Western Regional Space Grant Directors Meeting
Bend Oregon, September 2016

MODERN EDDINGTON EXPERIMENT (MEE)

Toby Dittrich
Portland Community College

Jack Higginbotham
Oregon State University

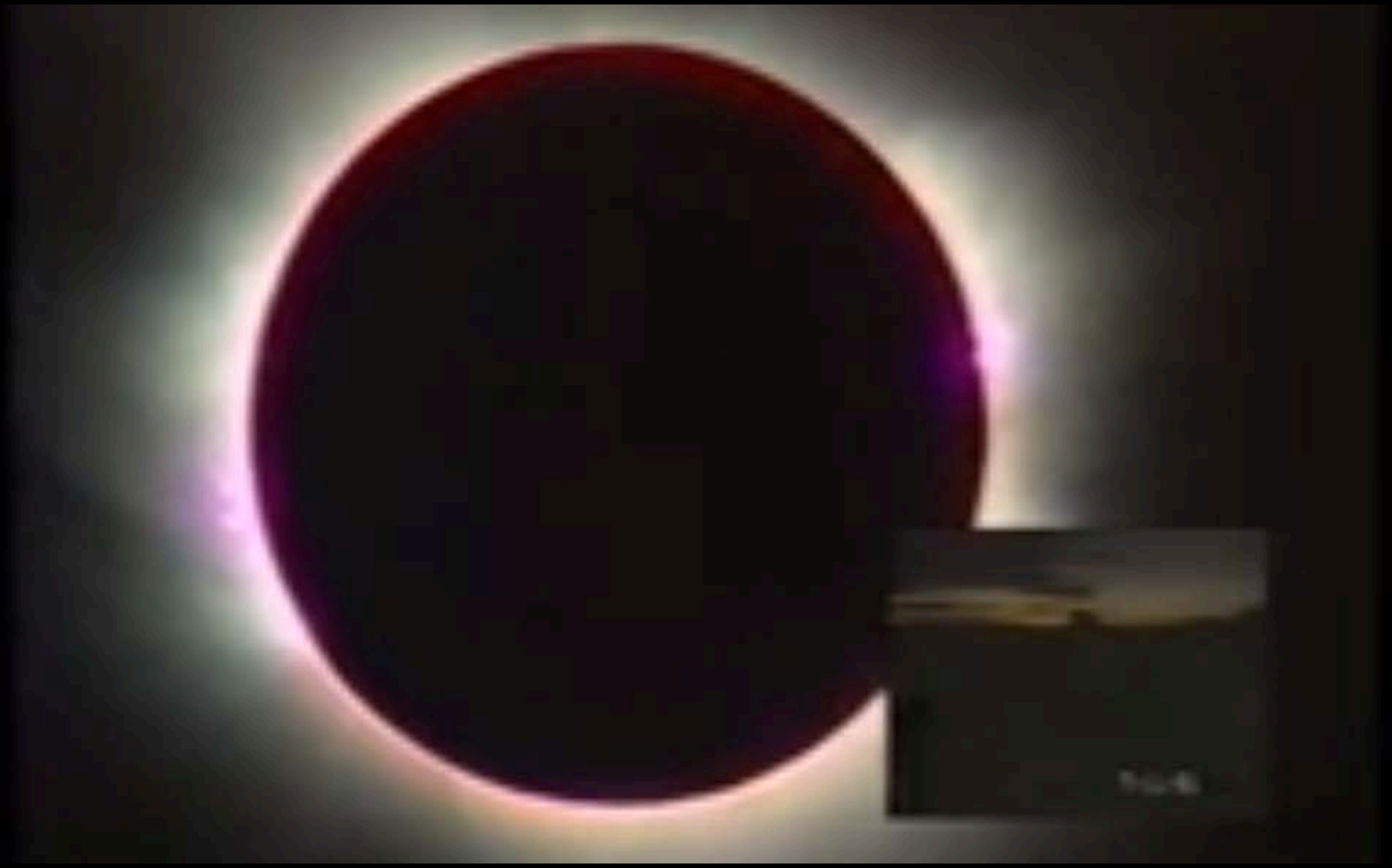
Ralph Emerson
PlaneWave Inc

Early Academic Interests

Interest in Eclipses?

La Paz Mexico Eclipse 1991

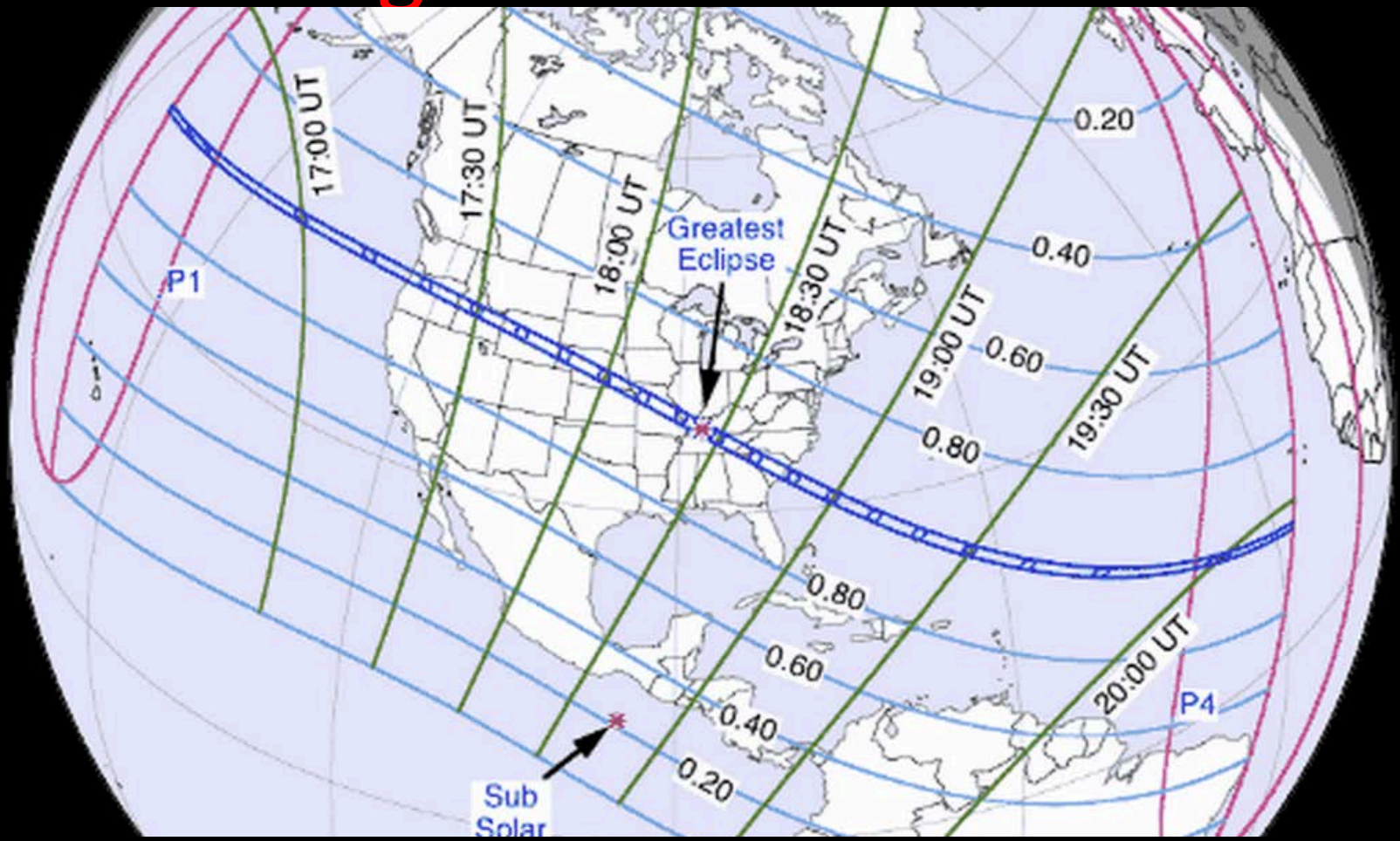
Youtube 1991 La Paz Eclipse




Bellatrix
Tejat Posterior
Mebsuta
Betelgeuse
Mintaka
Alnilam
Alnitak
Alhena
Castor
Sun
Pollux
Gomeisa
Procyon
Sirius
Mercury
Algenubi
Jupiter
Hydrobius
Mars
Regulus
Venus
ρ Pup

