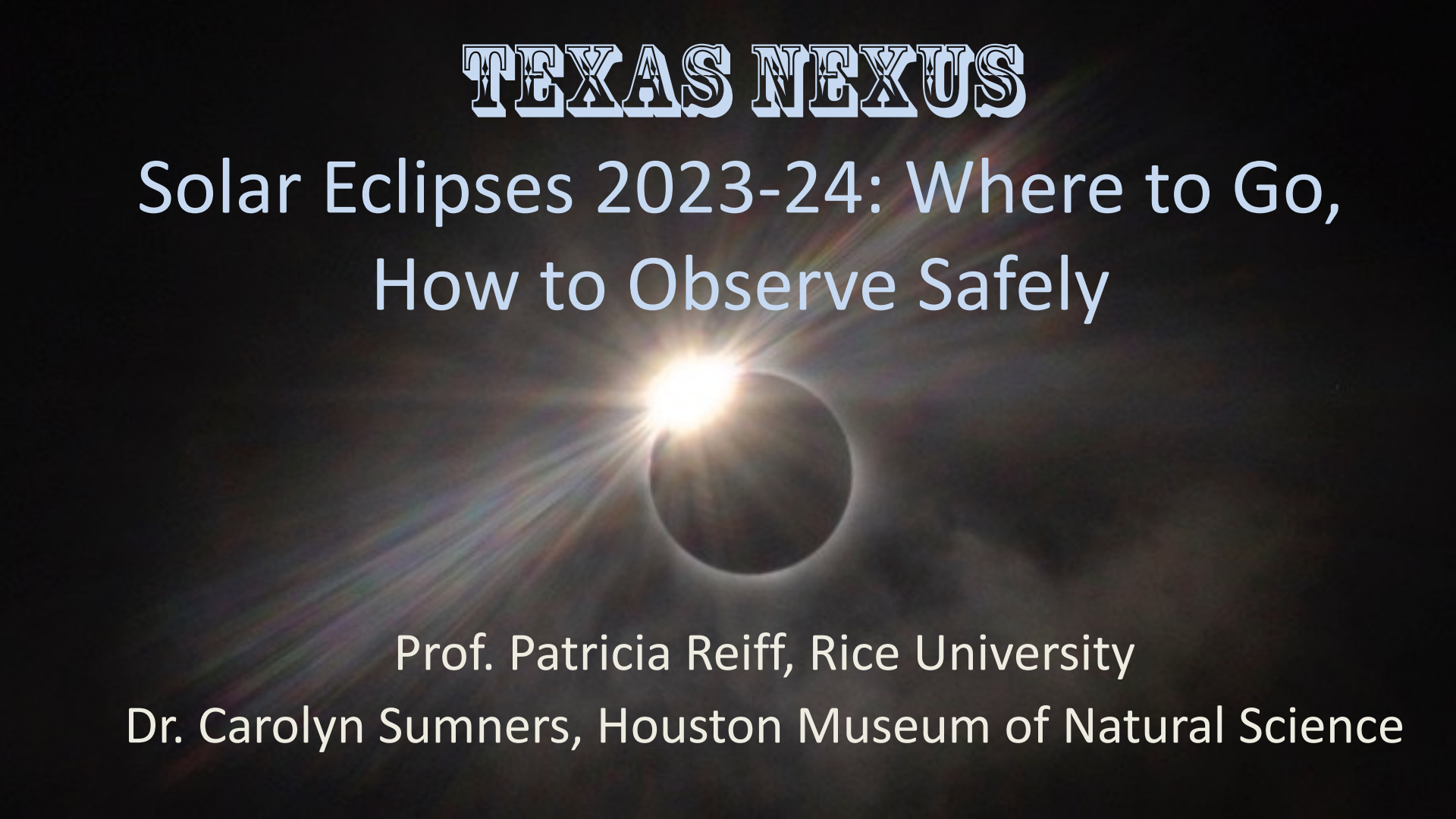
TEXAS NEXUS

Solar Eclipses 2023-24: Where to Go, How to Observe Safely



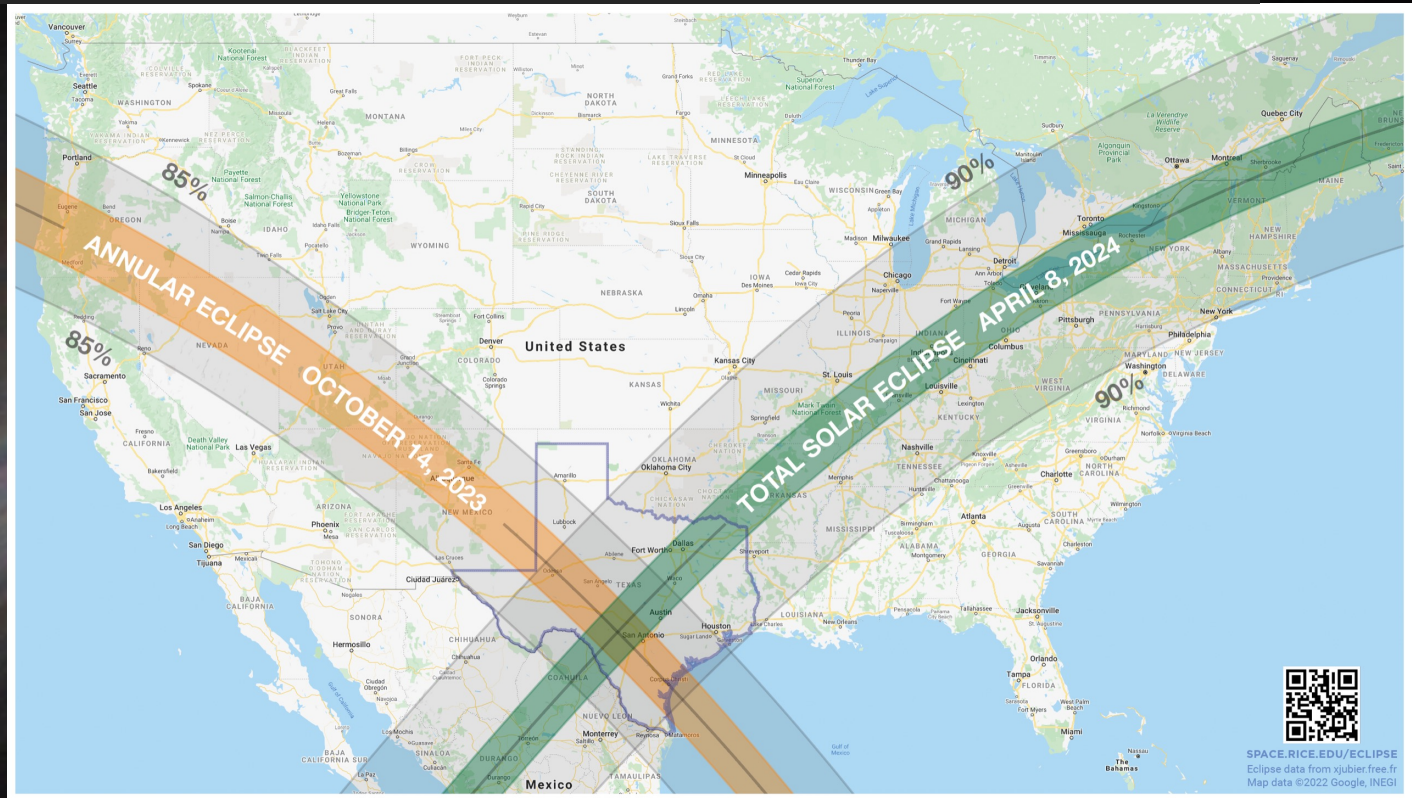
Prof. Patricia Reiff, Rice University

Dr. Carolyn Sumners, Houston Museum of Natural Science

TEXAS NEXUS

The orange band is the path of annularity

The green band is the path of totality



Solar/Lunar Eclipse 101

- Who (will be able to see it?)
- What (is a solar eclipse versus a lunar eclipse)
- Where (do I need to go to see it best?)
- Why (do I need to go to totality?)
- How (do I observe it safely?)
- When (is the next one?)

reiff@rice.edu

Solar/Lunar Eclipse 101

- **Who (will be able to see it?)**
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- When (is the next one?)

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Solar/Lunar Eclipse 101

- **Who (will be able to see it?)**
  - **Total lunar eclipse 11/8/2022 (ends at moonset)**
  - **Annular Eclipse 10/14/2023**
  - **Total Eclipse 4/8/2024**

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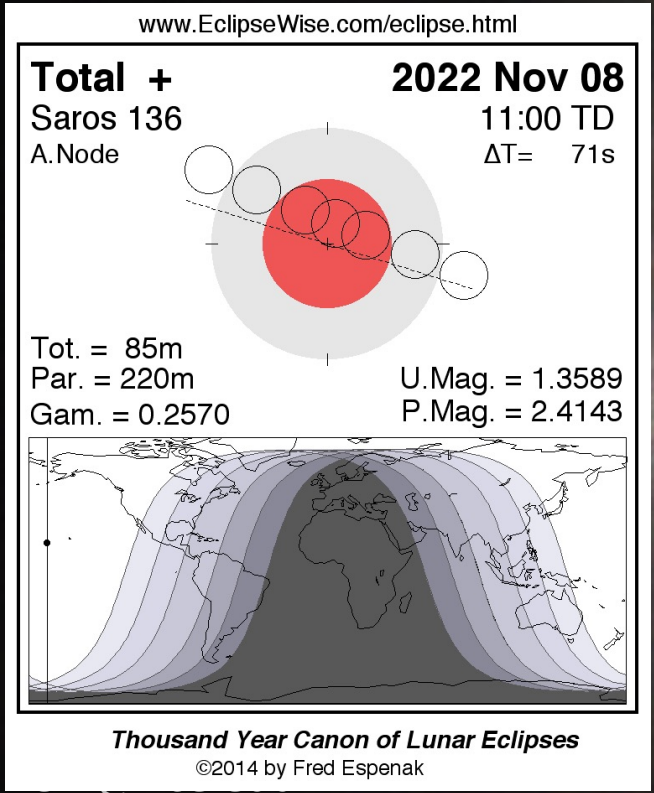
Solar/Lunar Eclipse 101

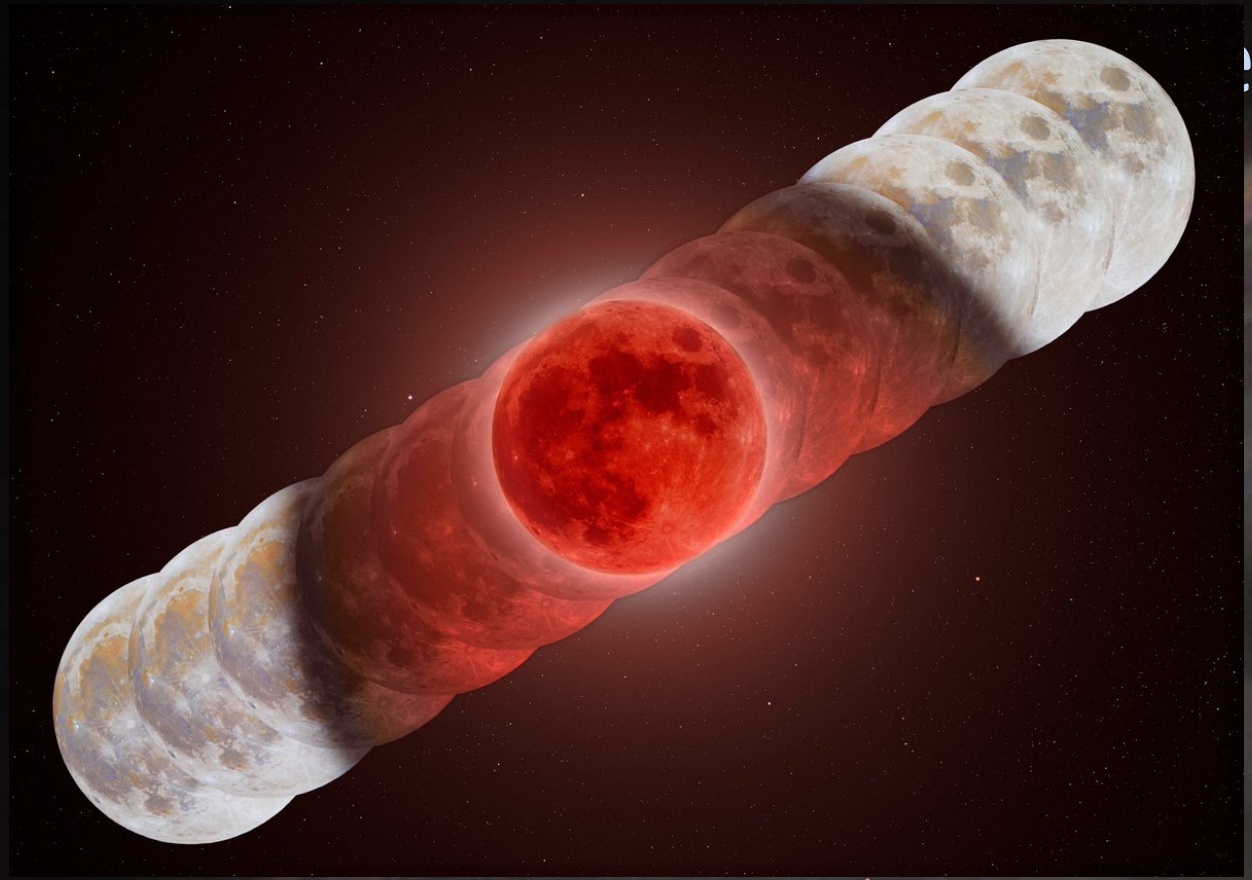
– Total Lunar Eclipse 11/8/2022



CST:
Start 02:03 (penumbral)
Start partial 03:10
Start total 04:17
Maximum 05:00
End Total 05:43
End partial 06:50 (after dawn)
End penumbral (after dawn)

Eclipse photo 11/8 courtesy Brian Cudnik, PVAMU

e 101



Awesome composite of the lunar eclipse of Nov 8 showing the size and shape of the Earth's shadow.