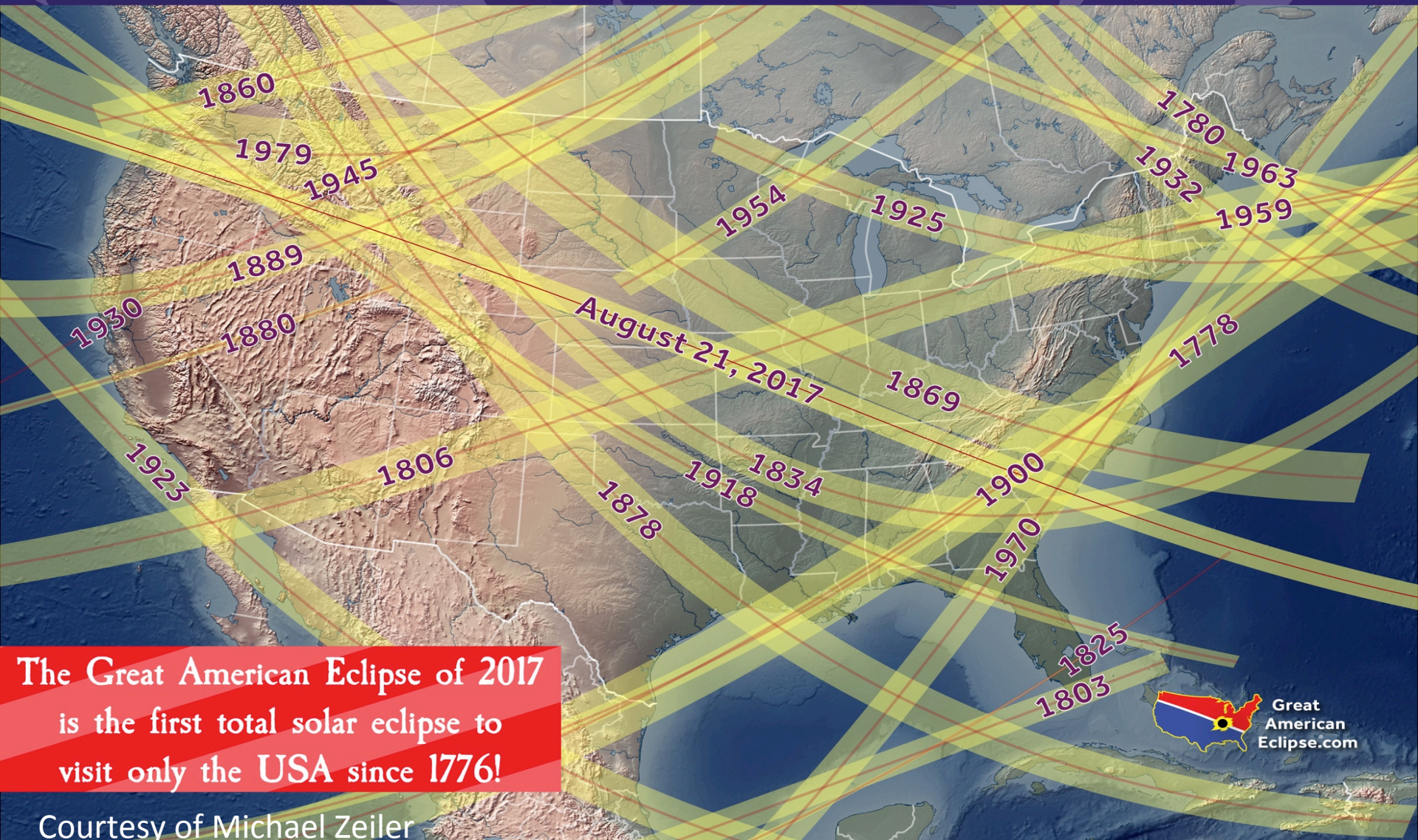

Pollux
Mercury
Jupiter
Mars
Regulus
Venus

August 21 2017



Courtesy of Michael Zeiler

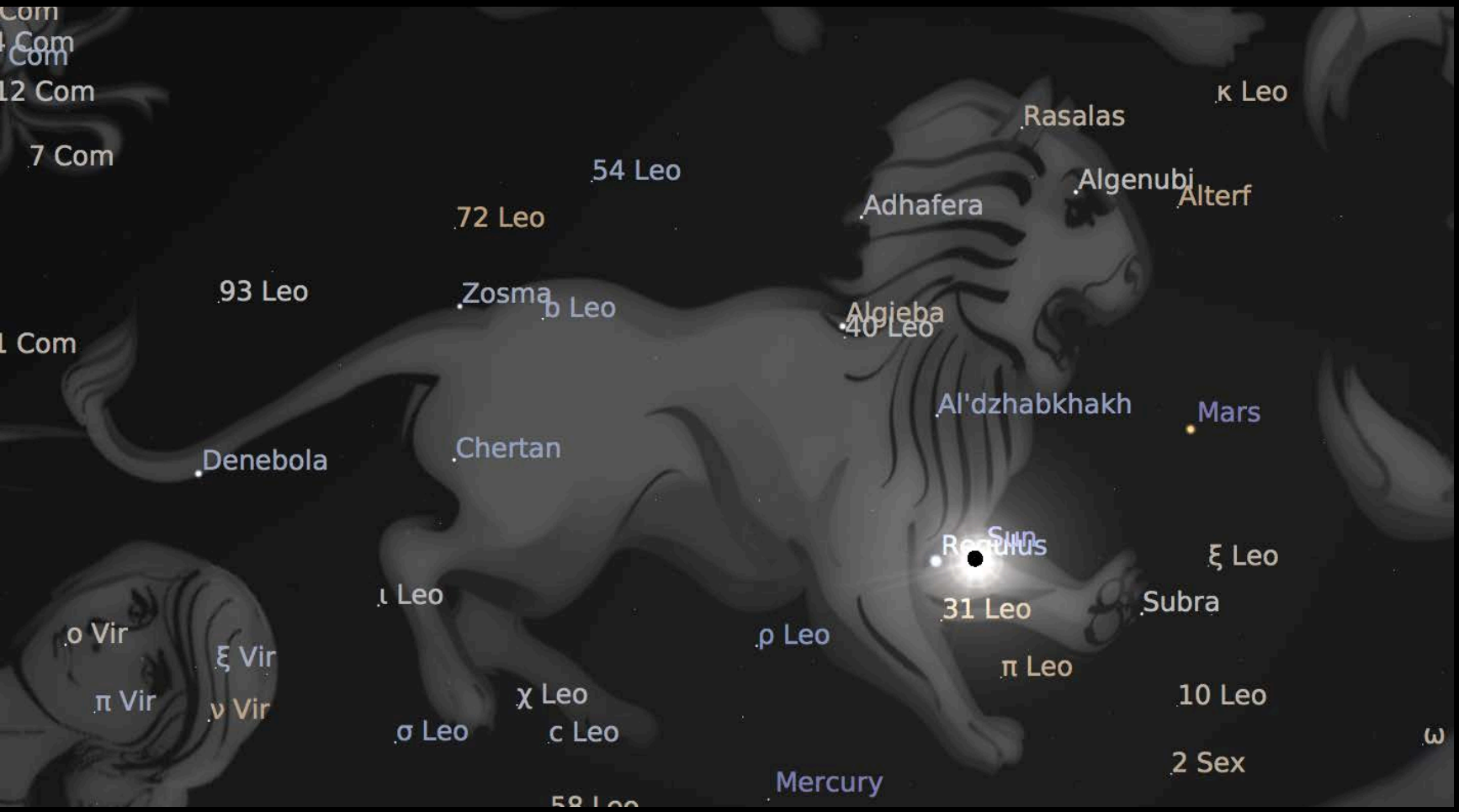
All the total solar eclipses across the United States of America from 1776 to 2017

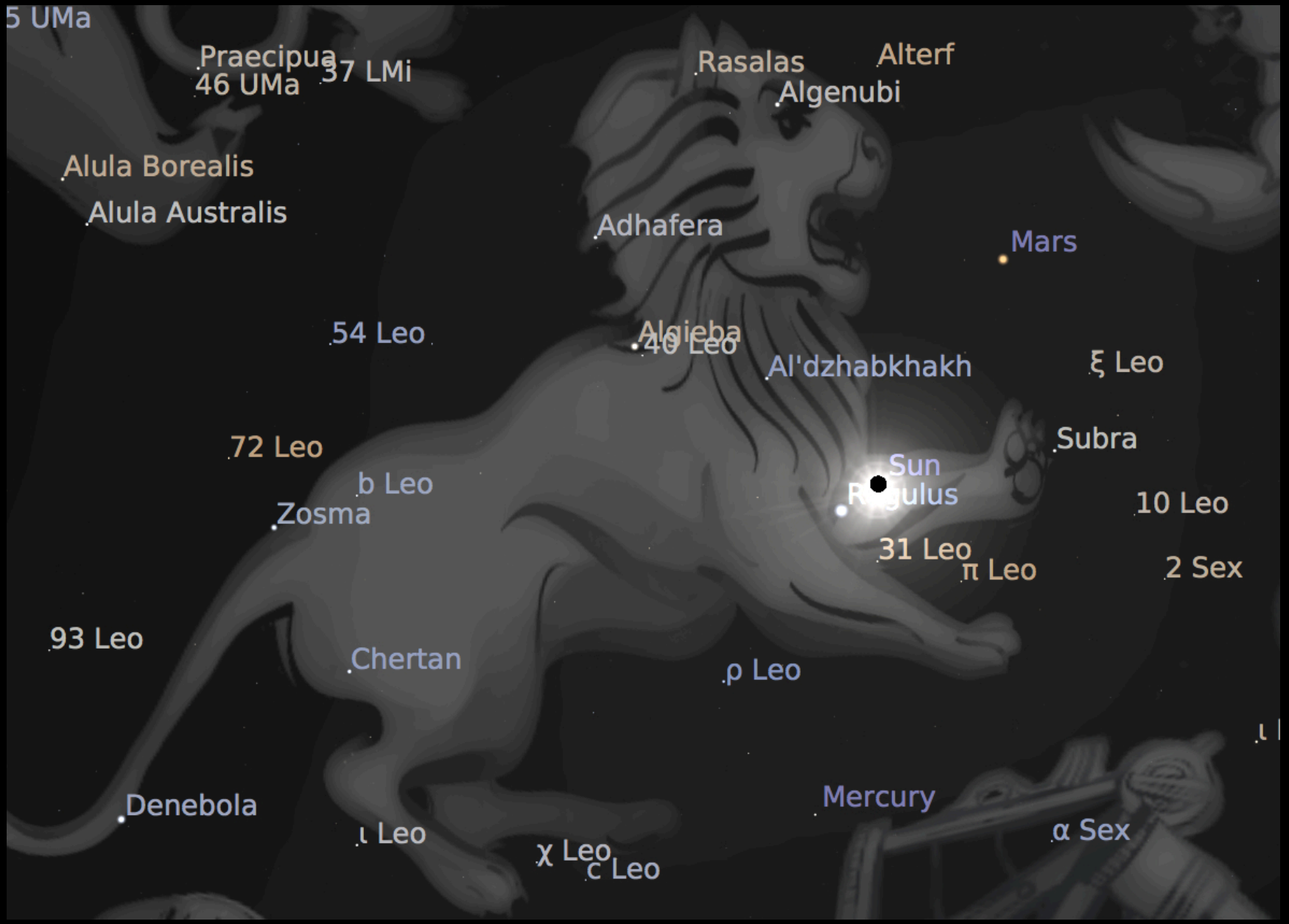


The Great American Eclipse of 2017 is the first total solar eclipse to visit only the USA since 1776!

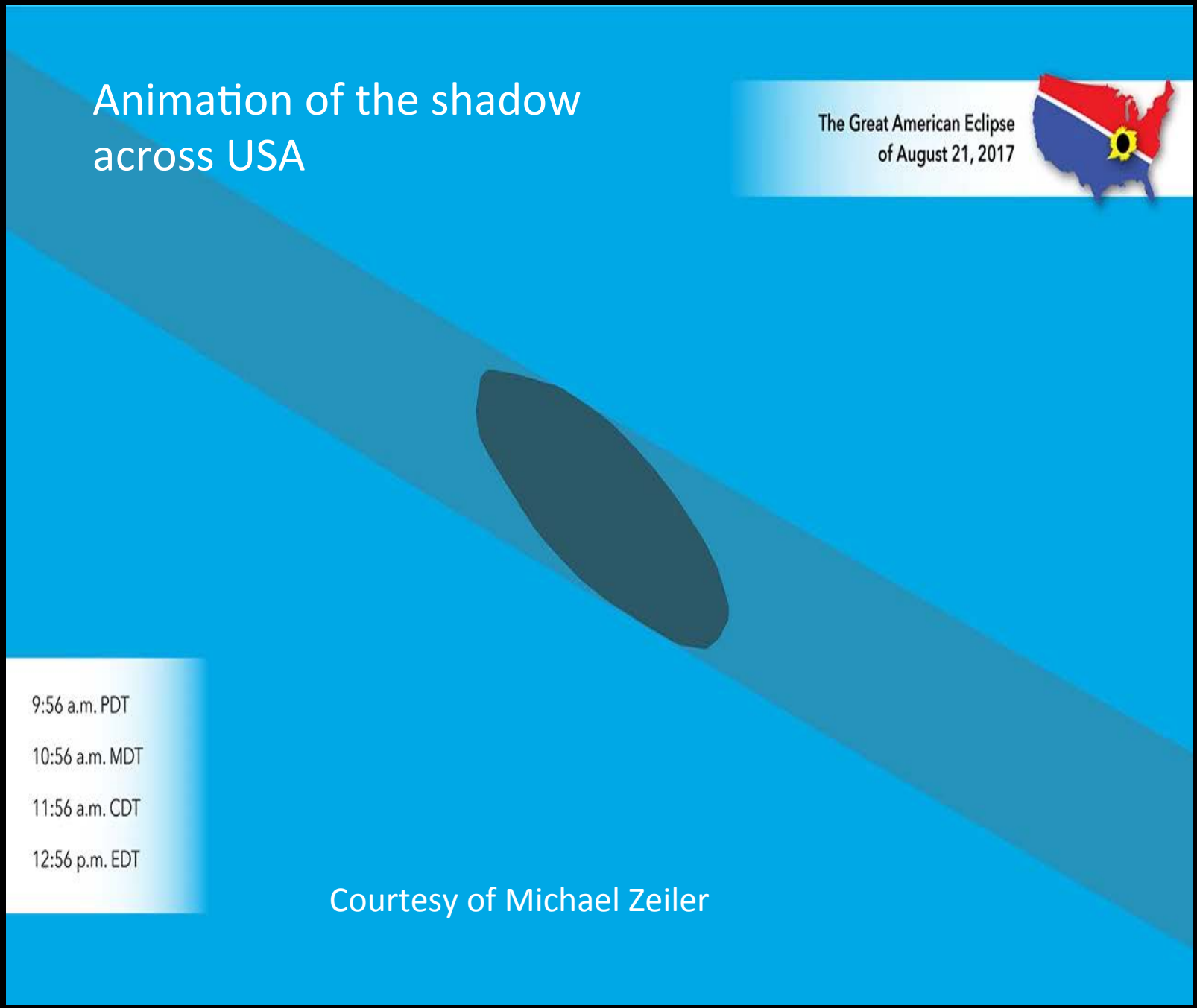
Courtesy of Michael Zeiler

Heart of Constellation LEO




5 UMa
Praecipua
46 UMa
37 LMi
Rasalas
Alterf
Algenubi
Alula Borealis
Alula Australis
Adhafera
Mars
54 Leo
Algieba
40 Leo
Al'dzhabkhakh
ξ Leo
72 Leo
Subra
Sun
b Leo
Regulus
Zosma
10 Leo
31 Leo
π Leo
2 Sex
93 Leo
Chertan
ρ Leo
Mercury
Denebola
ι Leo
χ Leo
c Leo
α Sex

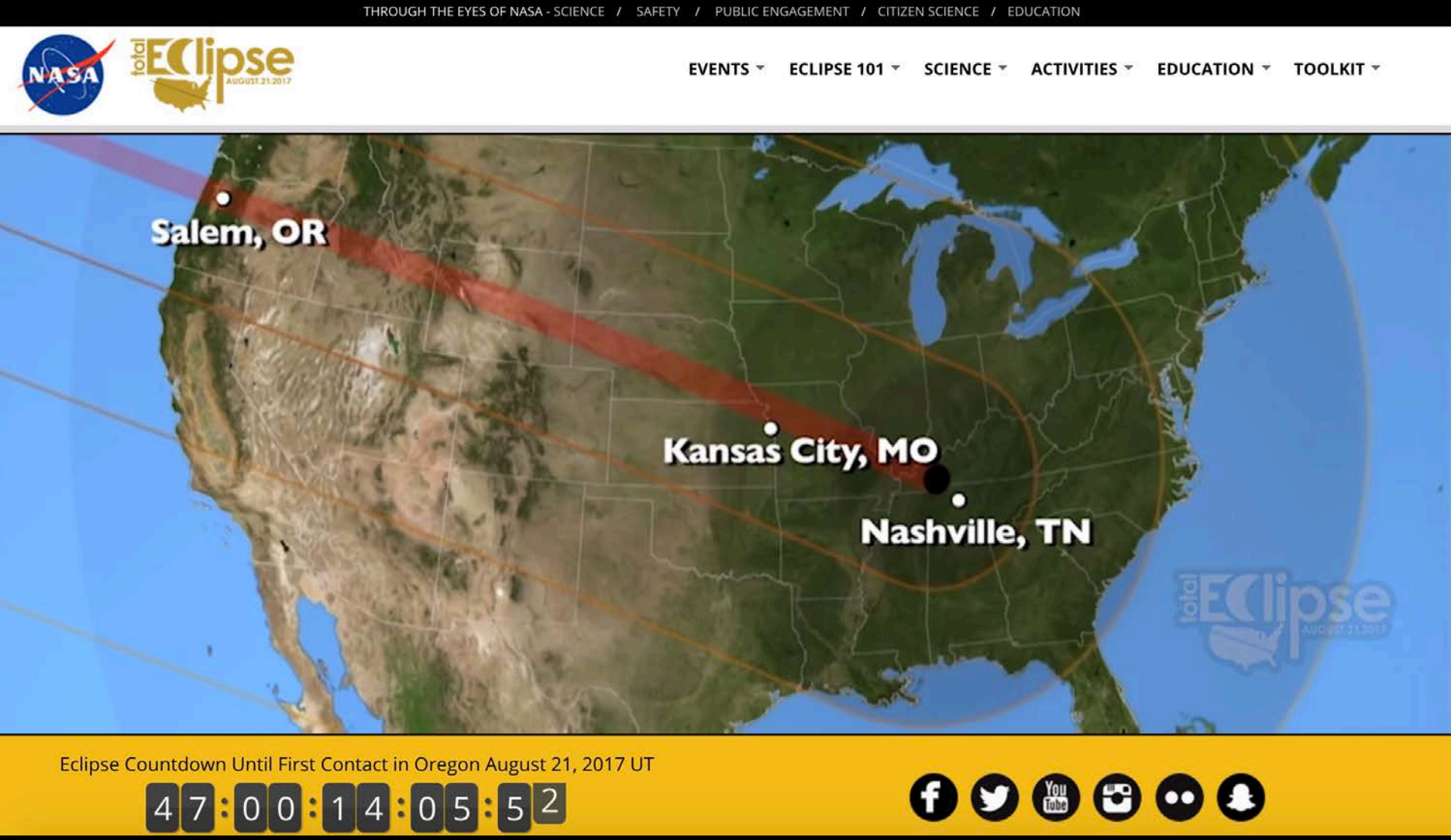
Animation of the shadow across USA



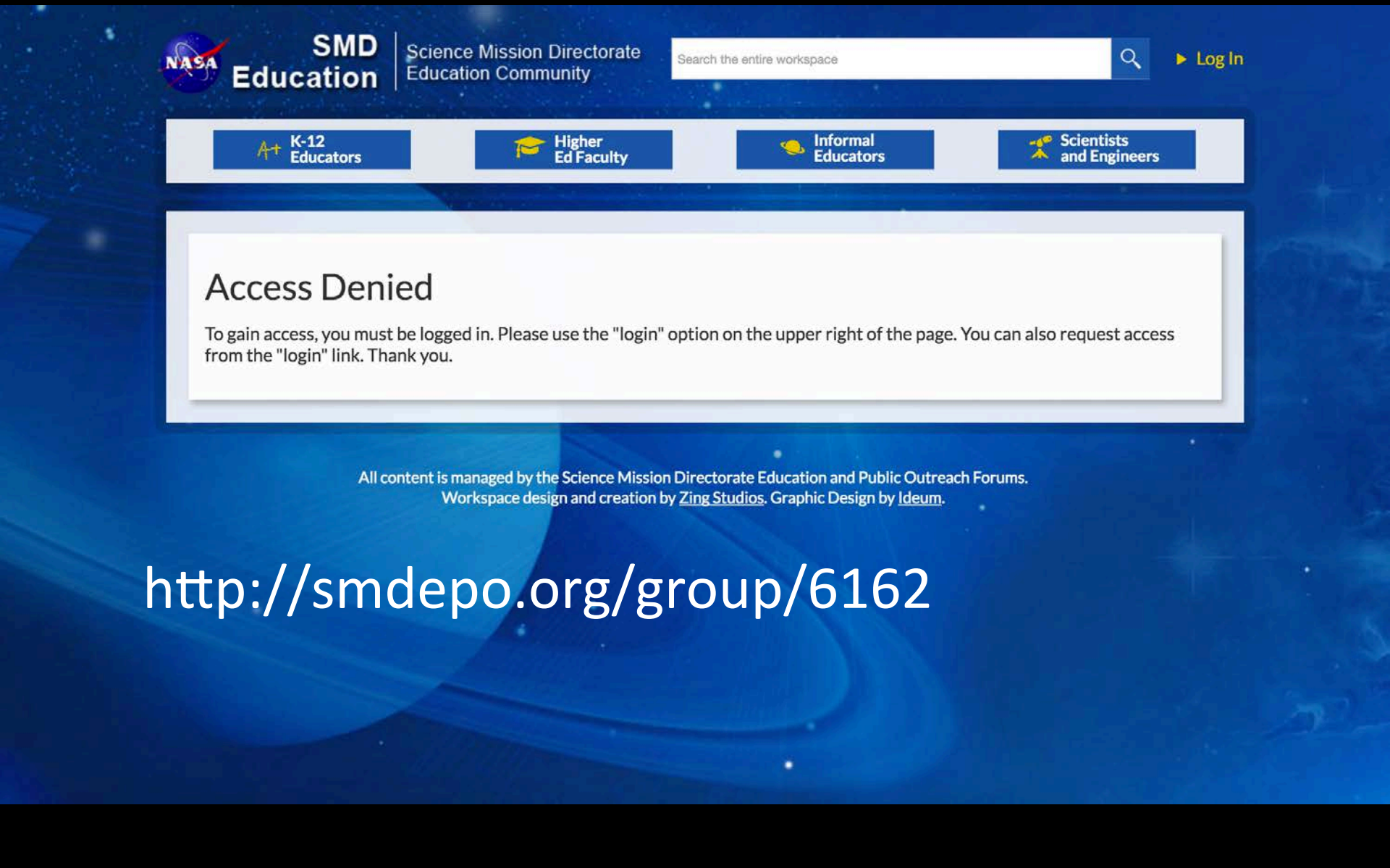
Courtesy of Michael Zeiler

National Space Grant Network

- States In path of Totality (or near)
- Oregon, Idaho, Wyoming, Nebraska, Iowa, Kansas, Missouri, Illinois, Kentucky, Tennessee, Georgia, North Carolina, South Carolina
- http://eclipse2017.nasa.gov



http://eclipse2017.nasa.gov/



http://smdepo.org/group/6162

nasa-eclipse2017] NASA Eclipse 2017 Telecon- Friday, September 16, 2016

Inbox x

Reed, Shannon P. (GSFC-670.0)[ADNET SYSTEMS INC] Sep 14 (11 days ago)

to nasa-eclipse20.

Good Morning,

Just a reminder that we will be holding our monthly (3rd Friday of the month) ***Eclipse 2017 Telecon*** Friday, September 16, 2016 at 3:00pm - 4:00pm (EDT).

AGENDA

-Eclipse Website Update
http://eclipse2017.nasa.gov

-Call for Challenges, Citizen Science and DIY Science Projects

-Eclipse Glasses and Eclipse in a Box update

-Safe Solar Viewing message

-SMDEPO Reminder
http://smdepo.org/group/6162

-Open Floor

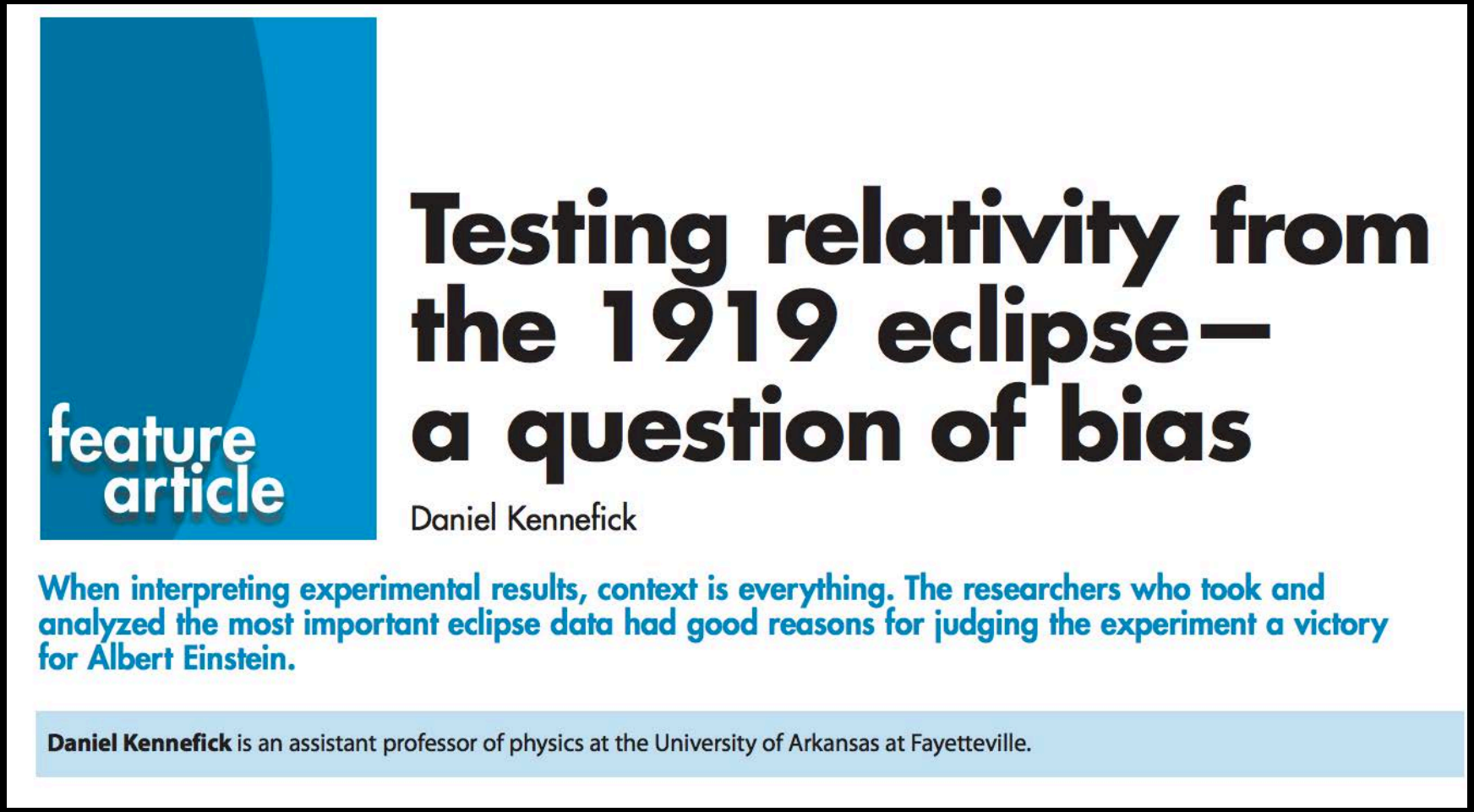
Telecon call-in information:
USA Toll Free #: 1-844-467-4685
USA Local/Toll #: 1-720-259-7012
Participant Passcode: #640276

Eclipse Resource Guide for teachers, students, and the public at the nonprofit Astronomical Society of the Pacific website: http://www.astrosociety.org/eclipse

Research Team

- Daniel Kennifick, University of Arkansas
- Don Bruns, StellarProducts.com
- Brad Schaefer, Lousiana State University

RESEARCH TEAM



feature article

Testing relativity from the 1919 eclipse—a question of bias

Daniel Kennefick

When interpreting experimental results, context is everything. The researchers who took and analyzed the most important eclipse data had good reasons for judging the experiment a victory for Albert Einstein.

Daniel Kennefick is an assistant professor of physics at the University of Arkansas at Fayetteville.

Arthur Stanley Eddington (1882–1944). In 1919 Eddington had already acquired a major reputation as a result of his work on the internal structure of stars. His enthusiasm for general relativity has led some historians to accuse him of bias in the analysis of the 1919 eclipse data. (Courtesy of the AIP Emilio Segrè Visual Archives.)