Eclipse composite 11/8 courtesy James McCarthy @AJamesMcCarthy . Prints can be ordered from https://cosmicbackground.io/products/shadows-and-sunsets

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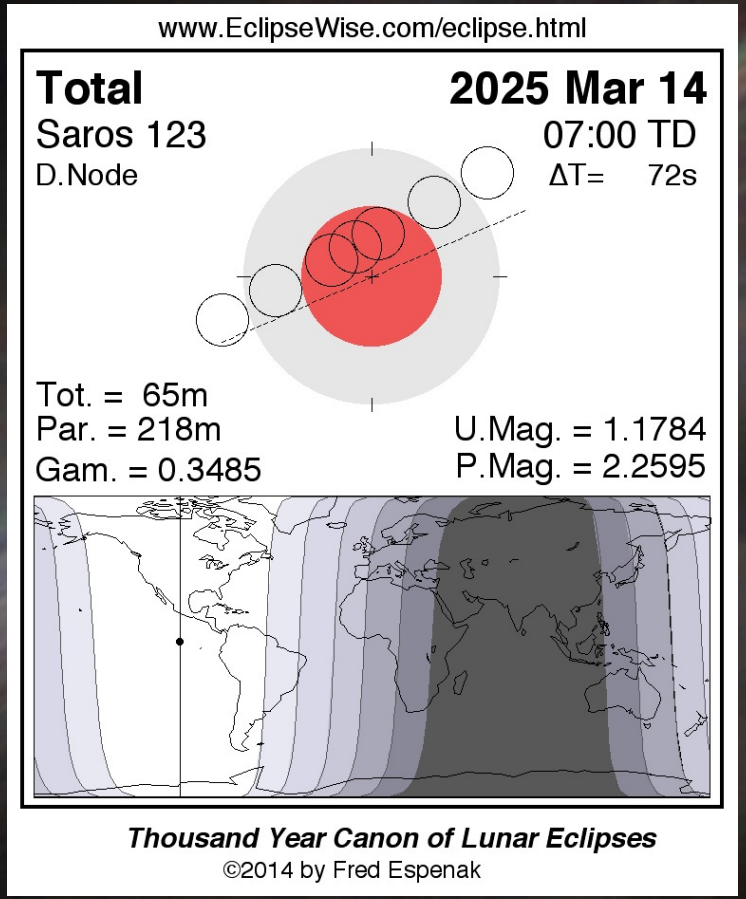
Solar/Lunar Eclipse 101

NEXT Total Lunar Eclipse from US: 3/13-14/2025 (near midnight)



Courtesy MrEclipse.com:
All times listed CST
Start penumbral 21:58 3/13
Start partial 23:10:34 3/13
Start total 00:27:09 3/14
End total 01:33:13
End partial 02:49:30
End penumbral 04:00:32

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Solar/Lunar Eclipse 101

Recent trip of mine

Total Solar Eclipse

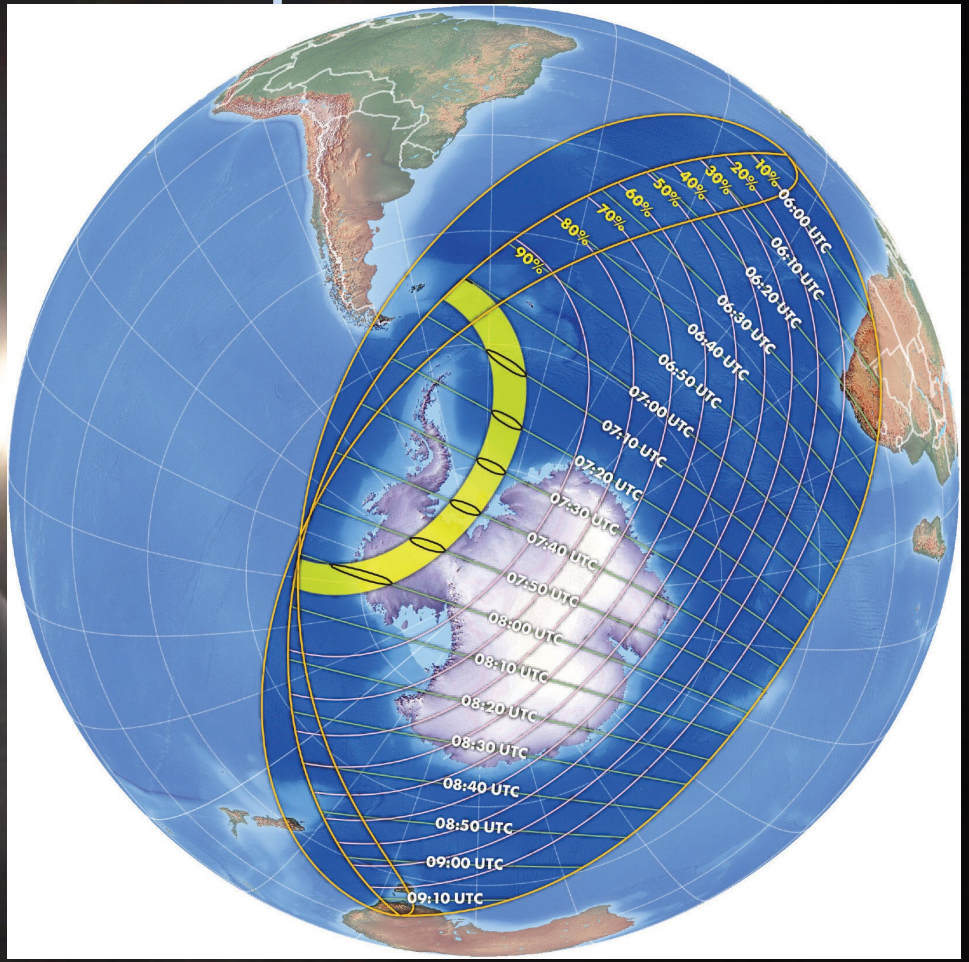
in Antarctica

Dec 4, 2021

(3:10 am local)

Midnight sun!!

(clouded out)



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Annular Solar Eclipse of 2023 Oct 14

Geocentric Conjunction = 17:36:28.8 UT J.D. = 2460232.233667
Greatest Eclipse = 17:59:21.0 UT J.D. = 2460232.249549

Eclipse Magnitude = 0.9520 Gamma = 0.3752

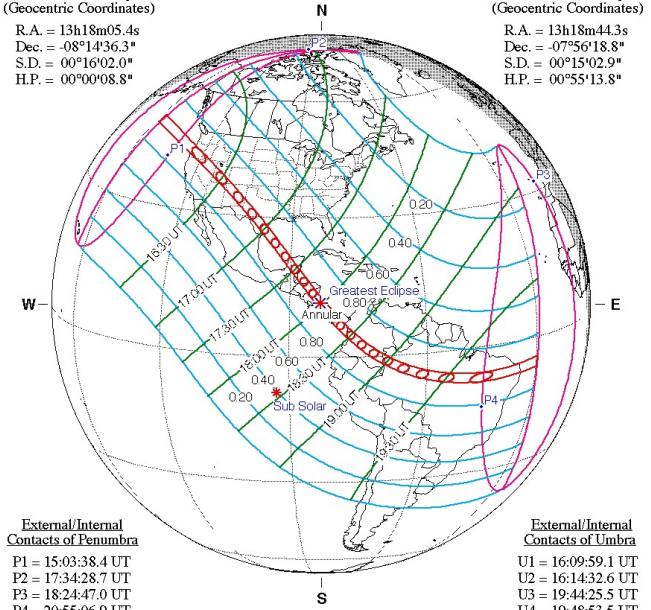
Saros Series = 134 Member = 44 of 71

Sun at Greatest Eclipse
(Geocentric Coordinates)

R.A. = 13h18m05.4s
Dec. = -08°14'36.3"
S.D. = 00°16'02.0"
H.P. = 00°00'08.8"

Moon at Greatest Eclipse
(Geocentric Coordinates)

R.A. = 13h18m44.3s
Dec. = -07°56'18.8"
S.D. = 00°15'02.9"
H.P. = 00°55'13.8"



External/Internal Contacts of Penumbra

P1 = 15:03:38.4 UT
P2 = 17:34:28.7 UT
P3 = 18:24:47.0 UT
P4 = 20:55:06.9 UT

External/Internal Contacts of Umbra

U1 = 16:09:59.1 UT
U2 = 16:14:32.6 UT
U3 = 19:44:25.5 UT
U4 = 19:48:53.5 UT

Local Circumstances at Greatest Eclipse

Lat. = 11°21.7'N Sun Alt. = 67.9°
Long. = 083°04.3'W Sun Azm. = 208.0°
Path Width = 187.4 km Duration = 05m17.2s

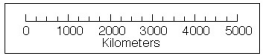
Ephemeris & Constants

Eph. = Newcomb/ILE
ΔT = 80.7 s
k1 = 0.2724880
k2 = 0.2722810
Δb = 0.0" Δl = 0.0"

Geocentric Libration
(Optical + Physical)

l = -3.80°
b = -0.48°
c = 20.45°

Brown Lun. No. = 1247



F. Espenak, NASA's GSFC - Fri, Jul 2,
sunearth.gsfc.nasa.gov/eclipse/eclipse.html

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

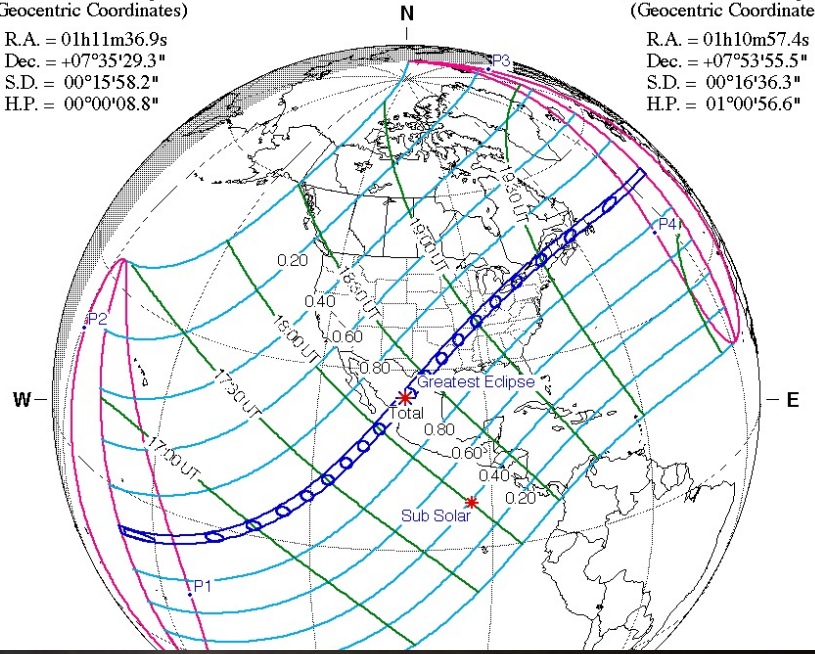
Saros Series = 139 Member = 30 of 71

Sun at Greatest Eclipse
(Geocentric Coordinates)

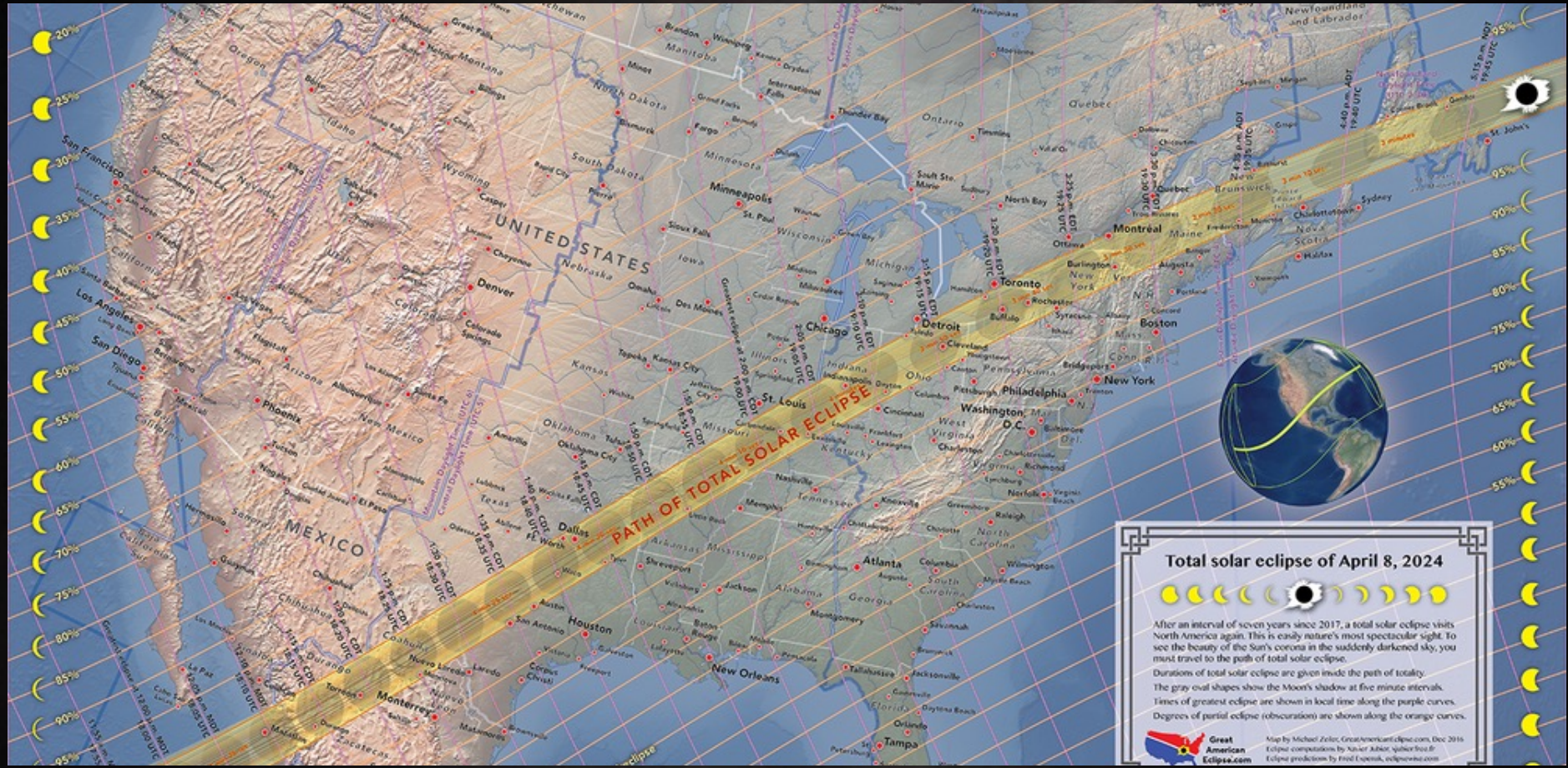
R.A. = 01h11m36.9s
Dec. = +07°35'29.3"
S.D. = 00°15'58.2"
H.P. = 00°00'08.8"

Moon at Greatest Eclipse
(Geocentric Coordinates)

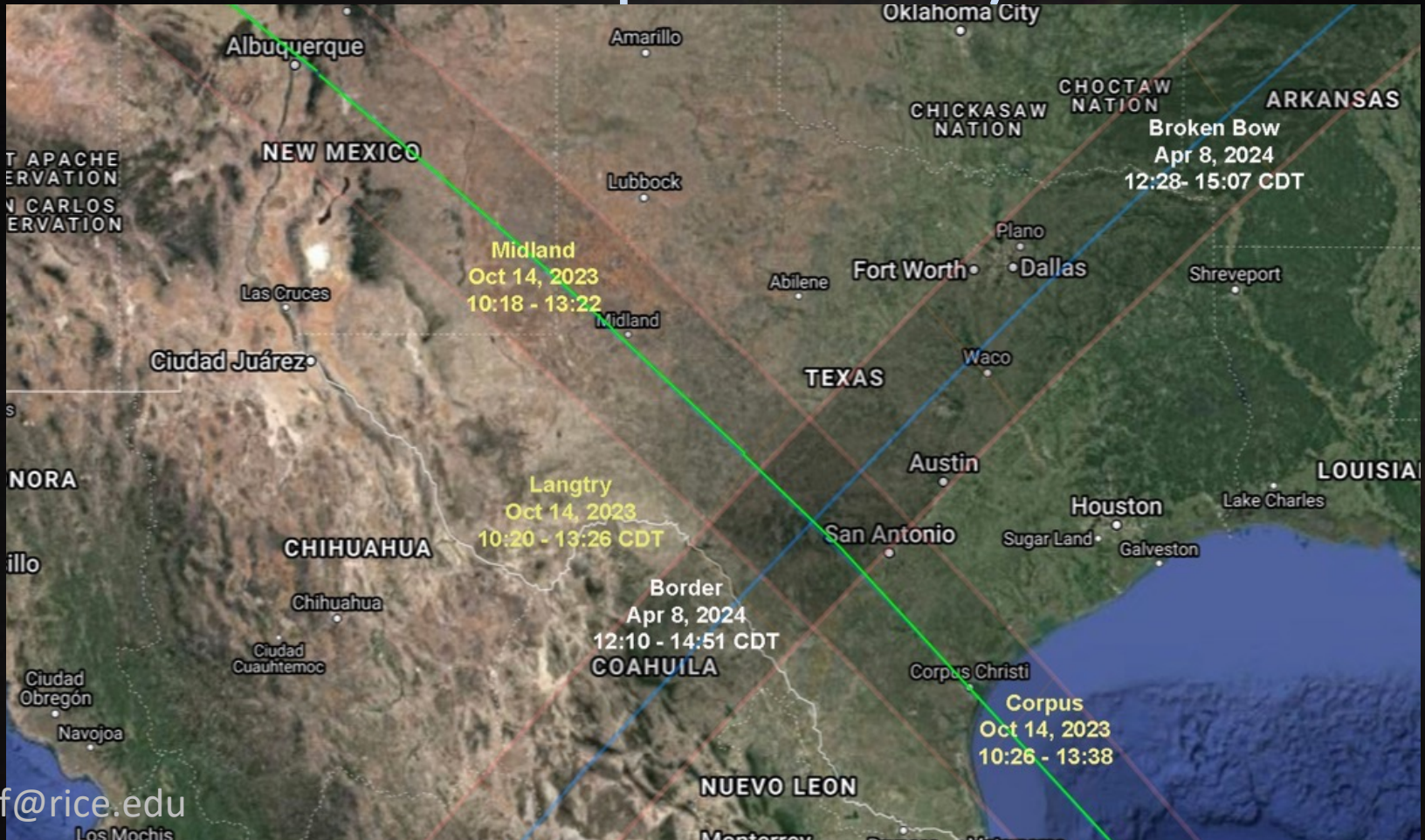
R.A. = 01h10m57.4s
Dec. = +07°53'55.5"
S.D. = 00°16'36.3"
H.P. = 01°00'56.6"



Solar Eclipse 2024



Texas Eclipses 2023/2024



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Solar/Lunar Eclipse 101

- Who (will be able to see it?)
- **What (is a solar eclipse versus a lunar eclipse)**
- Where (do I need to go to see it best?)
- Why (do I need to go to totality?)
- How (do I observe it safely?)
- When (is the next one?)