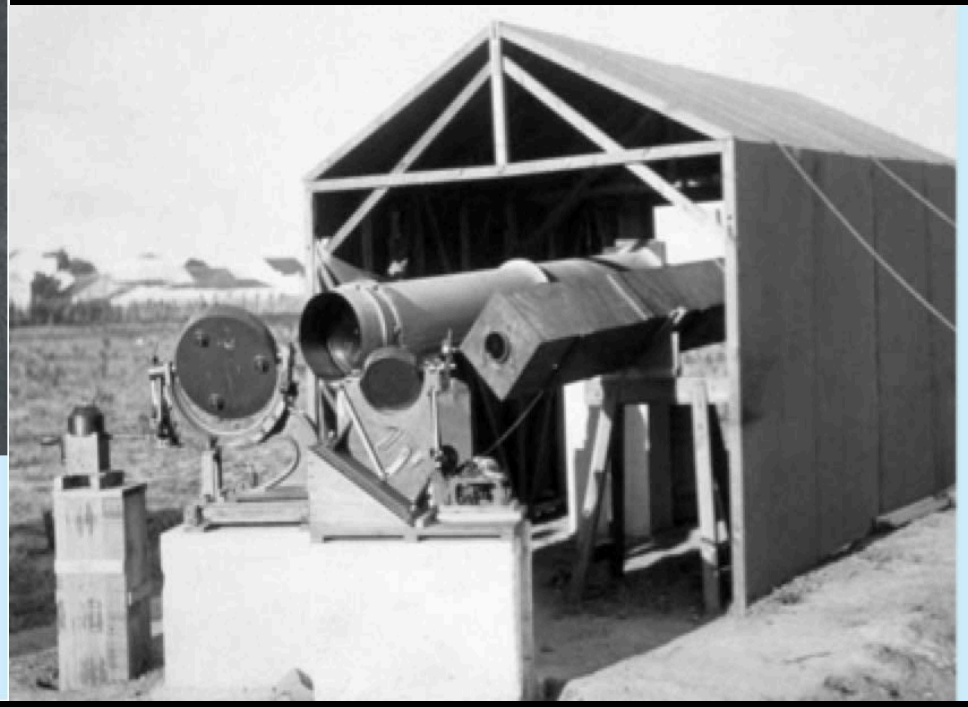
RESEARCH

- 1st Attempt – Lindeman & Lindeman

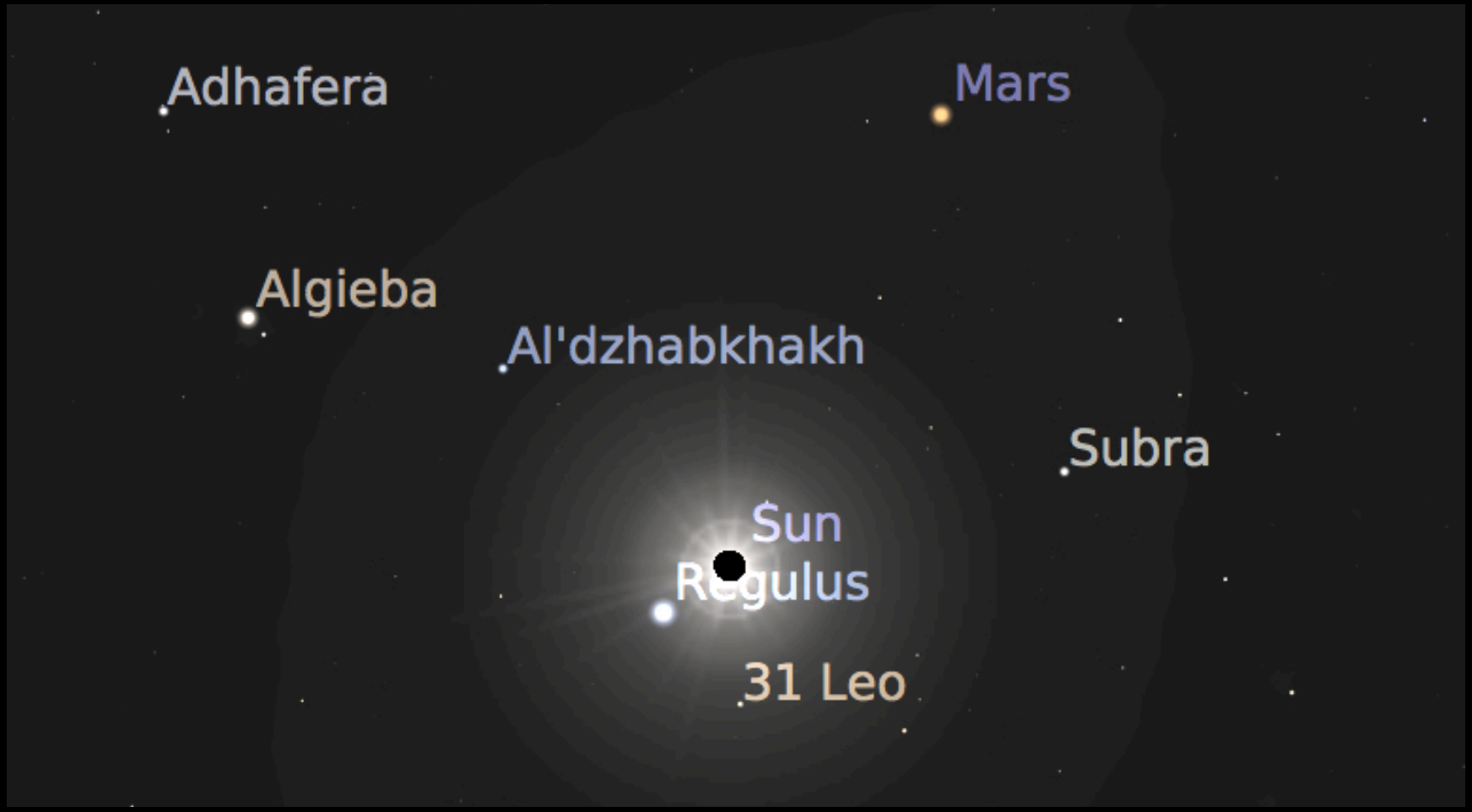
August 21, 1917 India

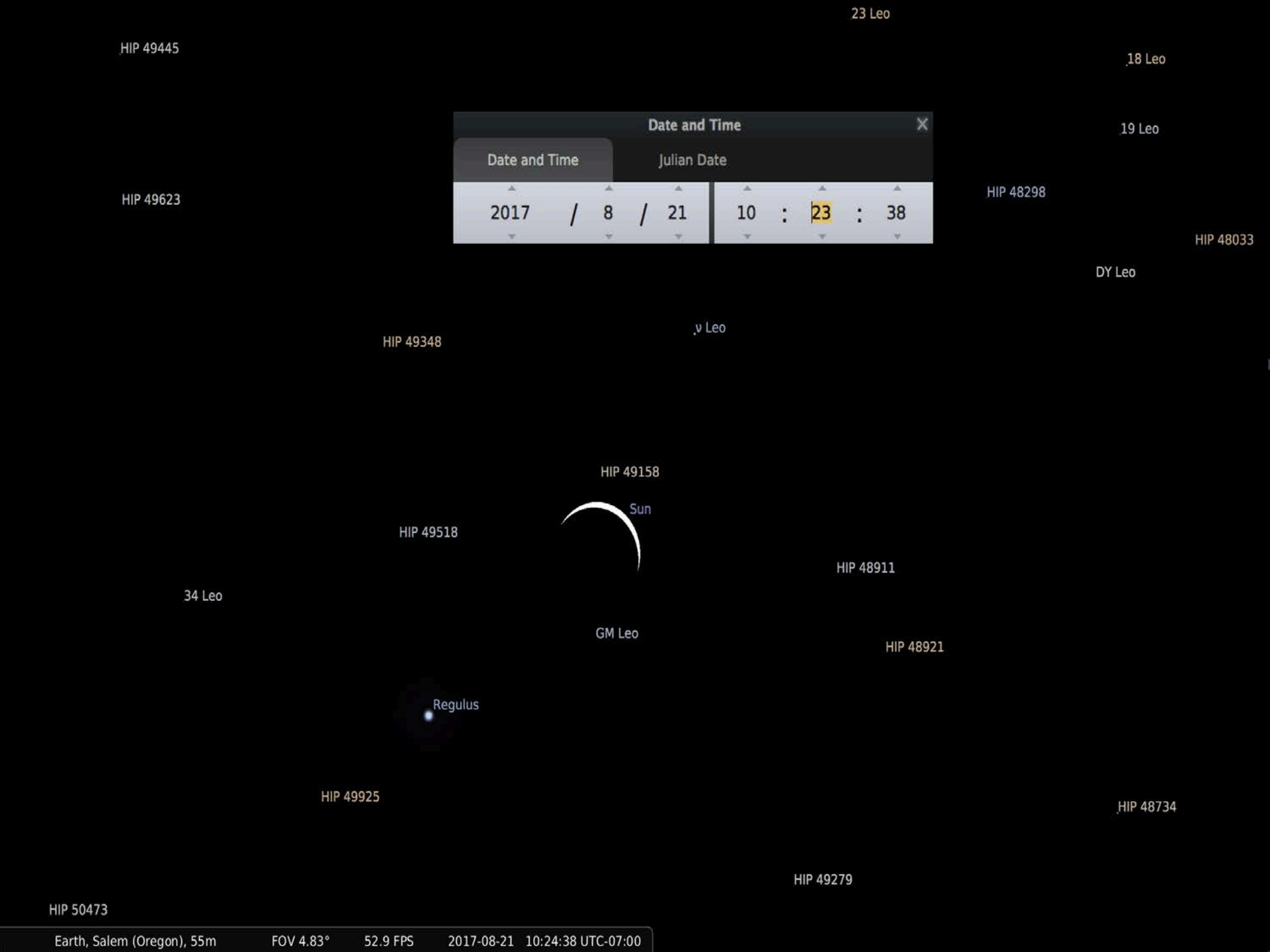
- 2nd Attempt – Eddington & Dyson, Crimea
- 3rd Attempt – Eddington & Dyson 1919

Africa and Brazil

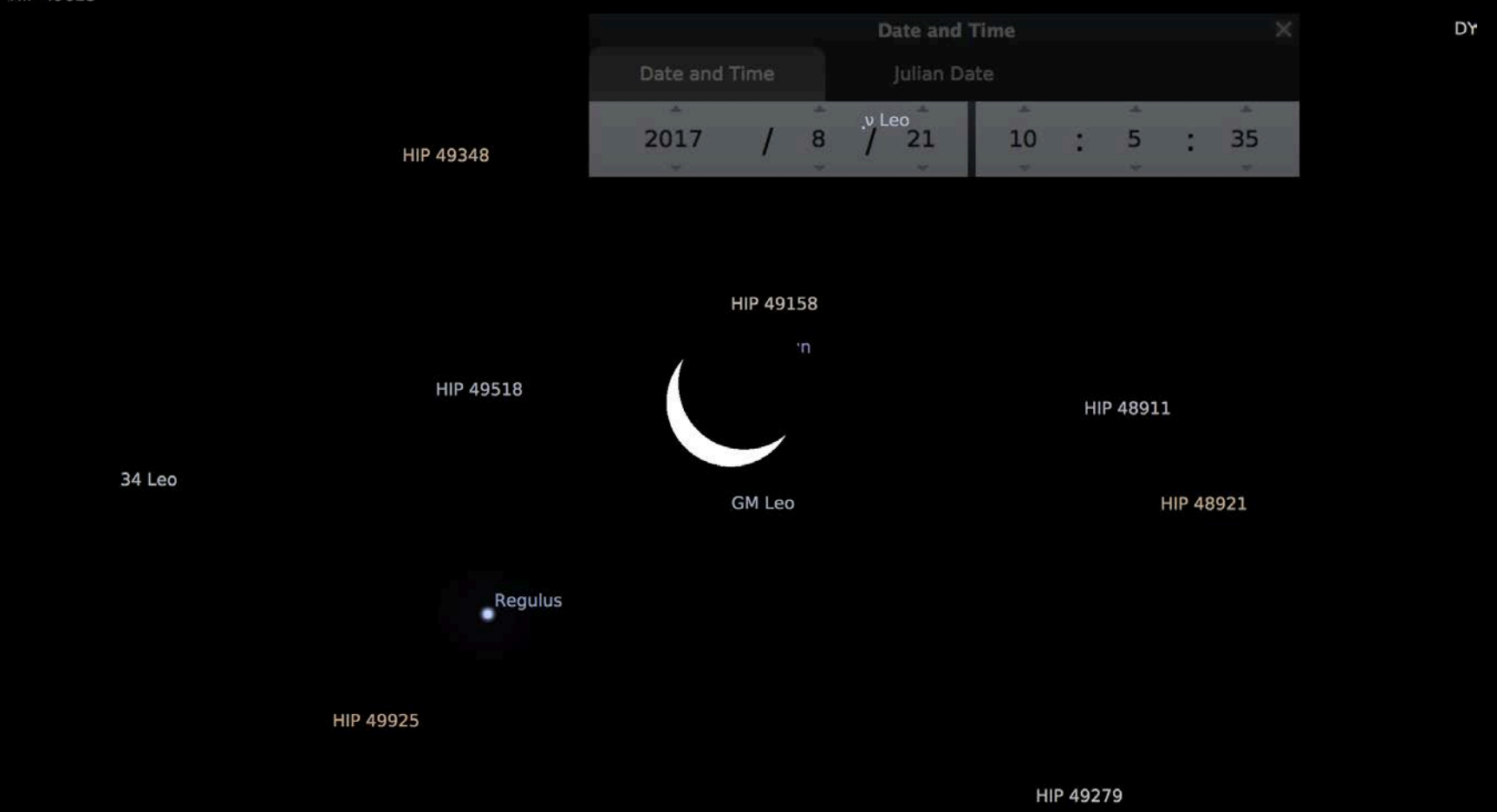


100th Anniversary
August 21 2017




23 Leo
HIP 49445
18 Leo
Date and Time
Date and Time
Julian Date
2017 / 8 / 21
10 : 23 : 38
19 Leo
HIP 49623
HIP 48298
HIP 48033
DY Leo
ν Leo
HIP 49348
HIP 49158
Sun
HIP 49518
HIP 48911
34 Leo
GM Leo
HIP 48921
Regulus
HIP 49925
HIP 48734
HIP 49279
HIP 50473
Earth, Salem (Oregon), 55m
FOV 4.83°
52.9 FPS
2017-08-21 10:24:38 UTC-07:00