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Solar/Lunar Eclipse 101

- **What (is a solar eclipse versus a lunar eclipse)**
  - **A SOLAR eclipse is the moon casting its shadow on the Earth**
  - **A LUNAR eclipse is the Earth casting its shadow on the moon**
  - **Totality means the ENTIRE sun will be blocked by the moon, allowing us to see the corona**

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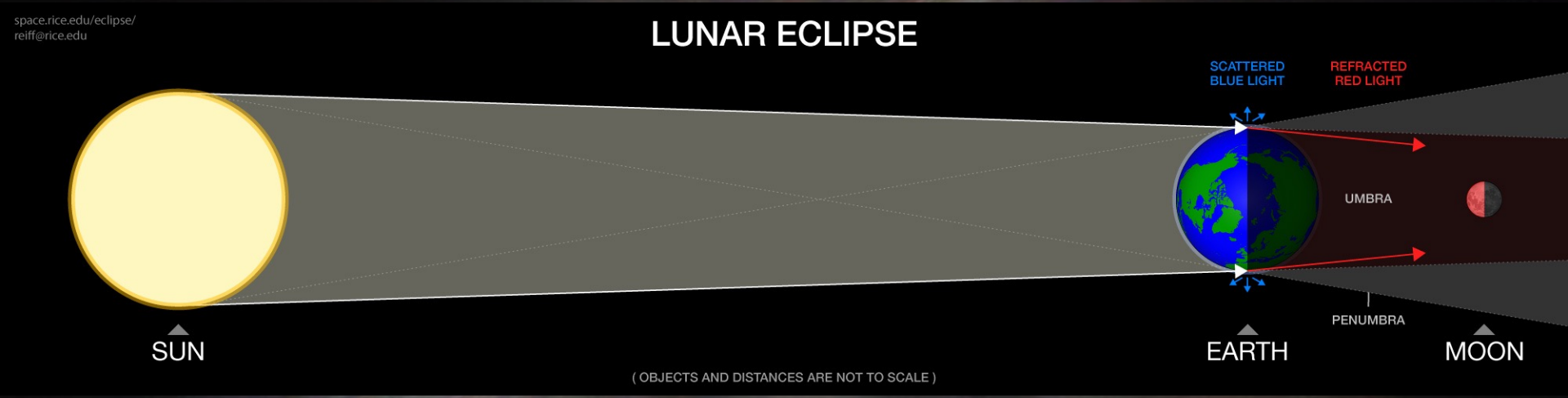
Solar/Lunar Eclipse 101



Lunar eclipse (from http://space.rice.edu/eclipse)

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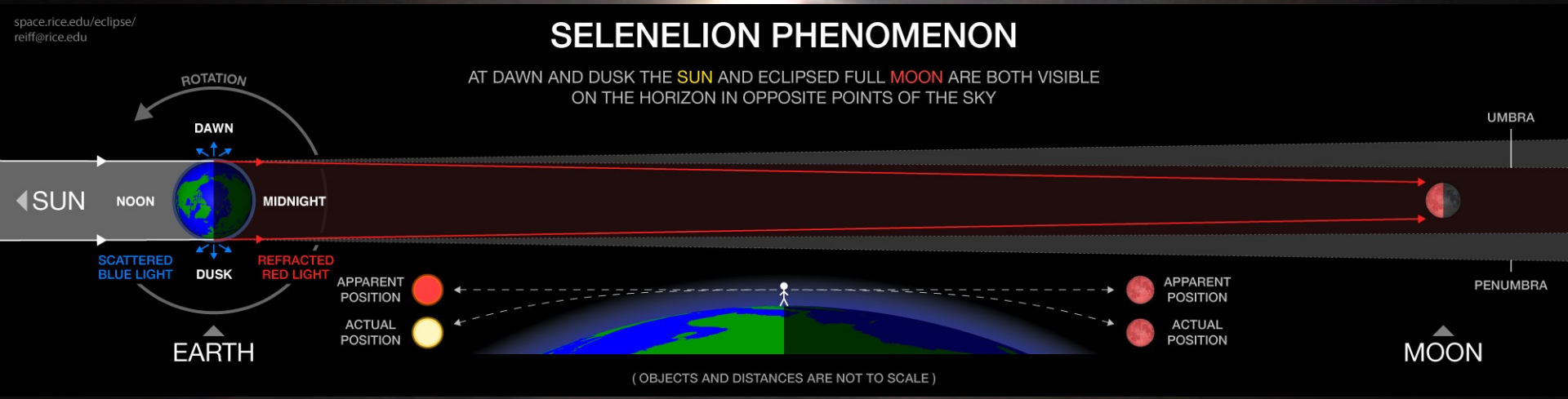
Selenelion

- **The November 8 2022 eclipse was a “selenelion” eclipse for the Eastern US**



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Selenelion

- ***A selenelion*** **is the eclipse at dusk or dawn so you can see the red sun AND the red moon at the SAME TIME. The sun's red light passed over us and lit the dark moon!**

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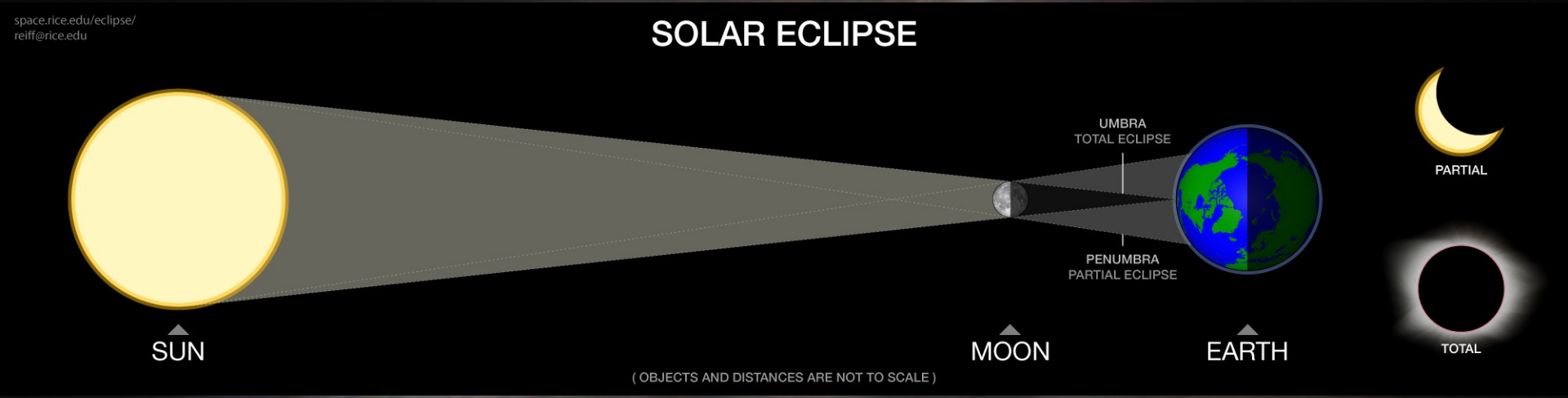
Solar/Lunar Eclipse 101



Solar eclipse (from http://space.rice.edu/eclipse)

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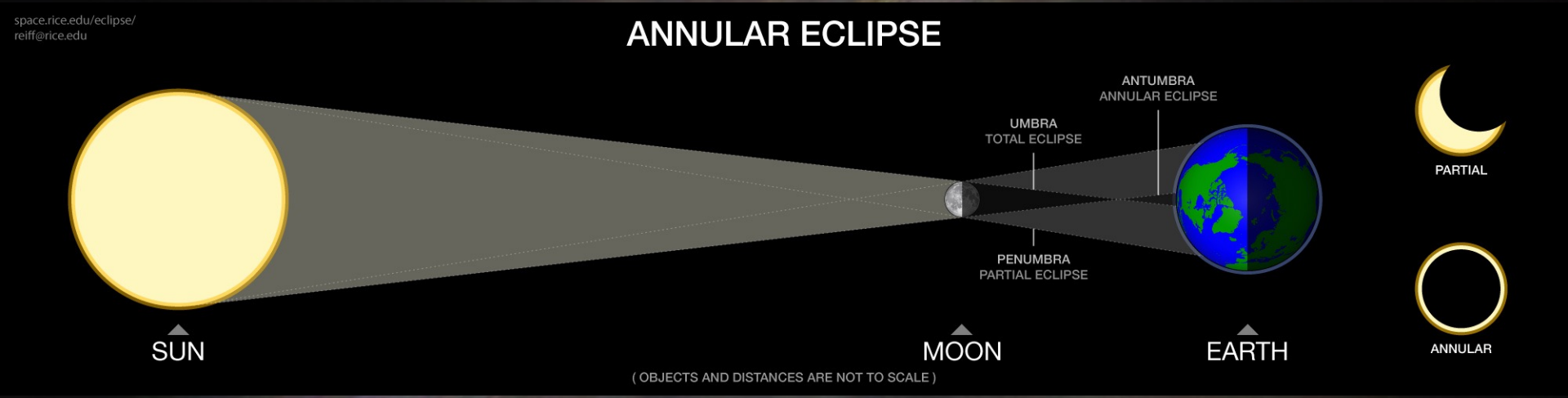
Solar/Lunar Eclipse 101

- **If the Moon is too far away to cover the entire sun we get an annular eclipse:**



Annular eclipse diagram (from http://space.rice.edu/eclipse)

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Solar/Lunar Eclipse 101

- **What (is a solar eclipse versus a lunar eclipse)**
  - **Movie on solar versus lunar eclipse geometry:**

https://space.rice.edu/eclipse/eclipse_animations.html

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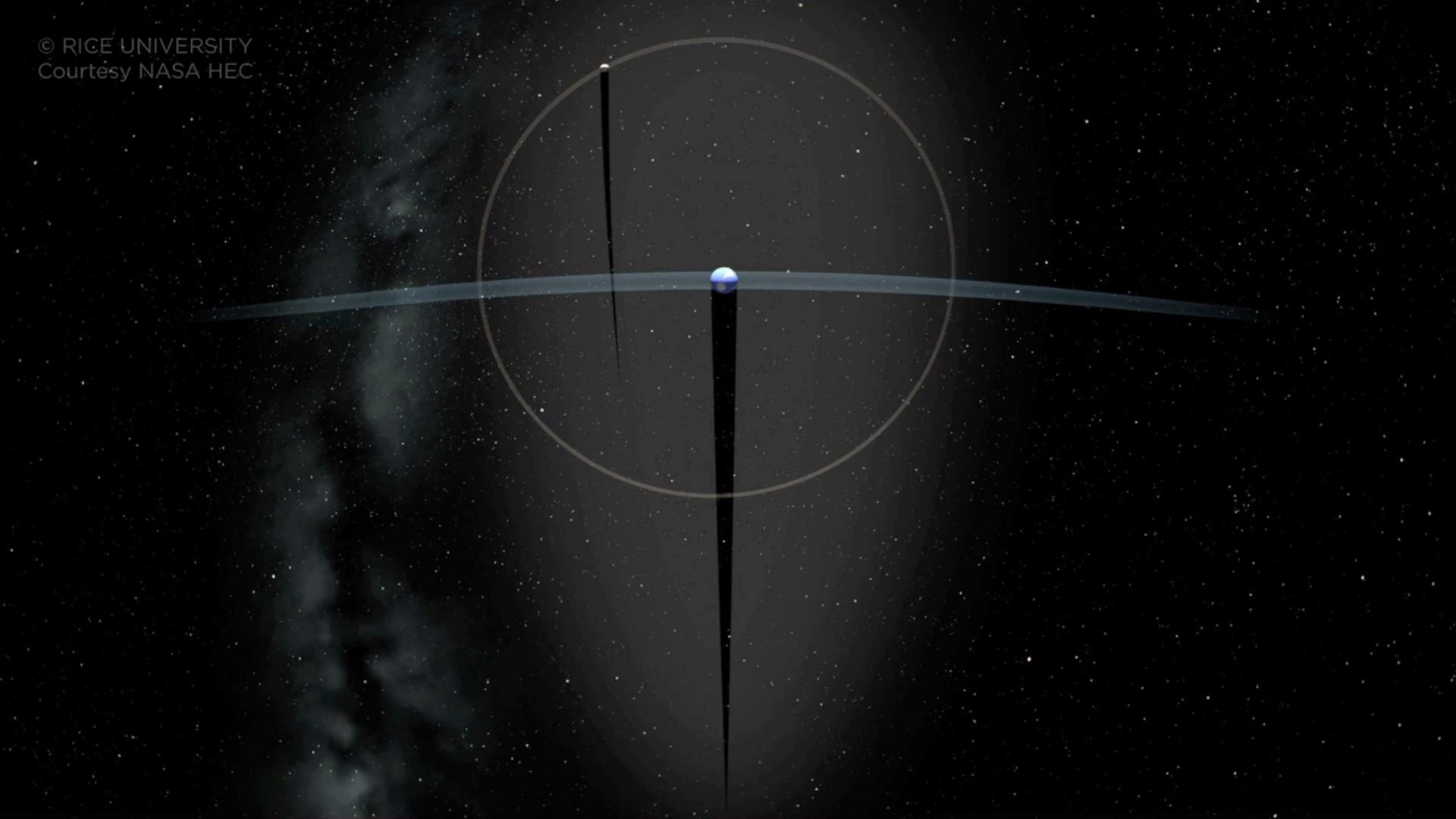
© RICE UNIVERSITY
Courtesy NASA HEC

Solar/Lunar Eclipse 101

- **What (is an annular eclipse)?**
  - **Movie on annular eclipse geometry:**
  - **NOTE - YOU MUST ALWAYS KEEP THE FILTERS ON**

https://space.rice.edu/eclipse/eclipse_animations.html

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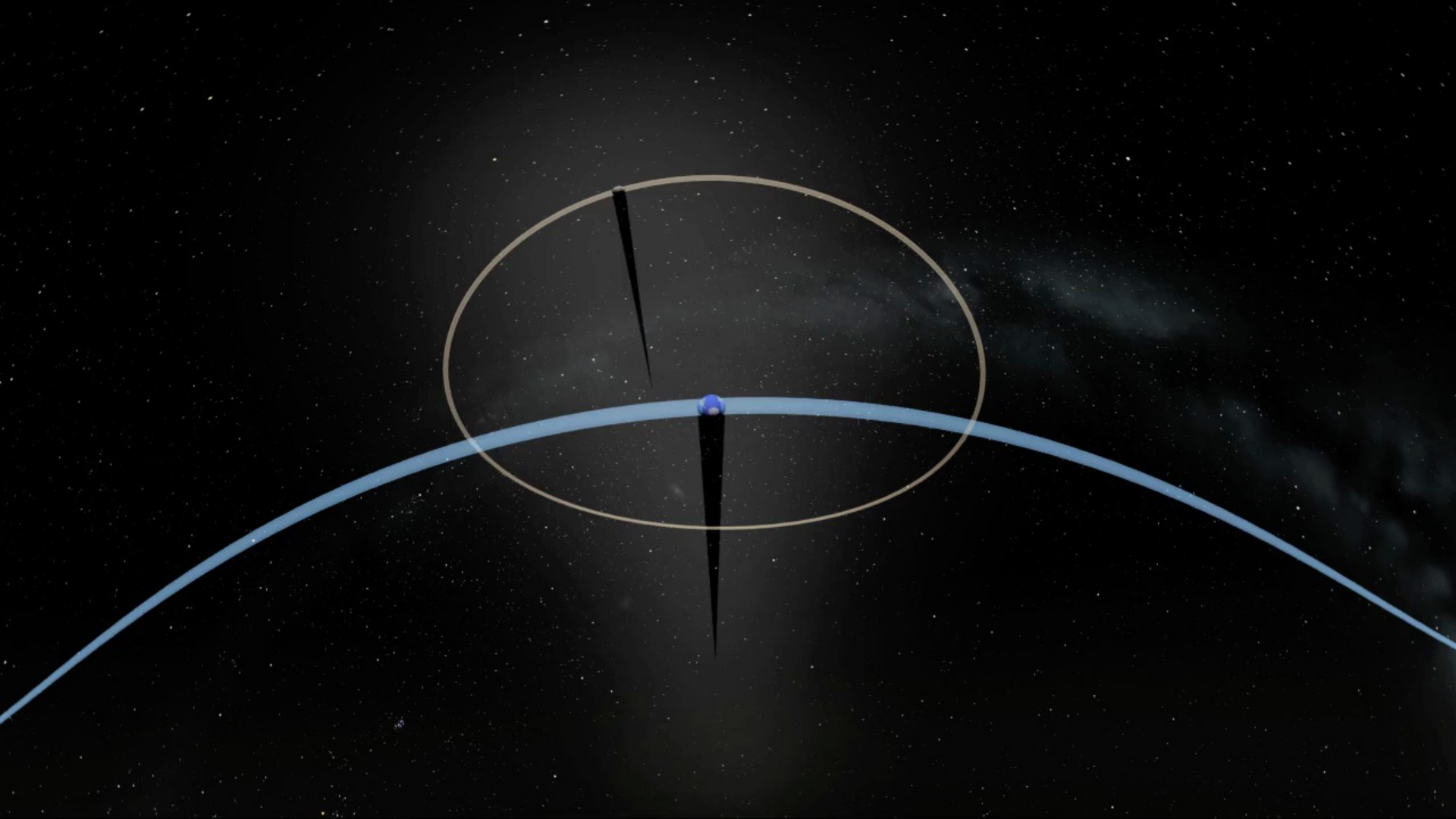

Solar/Lunar Eclipse 101

- **What (is an annular eclipse)?**
  - **Closeup Movie on annular eclipse:**
  - **NOTE - YOU MUST ALWAYS KEEP THE FILTERS ON**

https://space.rice.edu/eclipse/eclipse_animations.html

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Solar/Lunar Eclipse 101

- **What (is a solar eclipse versus a lunar eclipse)**
  - **Movie of what a total solar eclipse looks like from Earth's surface**
  - **Phases of the eclipse:**
    First contact: Moon starts to cover Sun (beginning of partial phase)
    Second contact: Moon completely covers Sun (start of totality)
    Third Contact: Moon starts to uncover Sun (end of totality)
    Fourth Contact: Last bit of Moon leaves sun (end of partial phase)

http://space.rice.edu/eclipse/animation/flatscreen/SolarEclipse_Earth_1280R264H.mp4

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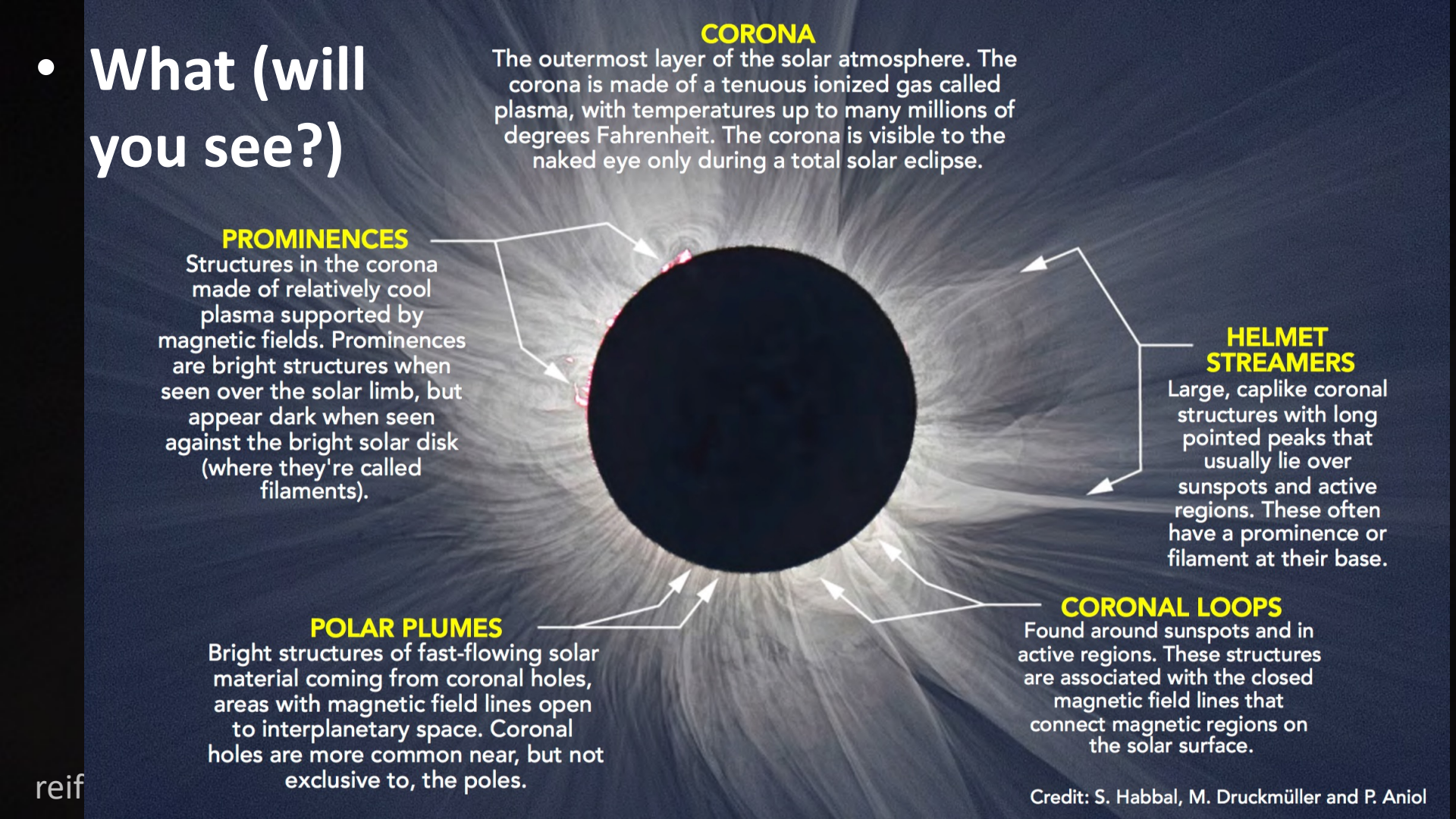
- **What (will you see?)**



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Solar/Lunar Eclipse 101

- **What will you see?**
  - **Movie of the Diamond Ring and Baily's Beads as seen from Earth**
    Last part of partial eclipse and beginning of totaliy

https://space.rice.edu/eclipse/eclipse_animations.html

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Courtesy NASA HEC

Solar/Lunar Eclipse 101

- **Here is an animation of the Moon's shadow crossing Earth as might be seen from the lunar surface**

https://space.rice.edu/eclipse/eclipse_animations.html

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© RICE UNIVERSITY
Courtesy NASA HEC

- Moon's shadow from orbit
- (actual photo)

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Solar/Lunar Eclipse 101

- **Moon's shadow from orbit (animation)**

https://space.rice.edu/eclipse/eclipse_animations.html

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Courtesy NASA HEC

Solar/Lunar Eclipse 101

- **Here is an animation of a lunar eclipse as seen from Earth:**

- **https://space.rice.edu/eclipse/eclipse_animations.html**

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Solar/Lunar Eclipse 101

- **Here is an animation of a lunar eclipse as might be seen from the Moon: (note it is a SOLAR eclipse for the folks on the Moon)**

https://space.rice.edu/eclipse/eclipse_animations.html

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Courtesy NASA HEC

Solar/Eclipse Eclipse 101

- Who (will be able to see it?)
- What (is a solar eclipse versus a lunar eclipse)
- **Where (do I need to go to see it best?)**
- Why (do I need to go to totality?)
- How (do I observe it safely?)
- When (is the next one?)

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Solar Eclipse 101

- **IF YOU POSSIBLY CAN, GO TO TOTALITY**
- Try to be no more than 1-2 hours from center line and plan a location
- Expect HEAVY traffic - **START EARLY!**
- Don’t drive when sun > 50 % covered
- Find a hotel an hour away… those in totality may be full or very expensive

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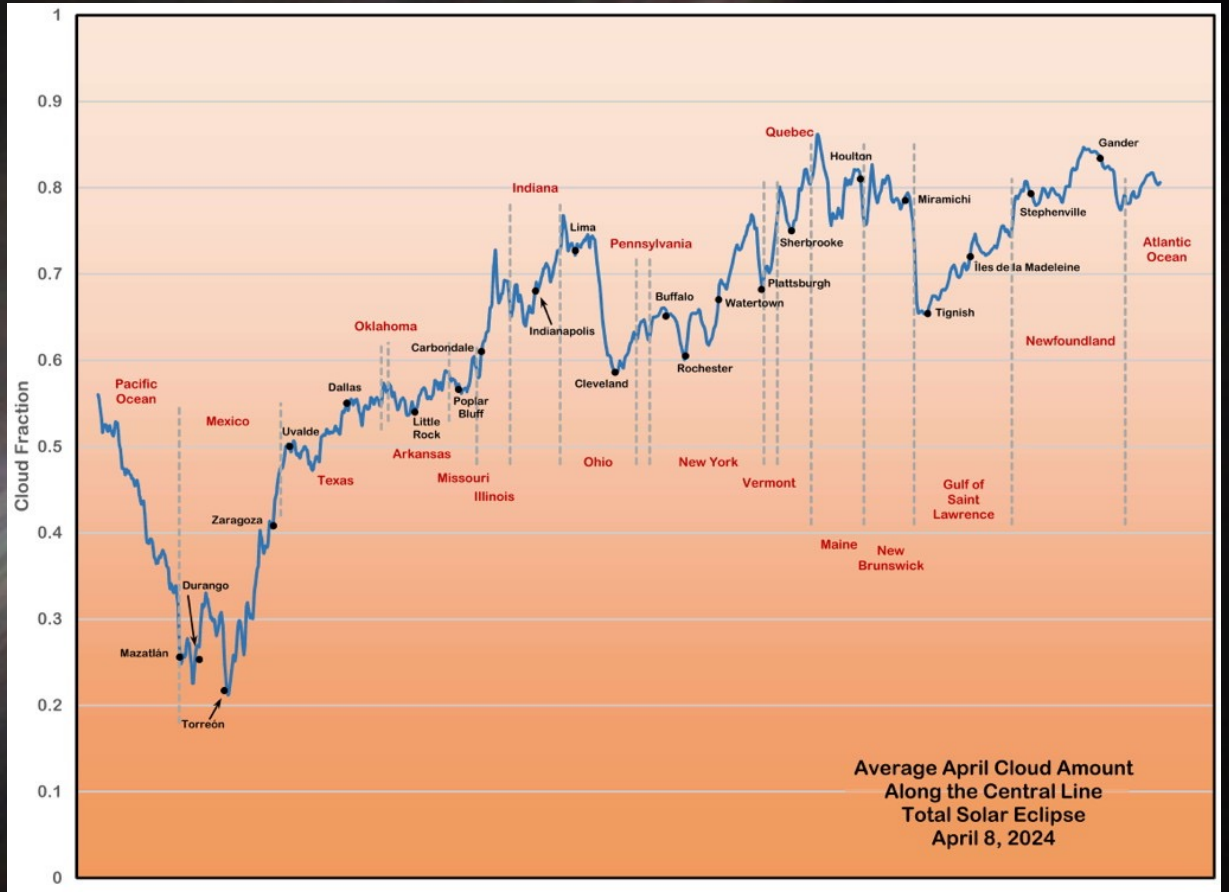
Solar Eclipse 101

WEATHER IS KEY



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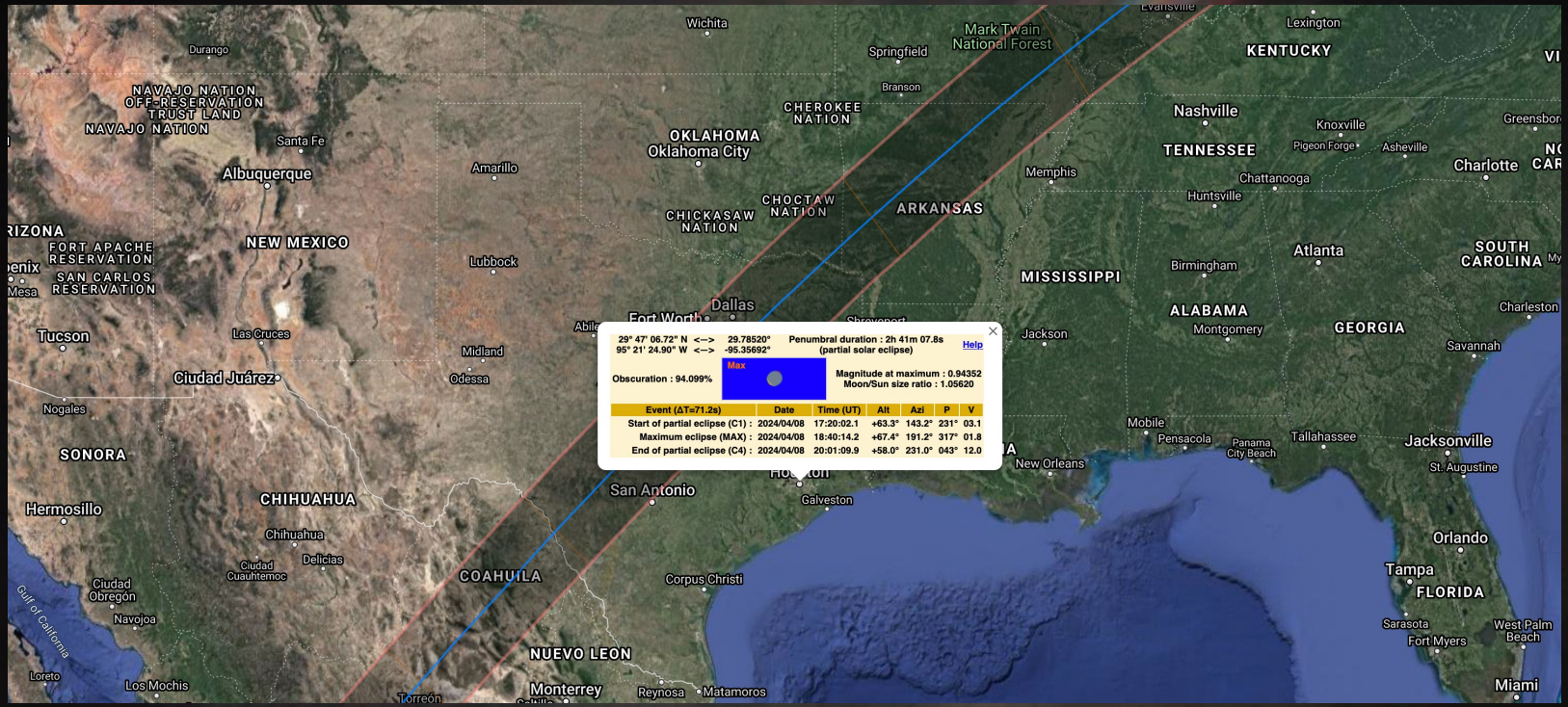
Interactive Map from xJubier.free.fr – check your location's times and coverage!