Eclipse Close Field View



Star Positions

Mag	Star	RA	Dec	dθ	r	Deflection
	Sun	10h 4m 3.9s	+11d 51' 43"			-------
1.35	Regulus	10h 9m 16.8s	+11d 52' 54"	1.2762°	4.79	0.365"
4.35	31 Leonis	+171 47’	+60 33’			
5.25	nu Leonis	+176 31’	+63 12’			
7.1	HIP 49328	10h 5m 32s	+11d 32' 39"	0.3995°	1.5	1.167"
7.75	HIP49158	10h 2m 51s	+12d 09' 41"	0.4216°	1.58	1.106"

Don Bruns

Don Bruns

Presented at the Society for Astronomical Sciences Symposium, June 17, 2016 in Ontario, CA

Measuring Starlight Deflection during the 2017 Eclipse: Repeating the Experiment that made Einstein Famous

Donald Bruns
7387 Celata Lane
San Diego, CA 92129
dbruns@stellarproducts.com

Abstract

In 1919, astronomers performed an experiment during a solar eclipse, attempting to measure the deflection of stars near the sun, in order to verify Einstein's theory of general relativity. The experiment was very difficult and the results were marginal, but the success made Albert Einstein famous around the world. Astronomers last repeated the experiment in 1973, achieving an error of 11%. In 2017, using amateur equipment and modern technology, I plan to repeat the experiment and achieve a 1% error. The best available star catalog will be used for star positions. Corrections for optical distortion and atmospheric refraction are better than 0.01 arcsec. During totality, I expect 7 or 8 measurable stars down to magnitude 9.5, based on analysis of previous eclipse measurements taken by amateurs. Reference images, taken near the sun during totality, will be used for precise calibration. Preliminary test runs performed during twilight in April 2016 and April 2017 can accurately simulate the sky conditions during totality, providing an accurate estimate of the final uncertainty.

Published in the SAS Proceedings, 2016

Telescope: Tele Vue NP101

Tele Vue-NP101is

TeleVue.com: Telescopes > Tele Vue-NP101is > Home

101mm, f/5.4 APO (Nagler-Petzval) Refractor - Imaging/Visual.
Based on exemplary wide field and planetary visual scopes with added features to make imaging easier and more flexible.

4.9° / 250x (Max. Visual Field / Max. Rec. Power)

TV-NP101is image
Heart & Soul Nebula with
STL11000M camera
(Fabian Neyer)

"Greater than expected! Pleasure to use, excellent optics. I don't need XXX no more."
—S.Y., Japan

-101 mm aperture
-capture 10th magnitude stars with 1 second exposures
-diffraction limit is only 1.3 arcsec at 630 nm

Camera: Microline 8051 CCD

MicroLine Cameras

Goodbye Goliath! MicroLine is smaller and lighter-weight than the competition, but outperforms them in key areas such as noise, frame quality, download speeds, bit-depth, and CCD cooling.

Sensor Cooling up to 65°C below ambient (air cooled)
Interline sensor operation at 12 MHz (16-bit)
Full frame sensor operation up to 12 MHz (16-bit)
Dual Super Coated AR Window - VIEW REFLECTANCE INFORMATION
Heavy weight performance in a 2.8 lbs package
Liquid or Air Cooled base
RBI Anti-Ghosting Technology standard
Video mode with interline sensors - focus and center images live!
Small Footprint (3.7 x 3.7 x 5in.)
Reaches operating temperatures in 5 minutes!
Single, Dual, or Quad Output (4 Ch) Capable

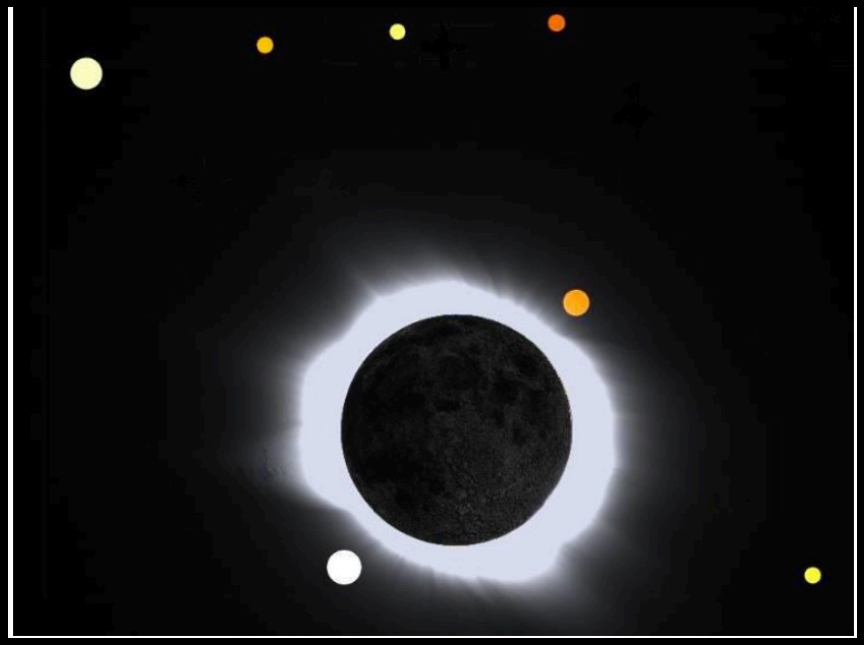
-pixels are only 5.5 microns wide
-2.1” per pixel
-2^o by 2^o field

Mount

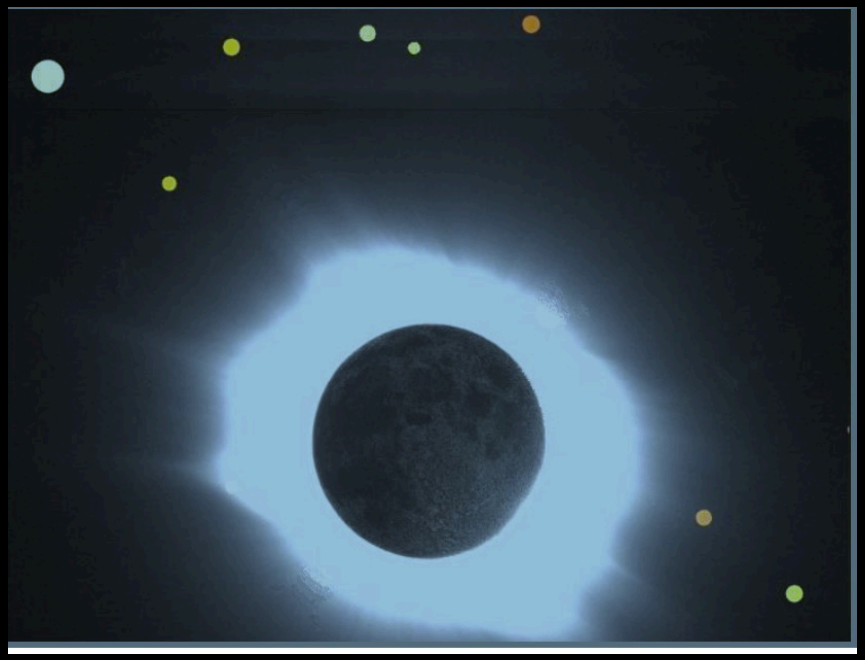
Figure 5. The Software Bisque MyT Paramount and matching tripod is portable, allowing a change in eclipse sites in case of bad weather. The periodic error, after correction, is sub-arcsecond, necessary for high quality images.

Anticipated Data

Short Exposure- 200 ms

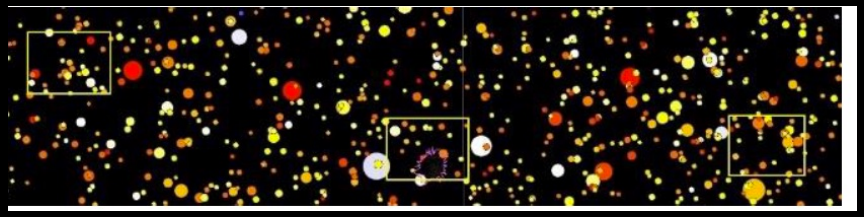


Long Exposure- 1 sec



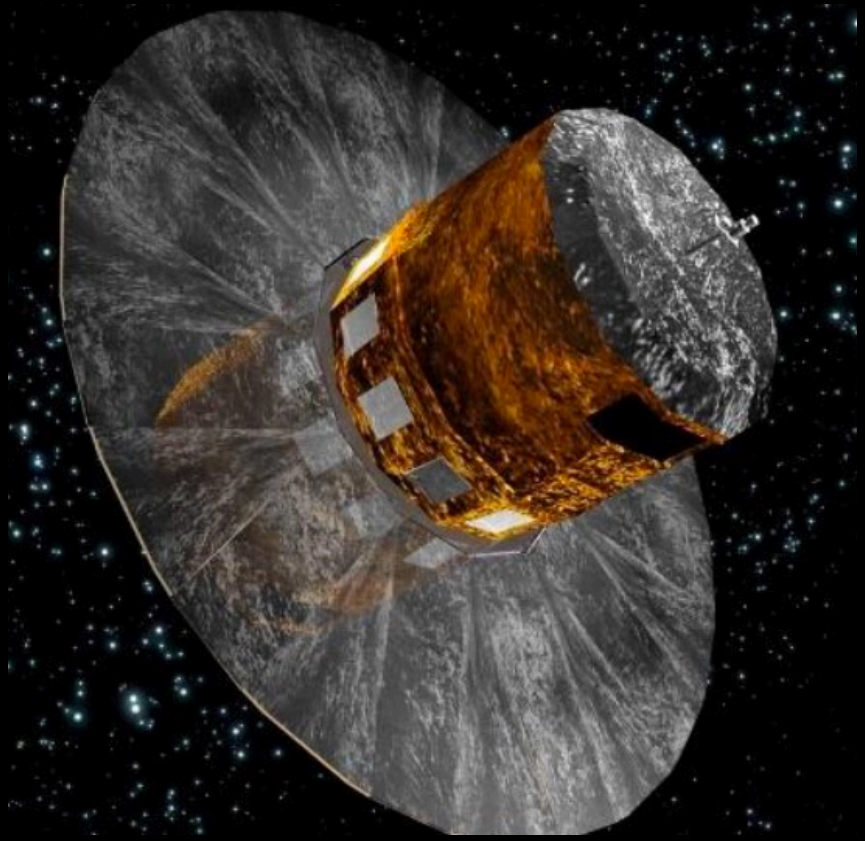
Additional Considerations

Calibration Reference Fields



0.000024 arcseconds.