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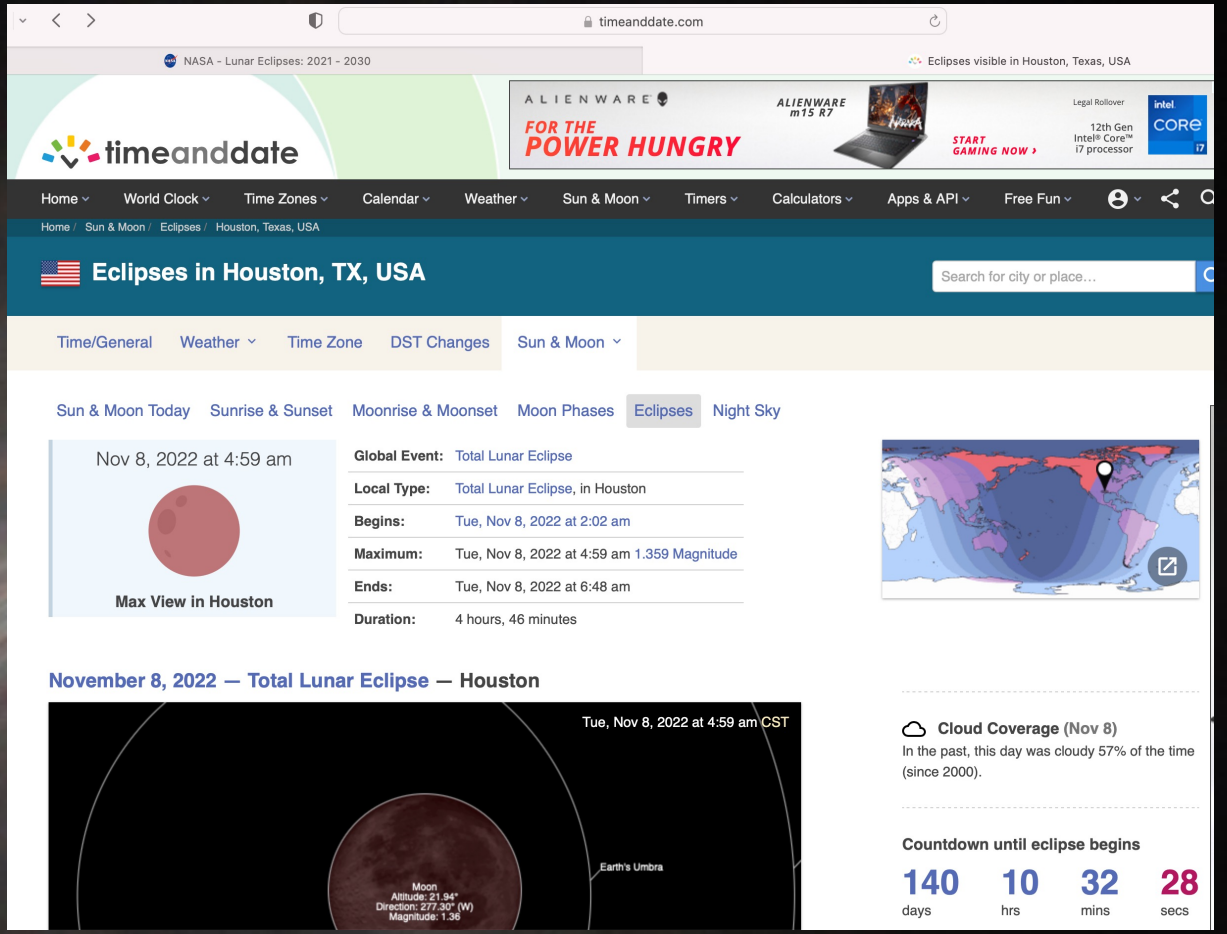
If you use this site, please **DONATE** – every Google map view costs him money

Find your next eclipses from **https://timeanddate.com/eclipse/**



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Solar Eclipse 101

- Who (will be able to see it?)
- What (is a solar eclipse versus a lunar eclipse)
- Where (do I need to go to see it best?)
- **Why (do I need to go to totality?)**
- How (do I observe it safely?)
- When (is the next one?)

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Solar Eclipse 101

- **Why (do I need to go to totality?)**
  - **Multisensory experience**
  - **Only way to see the diamond ring and corona**
  - **Shadows get sharp**
  - **Birds roost**
  - **Temperature falls, winds pick up**
  - **Clouds become more transparent**
  - **Each one IS different! Awe-inspiring!**

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Diamond rings I have seen

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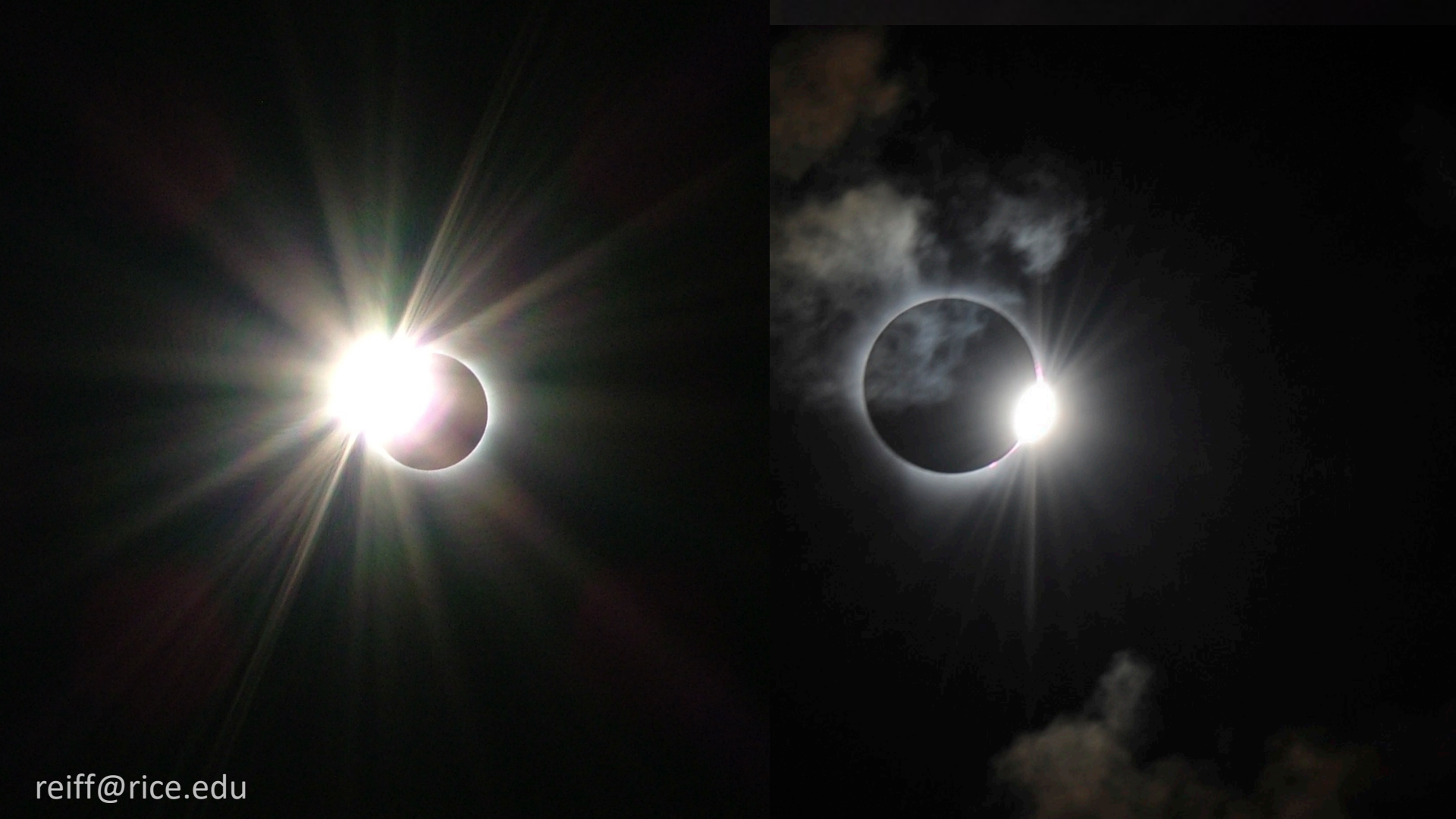

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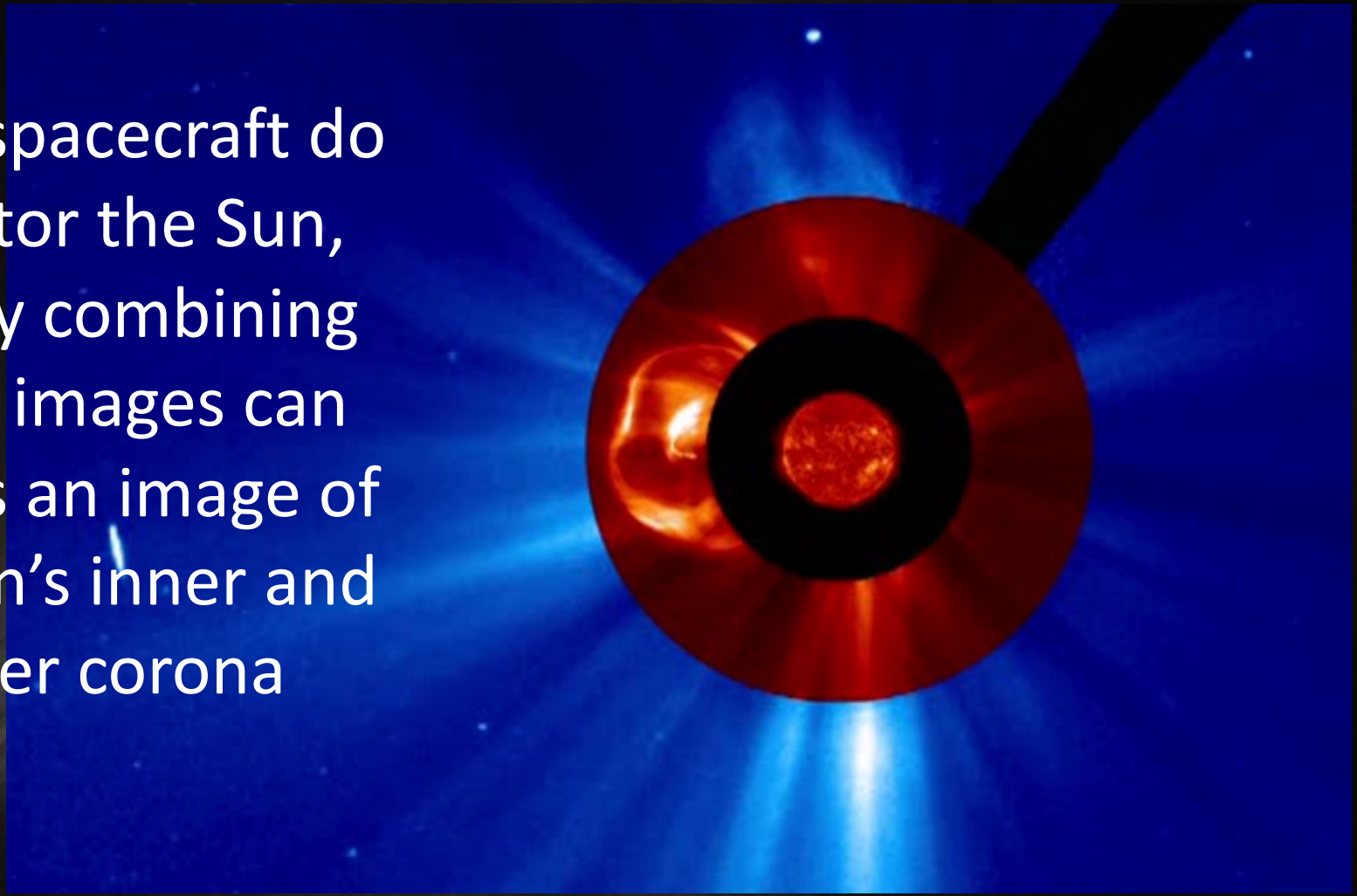
NASA spacecraft do monitor the Sun, and by combining three images can give us an image of the sun’s inner and outer corona



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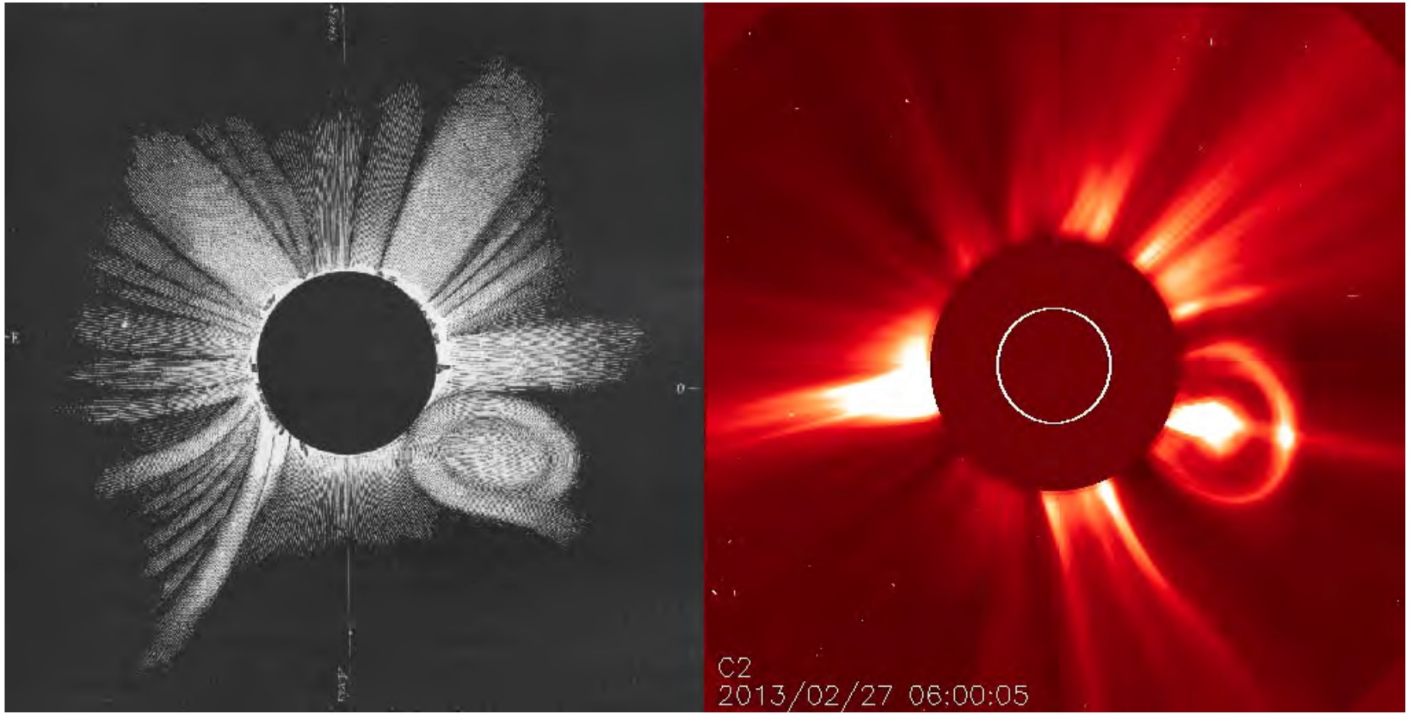
CORONAL MASS EJECTIONS FIRST SPOTTED DURING A TOTAL SOLAR ECLIPSE (1860)

But nothing beats being there!!



Left: Drawings of the 1860 eclipse by G. Tempel. Right: Modern-day instrument called a "coronagraph," which simulates a solar eclipse, blocking the sun to reveal the sun's outer atmosphere. Eruptions like the one depicted in Tempel's drawing are common observations in coronagraph images. Credit: ESA/NASA/SOHO

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Solar Max coronas are more symmetric – . . . . , . . this will be close to maximum

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Celebrate!

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- “sunset” all around you (these are my fisheye images from various eclipses)

  (China, 2008)

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- “sunset” all around you
- Some stars and planets may be visible

(Australia 2012)

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- This will be near-noon – best for the shadow and for shadow bands
- Moon shadow approaching at >1000 mph! (Libya, 2006)

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- Clouds become more transparent – we even saw Venus thru the thin clouds

(Ternate, 2016)

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Solar Eclipse 101

- Who (will be able to see it?)
- What (is a solar eclipse versus a lunar eclipse)
- Where (do I need to go to see it best?)
- Why (do I need to go to totality?)
- **How (do I observe it safely?)**
- When (is the next one?)

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Solar Eclipse 101

- **How (do I observe it safely?)**
  - **Eye protection KEY during partial phase**
  - **Special filters for binoculars and cameras**
  - **Only DURING TOTALITY is it safe to view with naked eye or unshielded binoculars**
  - **Projection techniques using binoculars or telescope**
  - **Pinhole cameras last resort (make a cardboard screen)**

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Safe observing!