Stellar Postions – Hipparchus Gaia



Bruns Expected Results

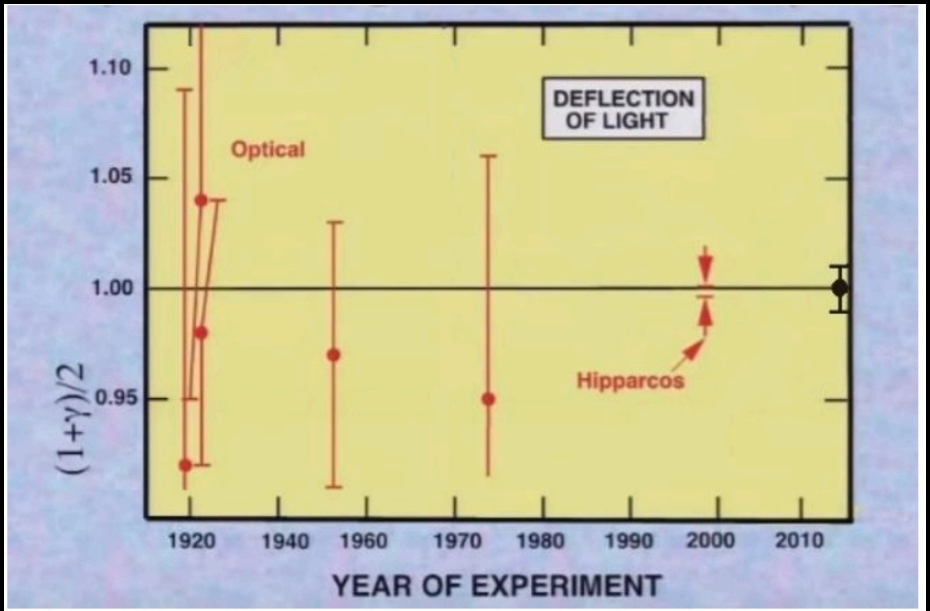
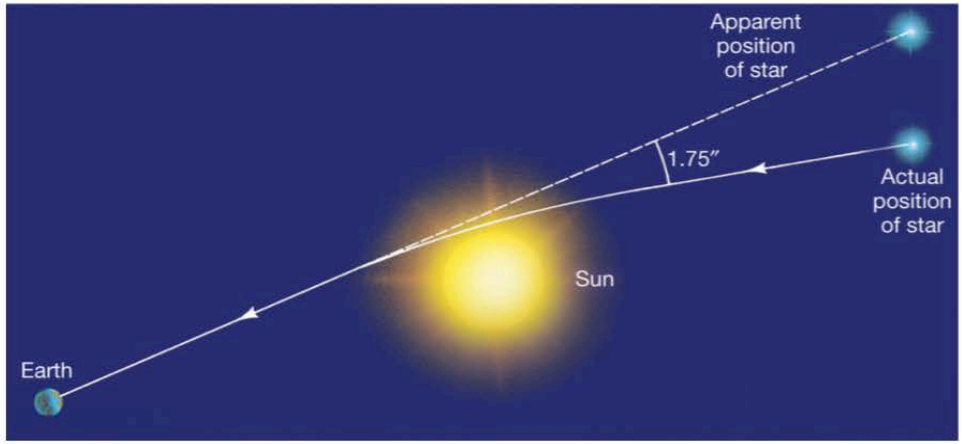


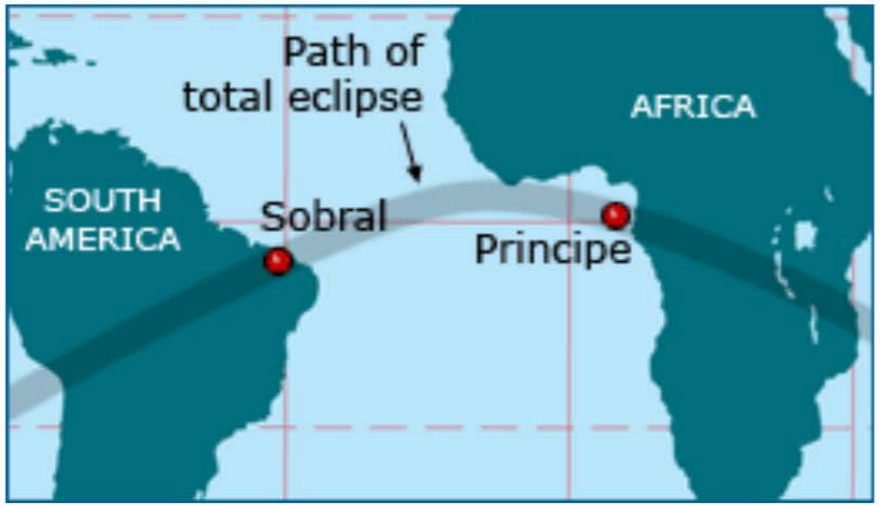
Figure 2. The deflection of light has been measured during a total eclipse only a few times in the last century. Hipparcos measured the deflection from space, not needing an eclipse, and has set the record for the most precise optical measurement. The marker on the right side of the graph represents the expected error of 1% for my 2017 experiment. Modified from [Will 2015]. Vertical scale is deflection normalized to Einstein's calculation.

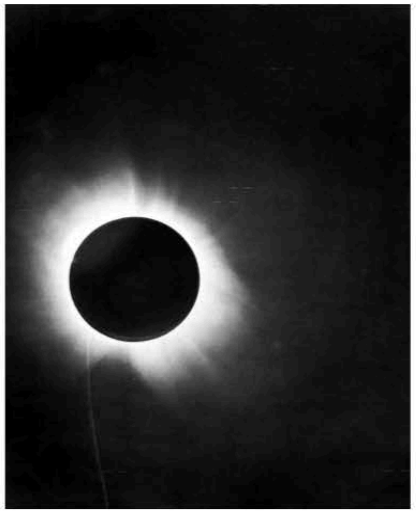
Dr. Brad Schaefer, LSU

THE MODERN EDDINGTON EXPERIMENT

Brad Schaefer (BRAS)







EINSTEIN TRIUMPHANT

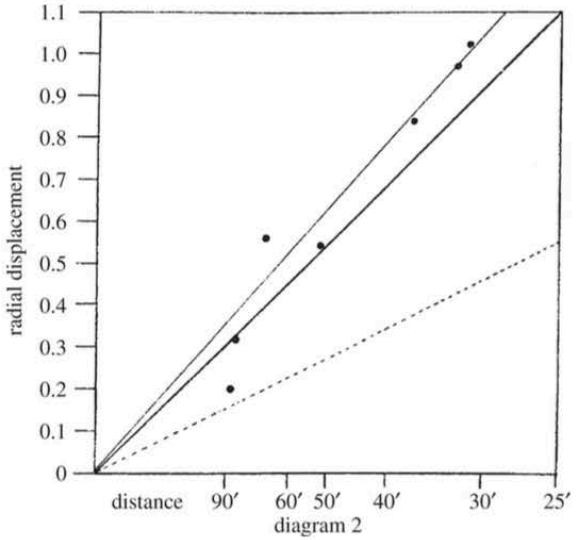


diagram 2

LIGHTS ALL ASKEW IN THE HEAVENS

Men of Science More or Less Agog Over Results of Eclipse Observations.

EINSTEIN THEORY TRIUMPHS

Stars Not Where They Seemed or Were Calculated to be, but Nobody Need Worry.

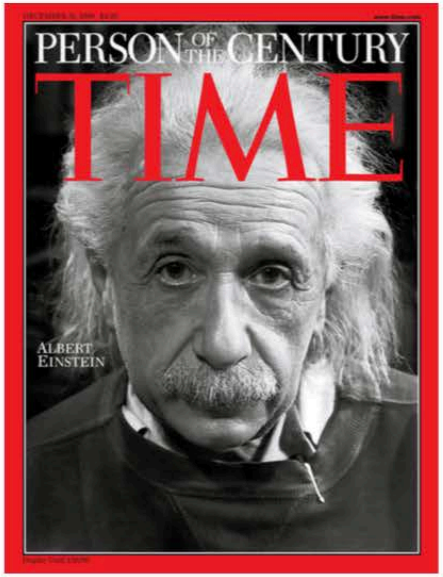
A BOOK FOR 12 WISE MEN

No More in All the World Could Comprehend It, Said Einstein When His Daring Publishers Accepted It.

Special Cable to THE NEW YORK TIMES.

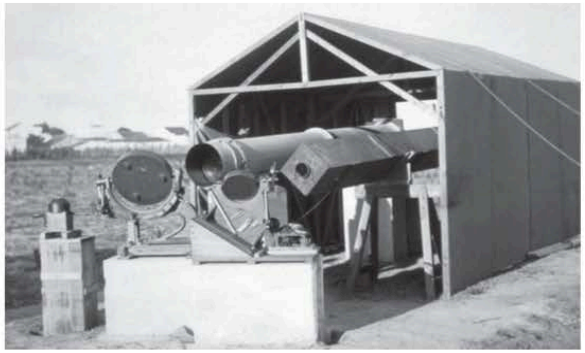
LONDON, Nov. 9.—Efforts made to put in words intelligible to the non-scientific public the Einstein theory of light proved by the eclipse expedition so far have not been very successful. The new theory was discussed at a recent meeting of the Royal Society and Royal Astronomical Society, Sir Joseph Thomson, President of the Royal Society, declares it is not possible to put Einstein's theory into really intelligible words, yet at the same time Thomson adds:

"The results of the eclipse expedition demonstrating that the rays of light from the stars are bent or deflected from their normal course by other aerial bodies acting upon them and consequently the inference that light has weight form a most important contribution to the laws of gravity given us since Newton laid down his principles."



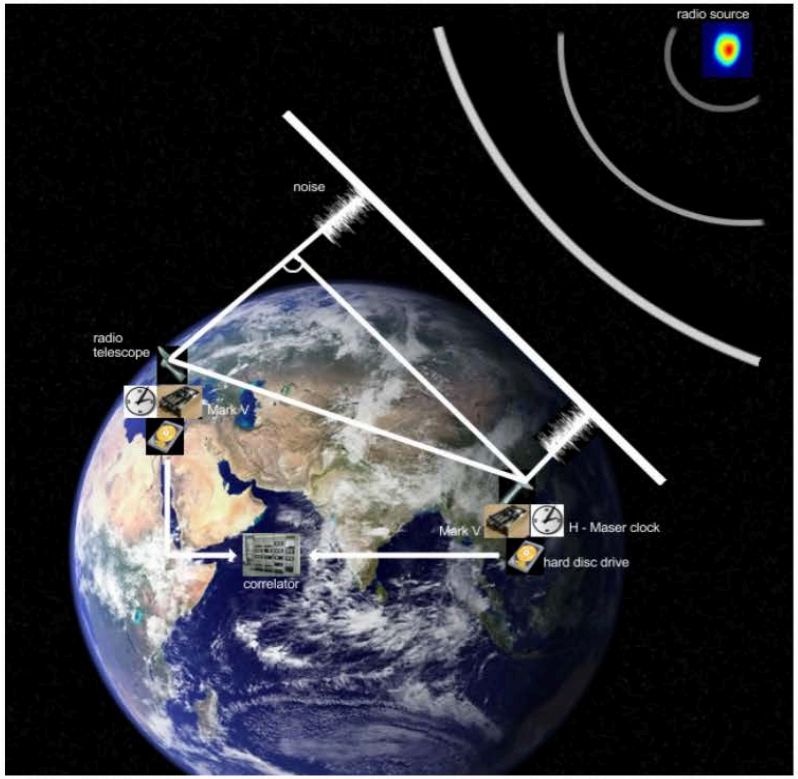
EDDINGTON EXPERIMENT AT OTHER SOLAR ECLIPSES

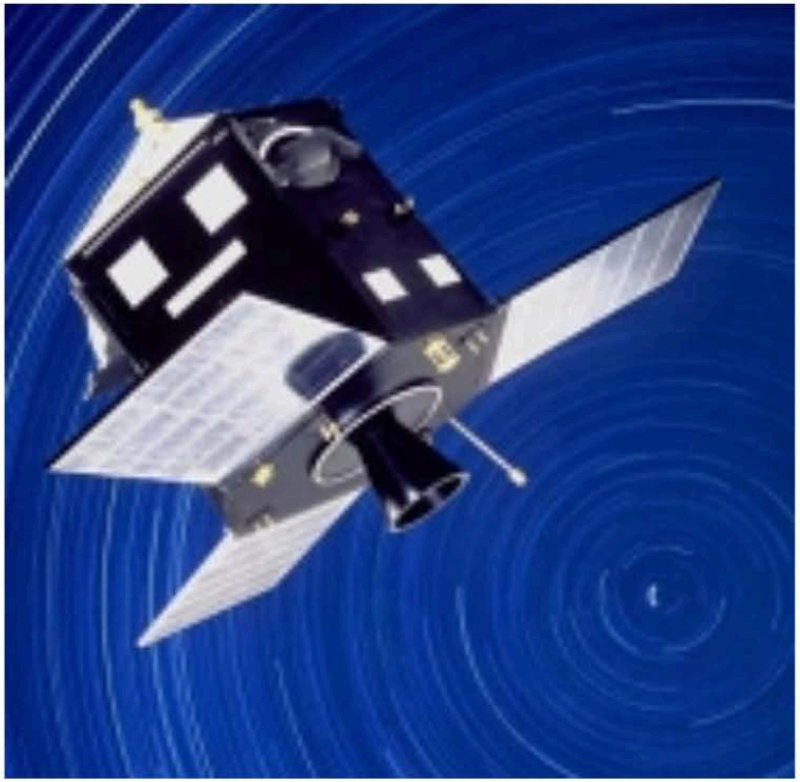
ECLIPSE		RESULT
1914	Crimea	Failed due to outbreak of WWI
1918	Goldendale Wash	Confused, maybe 0.87”
1922	Australia	1.72” ± 0.11”, 1.74” ± 0.3”, 1.77” ± 0.3”
1926	Sumatra	Failed
1929	Sumatra	1.75” ± 0.13”
1936	Russia, Japan	1.70” ± 0.40”, 2.73” ± 0.31”
1947	Brazil	2.01” ± 0.27”
1952	Khartoum	1.70” ± 0.10”
1973	Mauritania	1.66” ± 0.18”



LIGHT BENDING BY OTHER METHODS

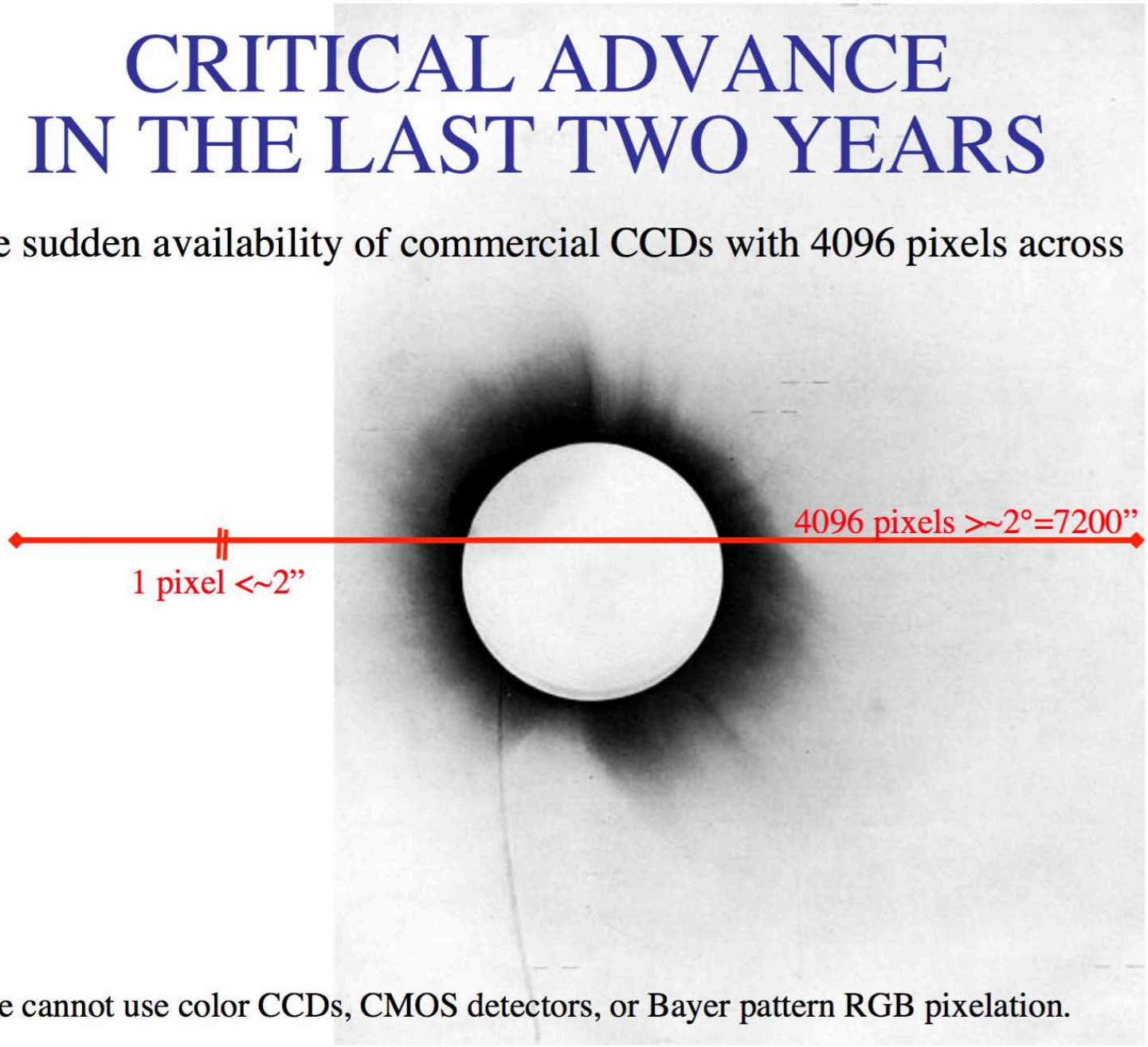
1995	VLBI (3C 273 & 3C 279)	0.34%
1997	*Hipparcos* (many optical stars far from Sun)	0.20%
2004	VLBI (541 radio sources)	0.045%
2009	VLBI (4 radio sources)	0.030%
2010	VLBI (541 radio sources)	0.012%





CRITICAL ADVANCE IN THE LAST TWO YEARS

★The sudden availability of commercial CCDs with 4096 pixels across



Note: we cannot use color CCDs, CMOS detectors, or Bayer pattern RGB pixelation.

BASELINE SYSTEM & PROCEDURE:

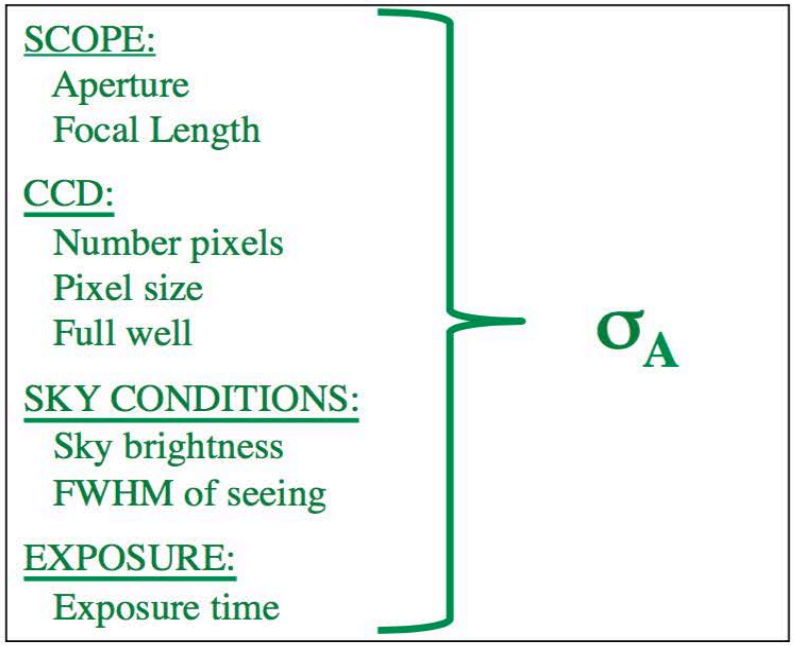
★6-inch f/5 scope (F=800 mm)
★Polar-aligned mount with good tracking and 'goto' ability
★SBIG STX-16803 (4096x4096, 9μ pixels, 100,000 e- full well)
★Prior nights, take night sky images to practice and to map coma
★During partial phase, focus scope on Pleiades, taken images
★During totality, take ~30 two-second exposures
★Immediately after totality, take Pleiades images

NEEDED: A FULL DETAILED CALCULATION OF EXPECTED ACCURACY IN MEASURING THE SHIFT

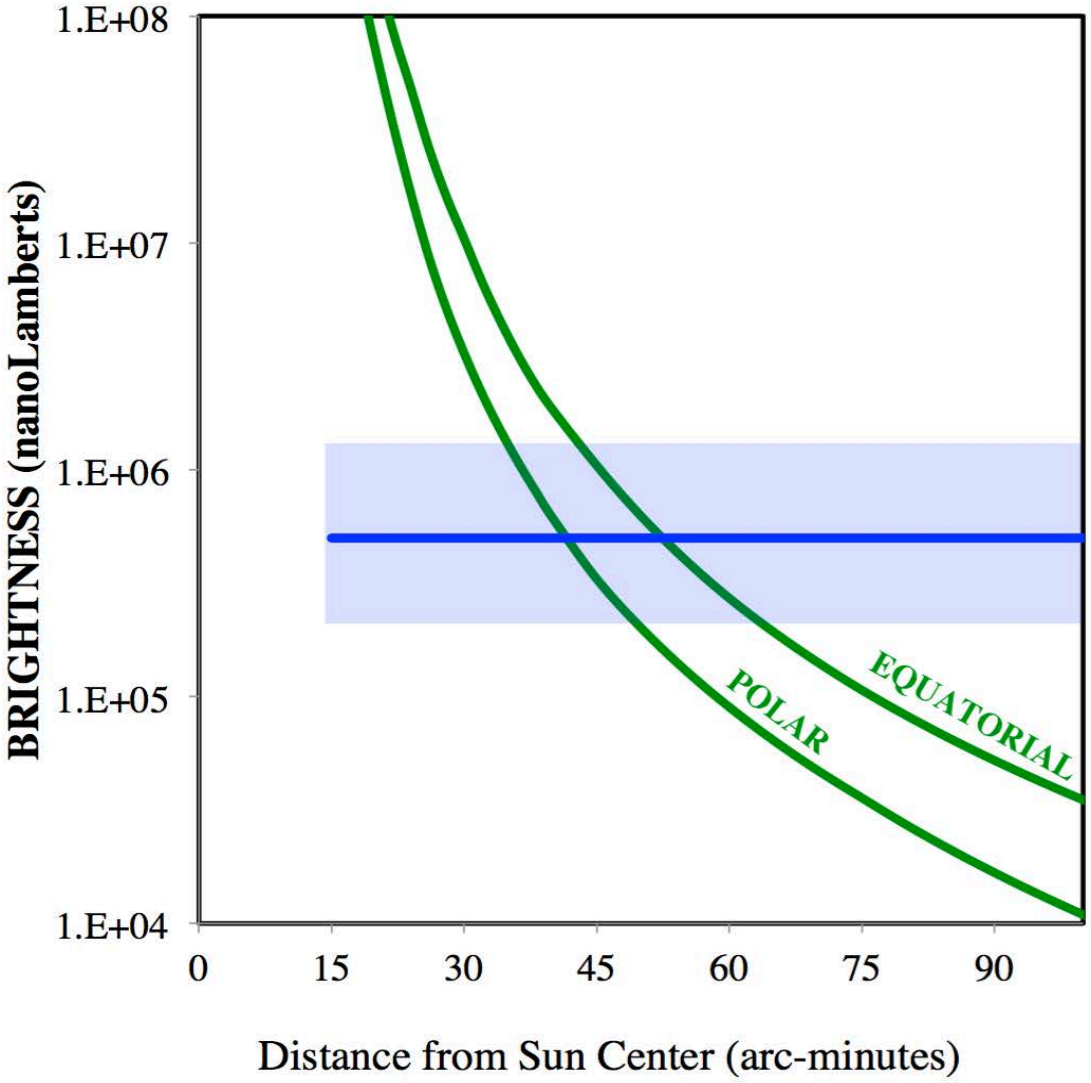
Model for the shift: $\Delta\Theta = A * 1.75" (15'/\Theta)$