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Solar Eclipse 101

SAFETY IS KEY! Download safety writeup in English and Spanish from NASA site

- **https://space.rice.edu/eclipse/pdf/evergreen_eclipse_flyer_english.pdf**
- **https://space.rice.edu/eclipse/pdf/evergreen_eclipse_flyer_spanish.pdf**

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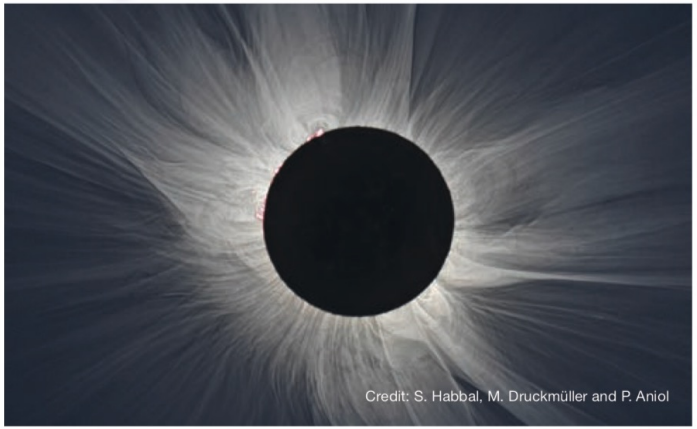
National Aeronautics and Space Administration

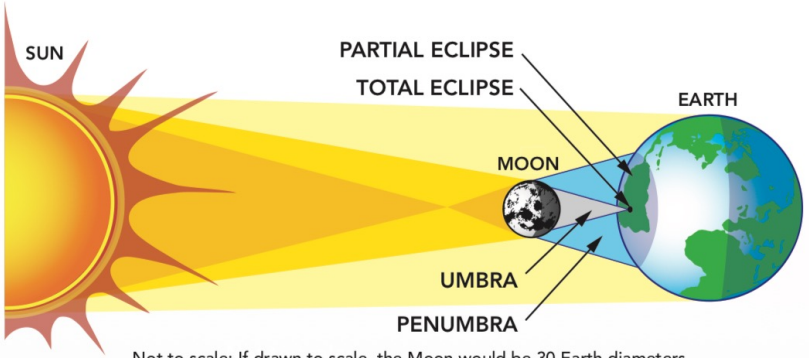
Experience a Solar Eclipse



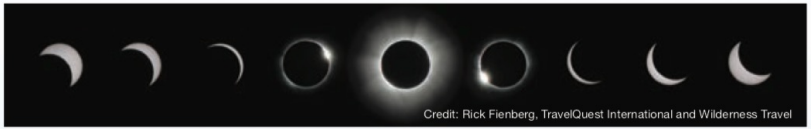
WHAT IS A SOLAR ECLIPSE?

A solar eclipse happens when the Moon moves between the Sun and Earth, casting a shadow on Earth, fully or partially blocking the Sun's light in some areas. There are different types of solar eclipses.

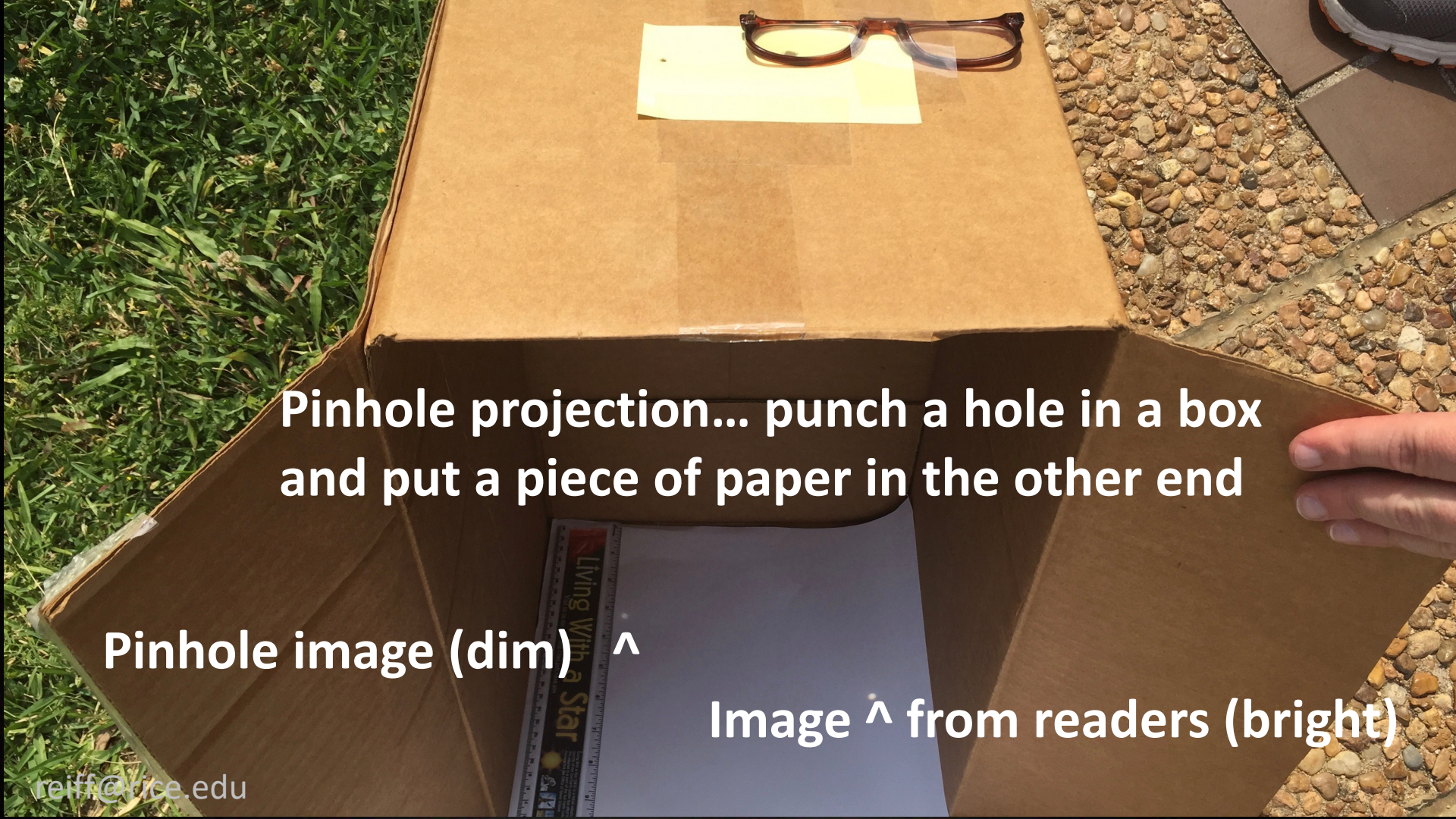
TOTAL SOLAR ECLIPSE



Not to scale: If drawn to scale, the Moon would be 30 Earth diameters away from Earth. The Sun would be 400 times that distance.



In this series of stills from 2013, the eclipse sequence runs from right to left. The center image shows totality; on either side are the 2nd contact (right) and 3rd contact (left) diamond rings that mark the beginning and end of totality respectively.



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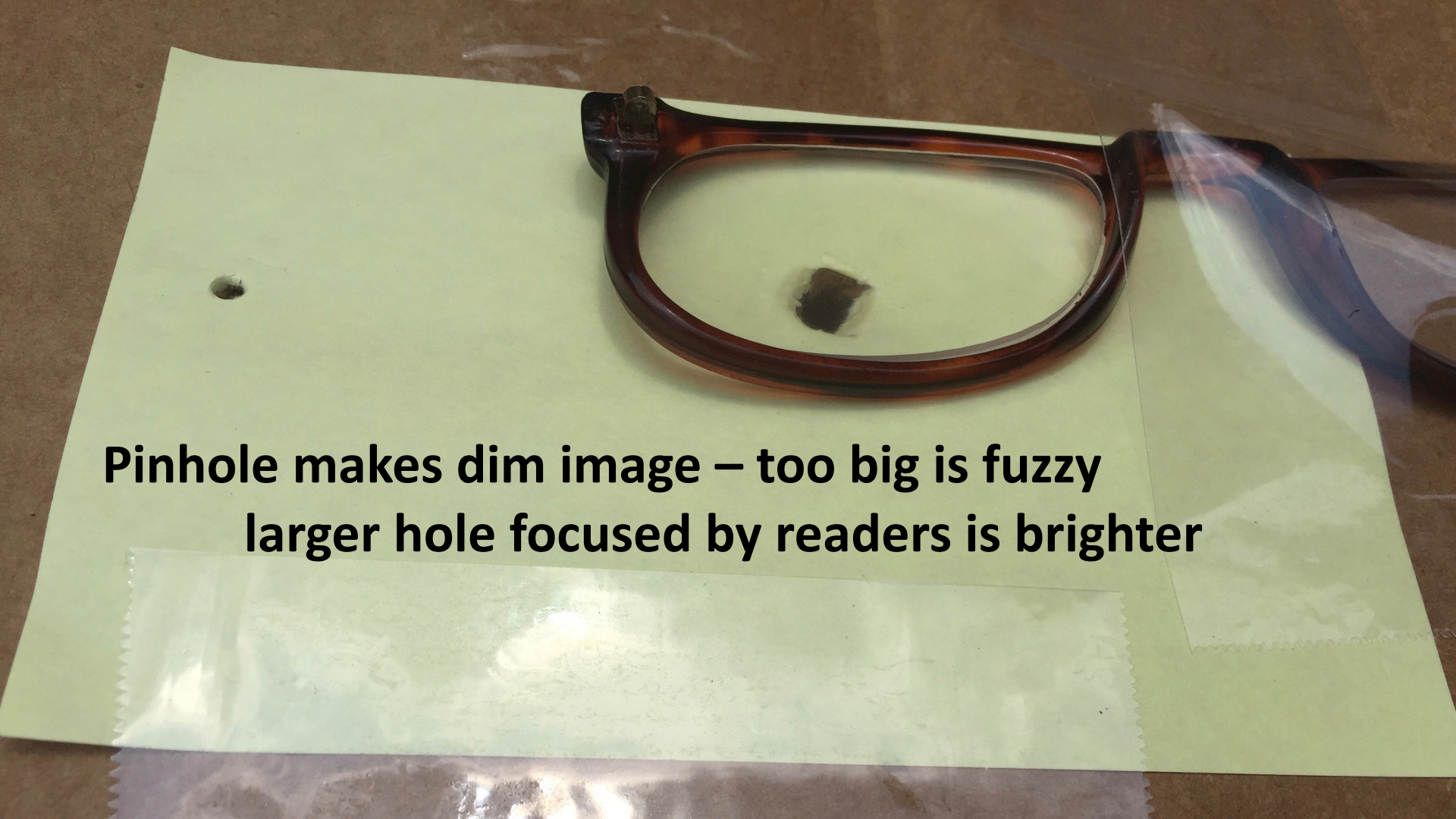
Pinhole makes dim image – too big is fuzzy
larger hole focused by readers is brighter

Fun way for a pinhole projection:
Punch holes in cardboard and photograph its shadow!

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- **Eclipse shades: cheap and easy! (But no magnifi-cation!)**

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Binoculars have numbers: A x B means A magnification and B aperture.

- Binoculars with solar filters are the best for partial eclipses
- These pop off easily for totality.

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- When the filters are on, it can be hard to find the sun.
- First, CLOSE YOUR EYES and face the sun (feel it warm on your face)

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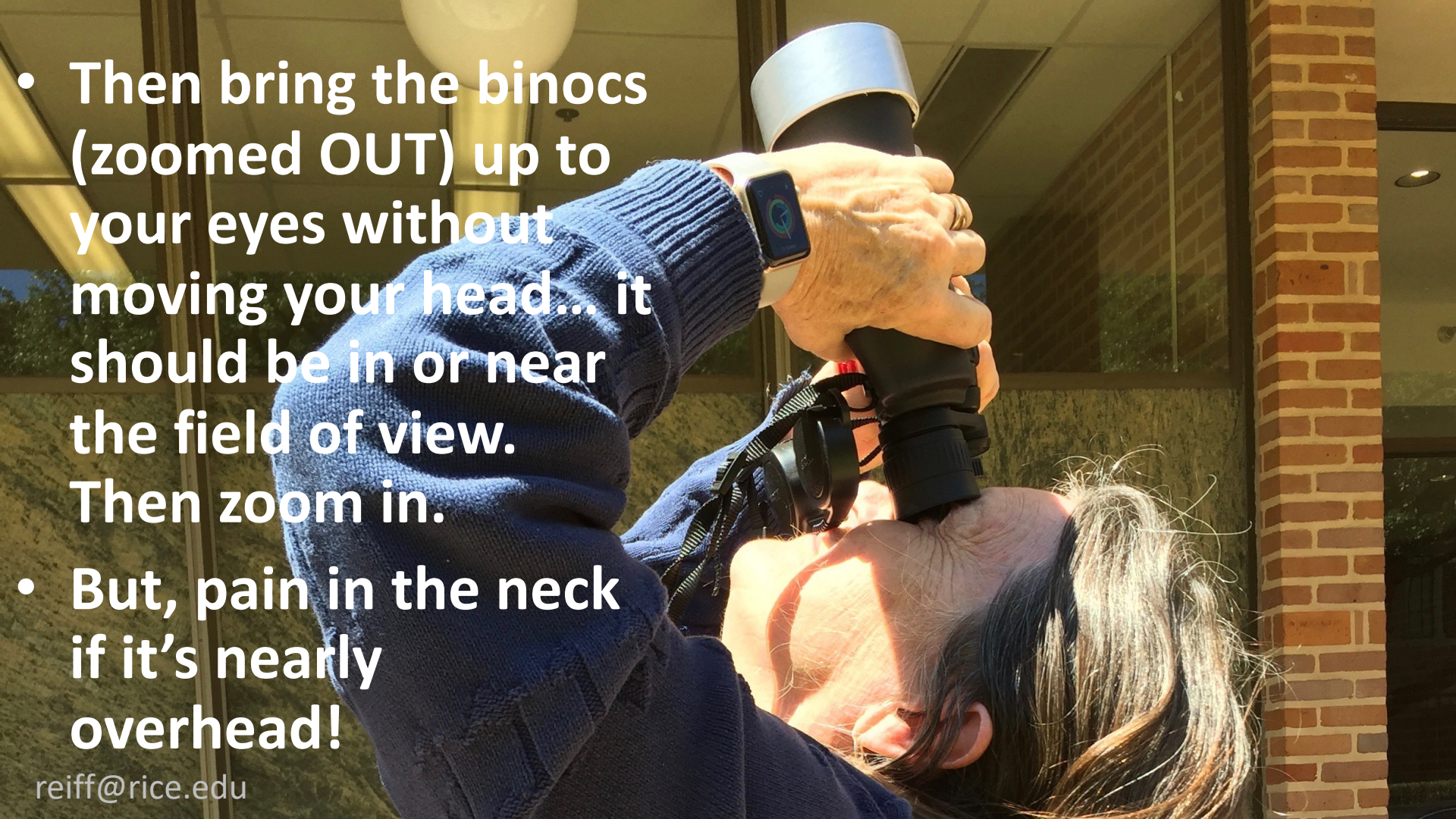
• Then bring the binocs (zoomed OUT) up to your eyes without moving your head… it should be in or near the field of view. Then zoom in.
• But, pain in the neck if it's nearly overhead!
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- More comfortable and easier to share if on a tripod!

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- **Filters on the OBJECTIVE NOT AT THE EYEPIECE**

- Need solar filters for each lens (Rainbow Symphony)
- Need a “binocular tripod adapter” (photo store or Amazon)

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- You can tape on a filter on the front of binoculars.
- Use Gaffer Tape for easy removal

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Binocular projection

- **This eclipse will be HIGH IN THE SKY (near solar noon) for much of the US, and regular binoculars with solar filters will crane your neck.**
- **Solution: Binocs on tripod with adapter – one lens uncovered**
- **Align by minimizing the shadow of the binocs**
- ***DANGER:* Ensure that people don't look through the binoculars!! Keep tripod very LOW to ground**

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Binocular projection

- Ideally put the image into a shadow area and use white cardboard to project the image onto.
- DANGER: Ensure that people don't look through the binoculars!! Keep tripod very LOW to ground
- May heat up your binocs, so use a cheap pair that has the tripod mounting screw (zoom is good)
- Requires "binocular tripod adapter" available online (not sold in most stores)

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Binocular projection

- **A drape makes a nice shadow (keep one lens uncovered)**

Telescope projection

- **A drape makes a nice shadow**

Solar Eclipse 101

- **Critical items:**
  - **Binocular tripod adapter**
  - **Solar filters**
  - **Tripod**

Everyone should have their own binoculars for totality!!

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- “Sunspotter” – not cheap but VERY safe and all get a good view.
- Easy to align
- Great for Sun high in the sky

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- “Sunspotter” even works for nearly-overhead sun.

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- **H-alpha telescope: expensive but allows you to preview the prominences**

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Solar Eclipse 101

- **Activities for groups:**
  - **Punching boards for pinhole pictures**
  - **Measure temperature before, during and after**
  - **Sunspotter**
  - **Filtered camcorder on a TV to monitor progress**
  - **Reading chart (smallest font readable)**
  - **Photographing eclipses under trees, straw hats**
  - **Monitoring animal behavior**

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Data Sheet

For temps, clouds and winds

Add in the fraction of sun covered later.

Be sure the thermometer is in the shade!

Eclipse Naturalist Observations Date:
Observer: Location:

Time	**Temp-erature**	**Cloud cover %**	**Type of clouds if any**	**Wind speed (mark "e" if estimated)**	**Wind from what direction?**	**Fraction of Sun covered**

Data Sheet

For animal / bird behavior

(add in the fraction of sun covered later)

Eclipse Naturalist Observations Date:

Observer: Location:

Time	Animal / bird species observed	Animal / bird behavior noted	Fraction of Sun covered

Solar Eclipse 101

- **What if it's cloudy:**
  - **Measure temperature and wind changes**
  - **Reading chart**
  - **Animal behaviors (roosting, etc)**
  - **Watch on NASA TV**
  - **Don't give up – clouds can become more transparent as totality approaches**
  - **Let your body experience what your eyes cannot**

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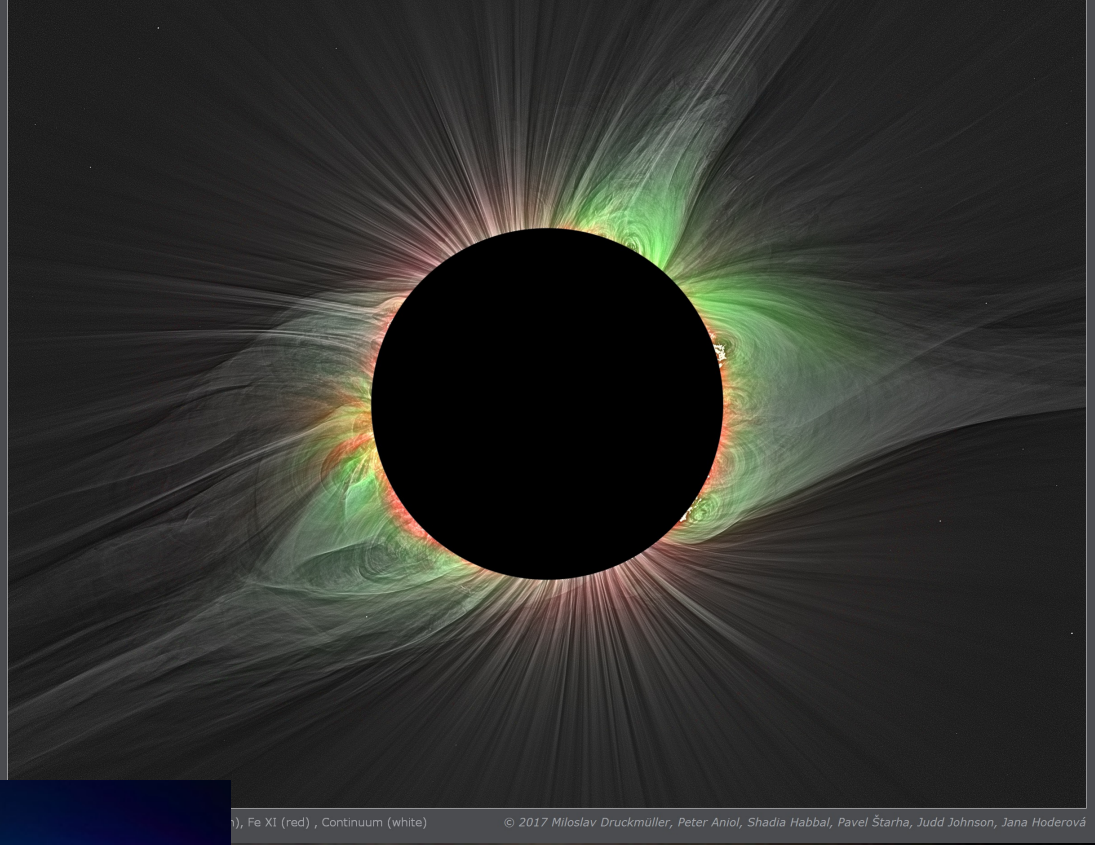
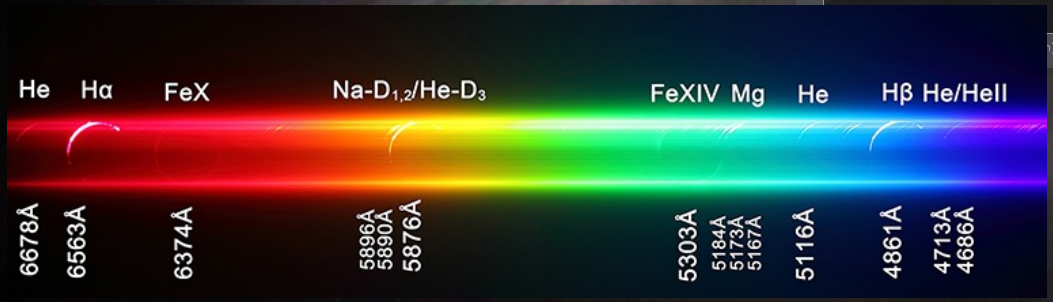
Citizen Science

- **Cool Science:**
  - **Corona temperature image**
    - **(green is 3.6M deg Fe XIV, red is 1.8M Fe XI)**
  - **Chromosphere Spectrum (below)**

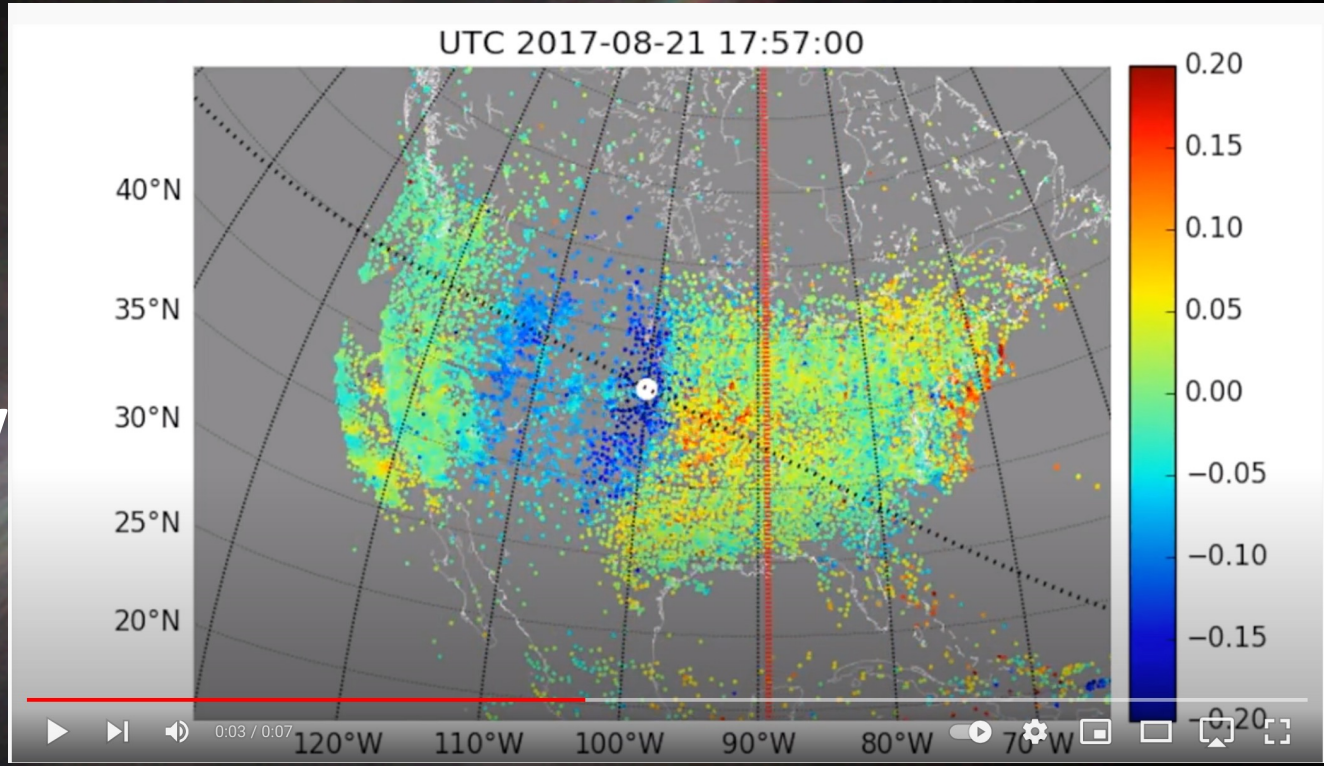




Courtesy M Druckmüller (top)
Jay Pasachoff (left)

Solar Eclipse 101

- **Cool Science:**
  - **Ionospheric bow waves**
  - **https://youtu.be/8vivMEVBwys**
  - **Eclipse QSO party!**



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Solar Eclipse 101

- Who (will be able to see it?)
- What (is a solar eclipse versus a lunar eclipse)
- Where (do I need to go to see it best?)
- Why (do I need to go to totality?)
- How (do I observe it safely?)
- **When (is the next one?)**

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Solar Eclipse 101

- **When (is the next one?)**
  - **Roughly 2 solar eclipses every year (but may be partial only)**
  - **Roughly 2-3 lunar eclipses each year**
  - **At least a partial lunar 2 weeks before and/or after a total solar eclipse**
  - **After the two in 2023/2024 the next ones thru Texas is a total in 2045 just touching the panhandle**

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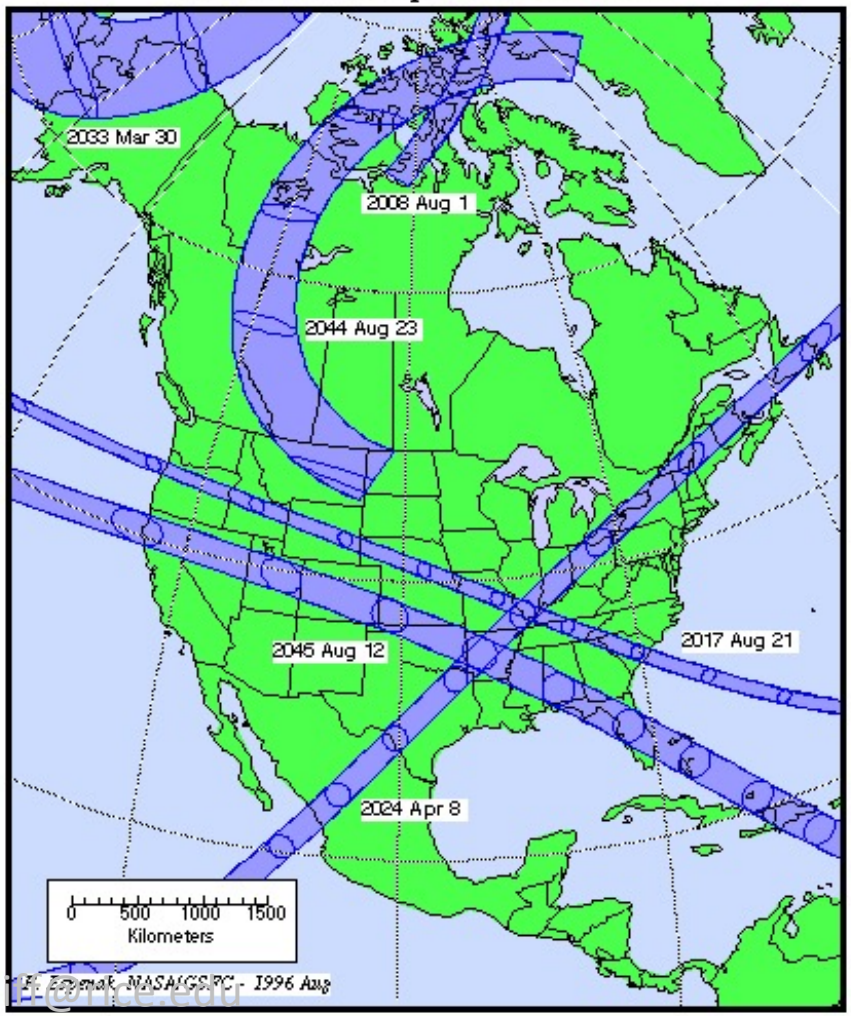
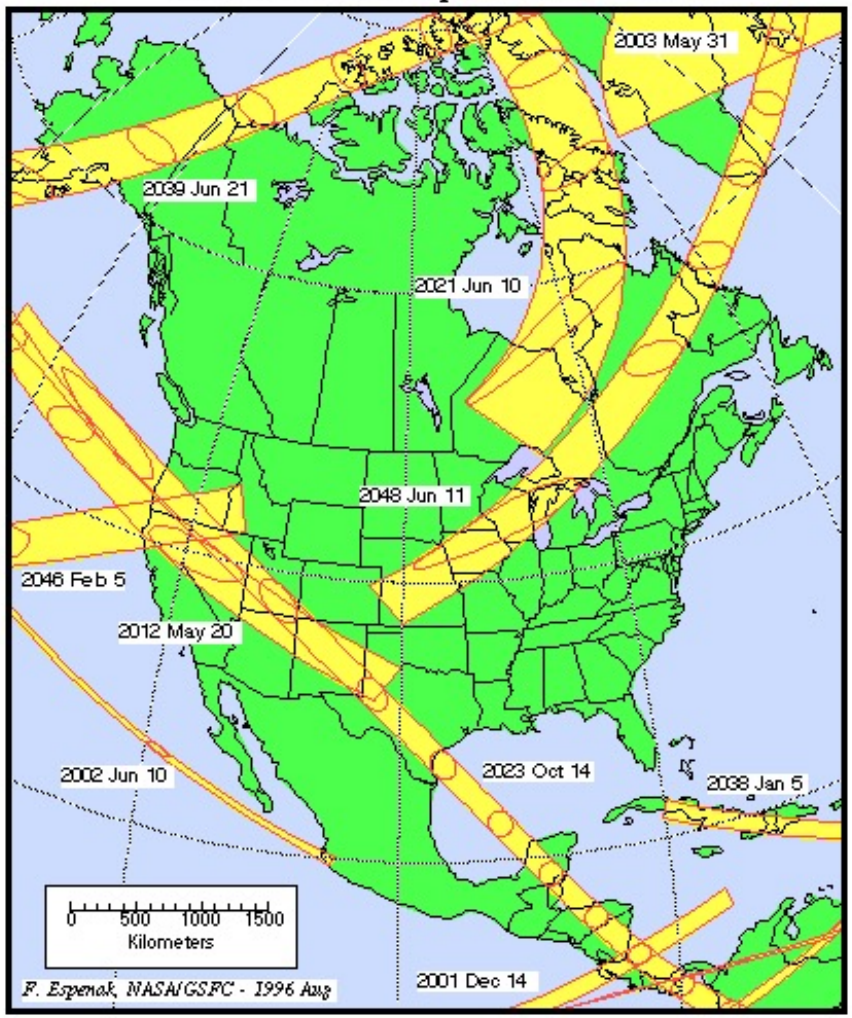

Total Solar Eclipses: 2001 - 2050
2033 Mar 30
2008 Aug 1
2044 Aug 23
2045 Aug 12
2017 Aug 21
2024 Apr 8
0 500 1000 1500
Kilometers
F. Espenak, NASA/GSFC - 1996 Aug


Annular Solar Eclipses: 2001 - 2050
2003 May 31
2039 Jun 21
2021 Jun 10
2048 Jun 11
2046 Feb 5
2012 May 20
2002 Jun 10
2023 Oct 14
2038 Jan 5
0 500 1000 1500
Kilometers
F. Espenak, NASA/GSFC - 1996 Aug
2001 Dec 14

Solar Eclipse 101

- PHOTOGRAPHY: Hard to get a perfect shot. Have to do range of exposures and put them together afterwards. Be sure you can manually set exposure and time, and TURN OFF FLASH!
- **Short exposures see prominences and chromosphere**
- **Long exposures get the corona but overexpose the prominences**
- **PRACTICE WITH THE FULL MOON – GET DETAIL**
- **YOUR EYES WITH BINOCULARS IS THE BEST**

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Solar Eclipse 101

- VIDEOGRAPHY: Again, be able to change exposure (“iris”) and set manual focus to infinity
- **Practice on the full moon**
- Videocamera with LCD viewfinding panel is safe to take off filter just before diamond ring… and will show some corona with the ring (but might overheat if left on the sun past totality)
- Set up a videocamera so it captures YOU and the sun – your own reactions and sounds will be the most fun memory you have of the event.

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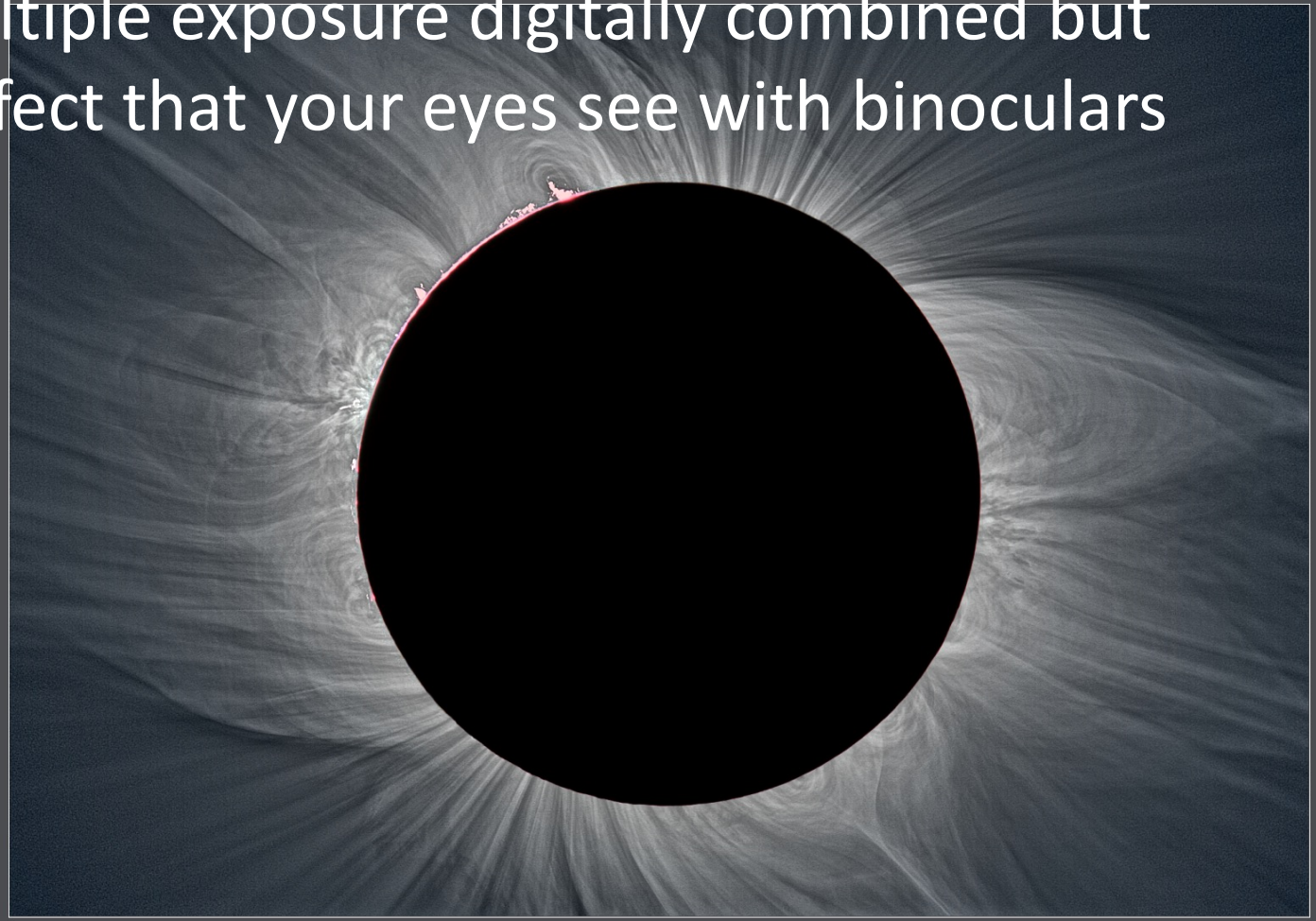
- This is a multiple exposure digitally combined but gives the effect that your eyes see with binoculars



Courtesy Druckmüller – he uses digital field line tracing- has done many eclipses www.zam.fme.vutbr.cz

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- This is a multiple exposure digitally combined but gives the effect that your eyes see if the sky is very clear

Courtesy Miloslav Druckmüller
www.zam.fme.vutbr.cz

Total Solar Eclipse 2006

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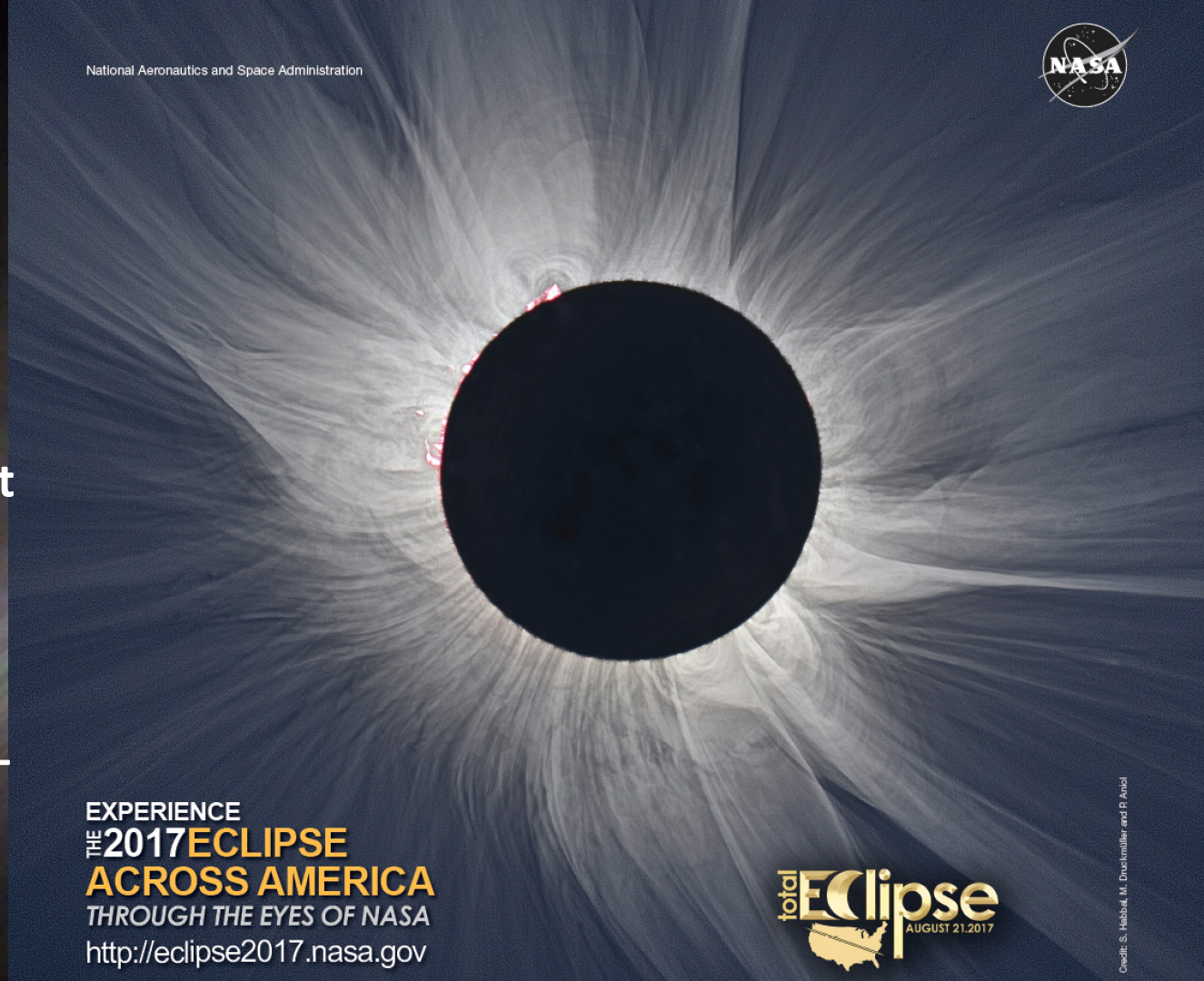
- **FIRST TIMERS: JUST ENJOY – don't spend your totality behind a lens!!**
- **Always put filters closest to Sun**
- **Be careful with viewfinder cameras**
- **Be sure you can adjust exposure and focus**
- **Be sure you can turn OFF the flash!**
- **Practice on full moon**
- **No moving after 95% - you might trip over someone!**
- **Red flashlight!**



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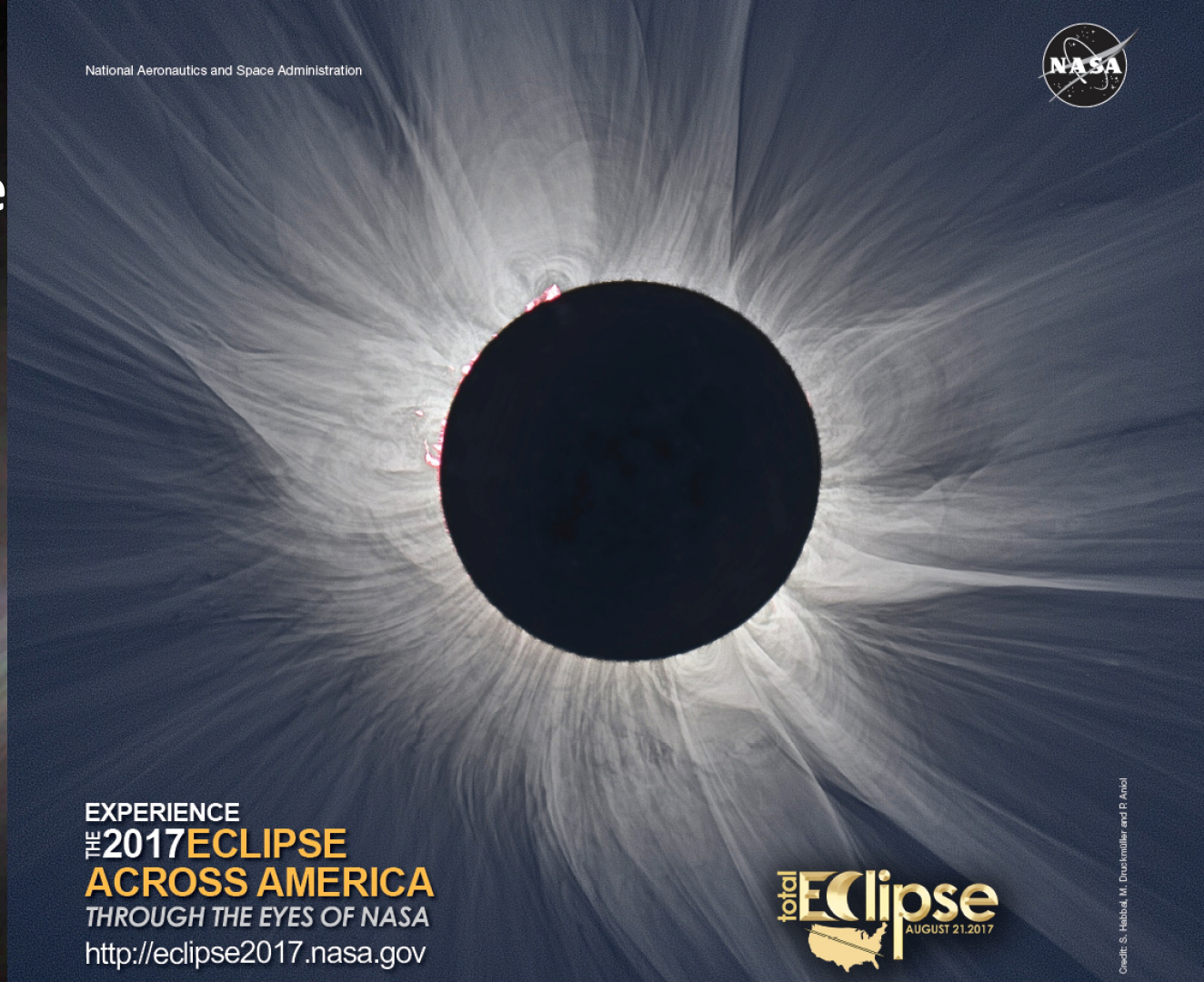
- This is a digitially combined image from several at various exposures.
- Courtesy Fred Espenak MrEclipse.com (from NASA download page)



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Solar/Lunar Eclipse 101

- **Test your eclipse knowledge:**
  - **Download the "TicTacToe" player with the eclipse data set.**
  - **Available from https://spaceupdate.com/software_tictactoe.php**
  - **Player is free; editor has 3- day free trial**
  - **Play rules like "Hollywood Squares"**

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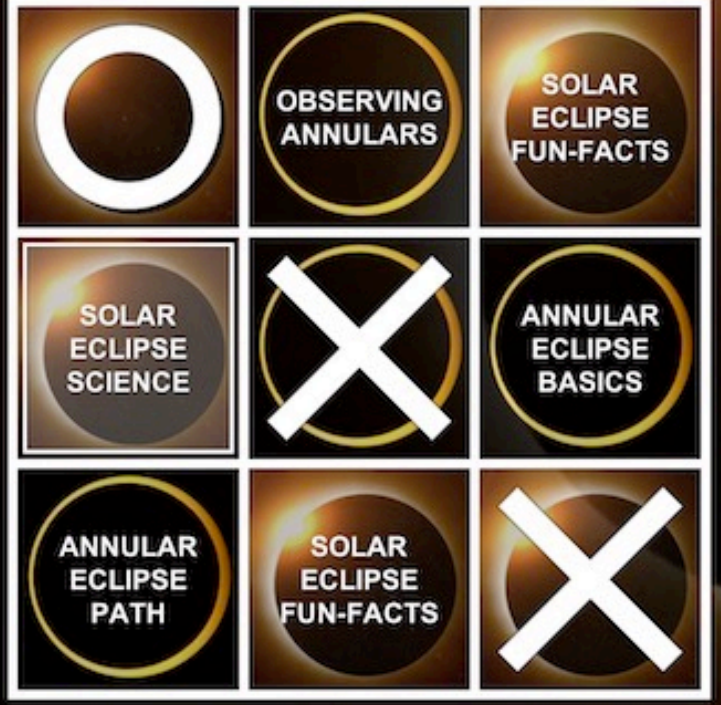
NEW GAME

TIC·TAC·TOE

HELP

ECLIPSES

SOLAR ECLIPSES



If there is a total solar eclipse anywhere on Earth, then two weeks before or two weeks after there will be a

A meteor shower

B lunar eclipse

C hurricane

D earthquake

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NEW GAME

TIC·TAC·TOE

HELP

ECLIPSES

SOLAR ECLIPSES

X	SOLAR ECLIPSE SCIENCE	X
O	X	LUNAR ECLIPSE BASICS
LUNAR ECLIPSE OBSERVING	SOLAR ECLIPSE SCIENCE	O

During totality...

A. the winds will die down

B. it will start raining

C. birds will roost

D. all of these

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Solar/Lunar Eclipse 101

- **More information:**
  - **–http://space.rice.edu/eclipse**
    - **Has links to many other sites**
    - **Download this powerpoint**
  - **–Join our eclipse news list: http://bit.ly/RiceEclipse**

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Solar/Lunar Eclipse 101

- **Solar Filters for binoculars:**
  - **http://www.rainbowsymphonystore.com/**
- **High quality photo filters from photo stores**
  - **E.g. online photo stores (B&H, etc)**
  - **Brick and mortar photo & astronomy shops (Land Sea & Sky, Orion)**

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Solar/Lunar Eclipse 101

Equipment Recommendations

- **Best binoculars: Zoom 8-20 x 50 (ok: non zoom 10 or 12x 35 or 50) (check by looking at stars)**
- **Best camera: SLR with manual focus and exposure, 300mm or more telephoto (ok: digital camera with optical zoom, "sunset mode"). DO NOT USE DIGITAL ZOOM or FLASH**
- **Best camcorder: HD or 4K with manual focus and exposure option. (ok: other camcorders with LCD viewfinder). For groups, link to TV set or school video**

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Solar/Lunar Eclipse 101

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……. “Doctor Pat”, Rice University

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