A=0.0 no shift
A=0.5 Newtonian case
A=1.0 GR prediction

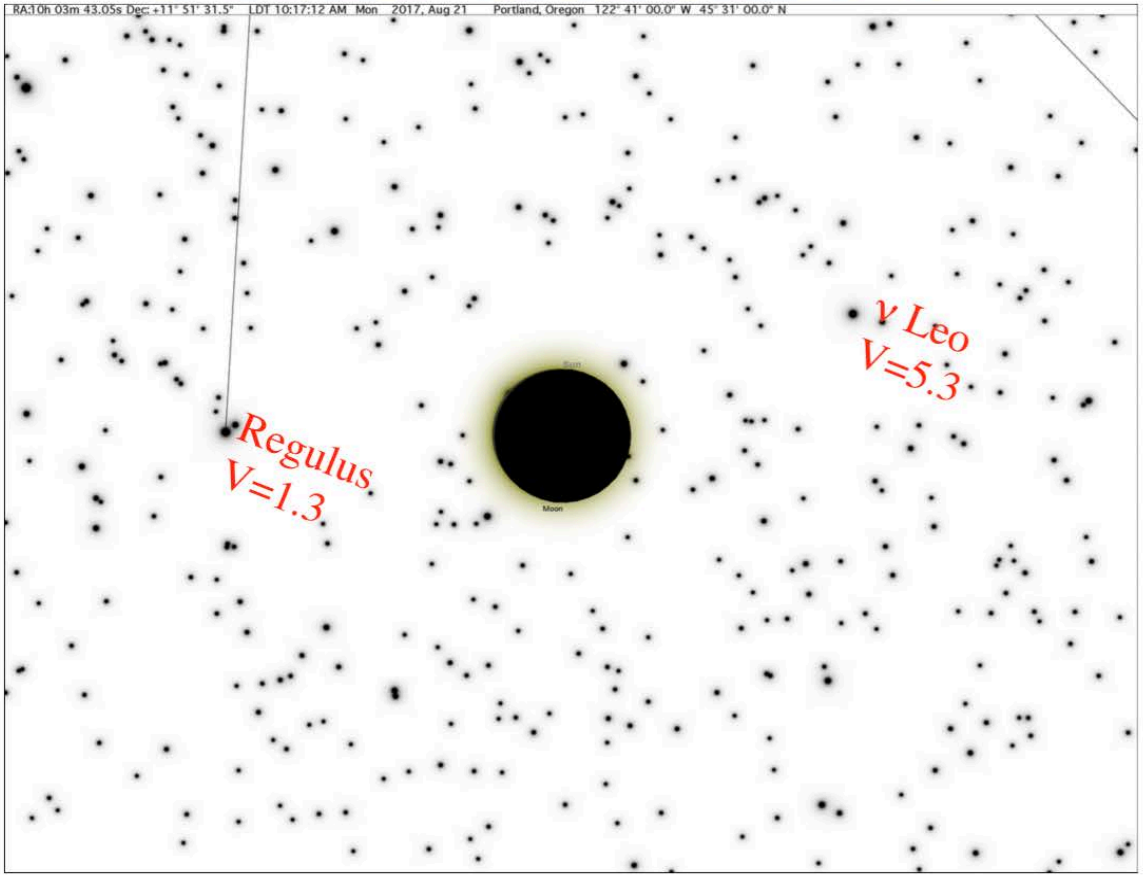
★Corona brightness
★Sky brightness
★Star catalog
★e- on CCD from stars
★e- on CCD from background
★Centroid accuracy
★Calculate σ_A



SKY & CORONA BRIGHTNESS



STAR CATALOG



STAR	Θ (')	V (mag)	ΔΘGR (")
Tyc 0832-0973-1	17.6	11.65	1.49
Tyc 0832-1033-1	21.5	10.99	1.22
Tyc 0833-0457-1	22.8	11.12	1.15
HD 86898	23.1	7.80	1.14
Tyc 0832-0276-1	23.6	11.20	1.11
Tyc 0833-0812-1	23.8	11.64	1.10
Tyc 0832-0272-1	24.9	11.74	1.05
HD 87271 = GM Leo	26.1	7.13	1.01

e- ON CCD

$B_{bck} = B_{corona} + B_{sky}$

$\Theta_{pixel}=(L_{pixel}/1000)*206264/F$

$\Theta_{edge}=0.5*N_{pixel}*(L_{pixel}/1000)*206264/F$

Total Electrons On CCD in V-band $= E_{star} = (150{,}000\ e\text{-})*D^2*\Delta T*10^{-0.4V}$

Total Electrons On CDD over 1 sq-arc-sec $= E_{bck} = (4.4x10^{-6}\ e\text{-})*B_{bck}*D^2*\Delta T$

Pixel Saturated if $(E_{star}+E_{bck})*\Theta_{pixel}^2 > E_{max}$

Star detected if SNR $= E_{star}/(E_{star.}+E_{bck}*\pi*\Theta_{star}^2)^{0.5} > 5$

D = scope aperture (cm)
F = focal length (mm)
L_{pixel} = pixel size (μ)
N_{pixel} = pixels on a side (#)
E_{max} = full well (e-)
ΔT = exposure time (s)
Θ_{star} = FWHM (“)
B_{sky} = sky brightness (nL)
B_{corona} = corona bright. (nL)
V = star magnitude (mag)
Θ = offset from Sun center (‘)

CENTROID ACCURACY

$\sigma_{centroid} =[(FWHM/2.36/SNR)^2+(\Theta_{pixel}f/SNR)^2]^{0.5}$

$f = 1.3 + 0.8*[(FWHM/2.36/\Theta_{pixel})-1]^2$

ACCURACY FOR EINSTEIN SHIFT

$A_{best} = \Sigma\ [(\Delta\Theta_i*1.75”*(15’/\Theta))/\sigma_{centroid}]^2\ /\ \Sigma\ [1.75”*(15’/\Theta))/\sigma_{centroid}]^2$

$\sigma_A = (A_{best} * \Sigma\ [1.75”*(15’/\Theta))/\sigma_{centroid}]^2\ )^{-0.5}$

SYSTEMATIC PROBLEMS & SOLUTIONS

★Too few stars recorded.

CCDs go deep with adequate exposure

Require fields of view larger than ~2°

★PlateScale/GRshift degeneracy.

Image Pleiades (or Praesepe) immediately before/after totality

Have large field of view (larger than ~2°)

★Coma in scope can cause uncontrolled radial shifts.

Image Pleiades (or Praesepe) immediately before/after totality

Images of night sky during nights before and after

RESULTS

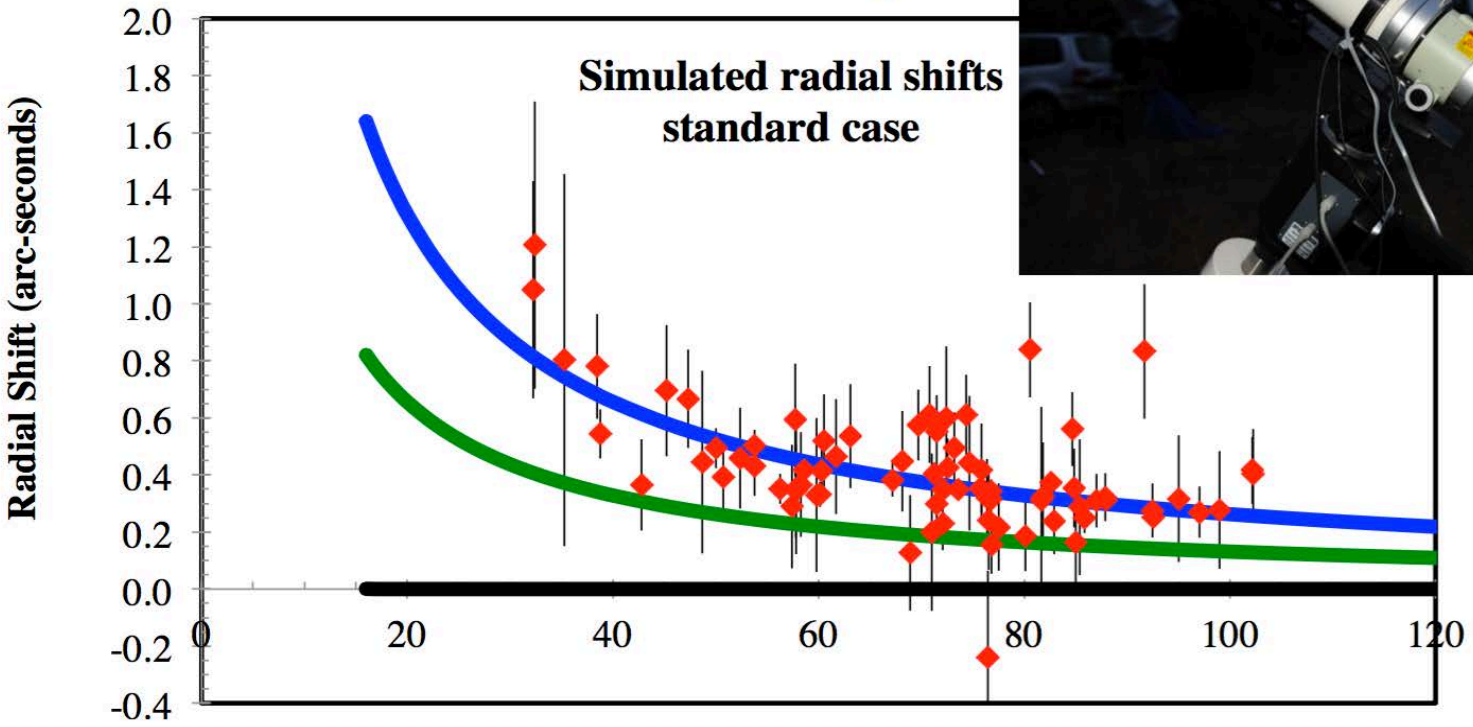
★One person:

ONE IMAGE: 1.0% accuracy, better than all prior expeditions

FROM ALL ECLIPSE: 0.19% accuracy - WOW

★Many people:

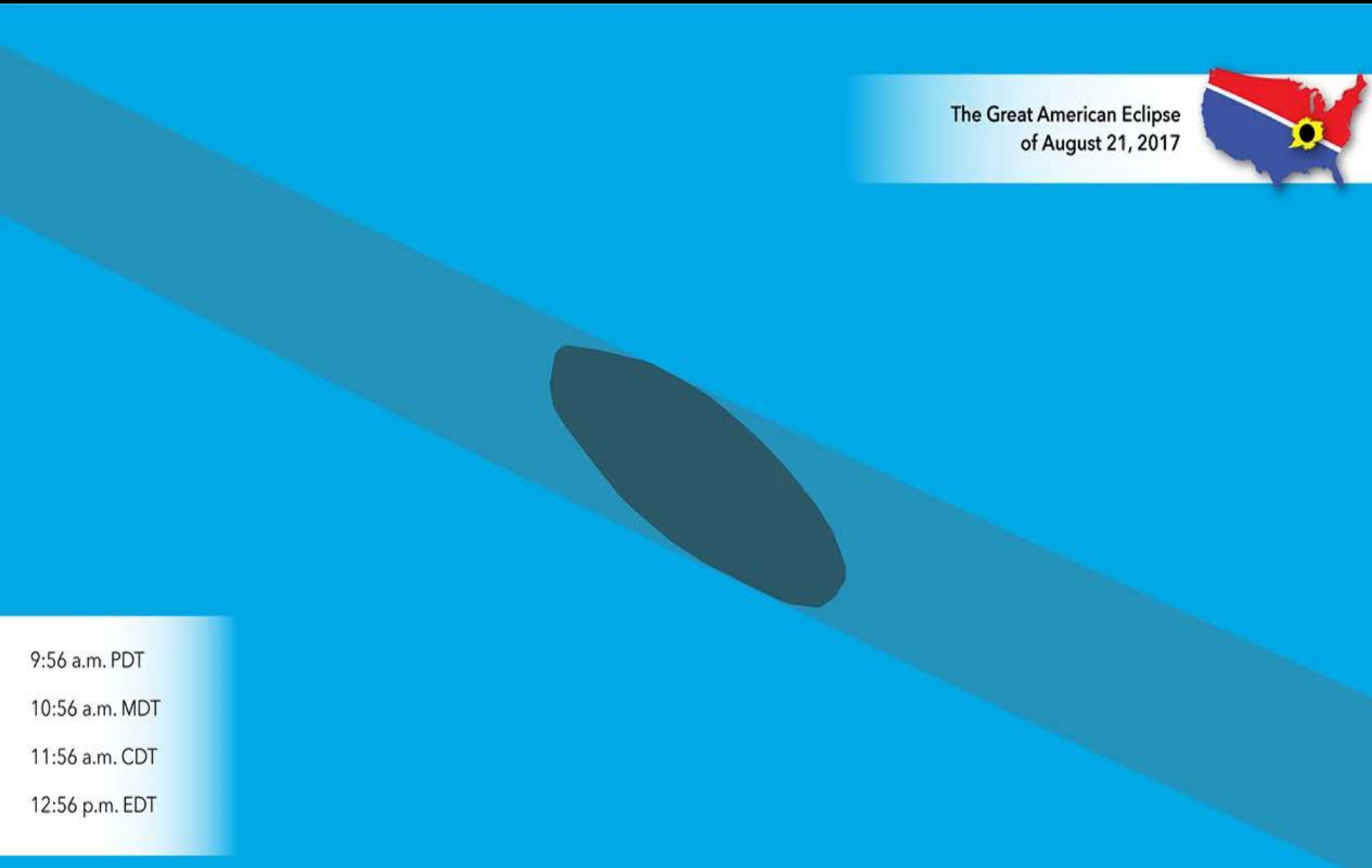
~100 PEOPLE: 0.019% accuracy



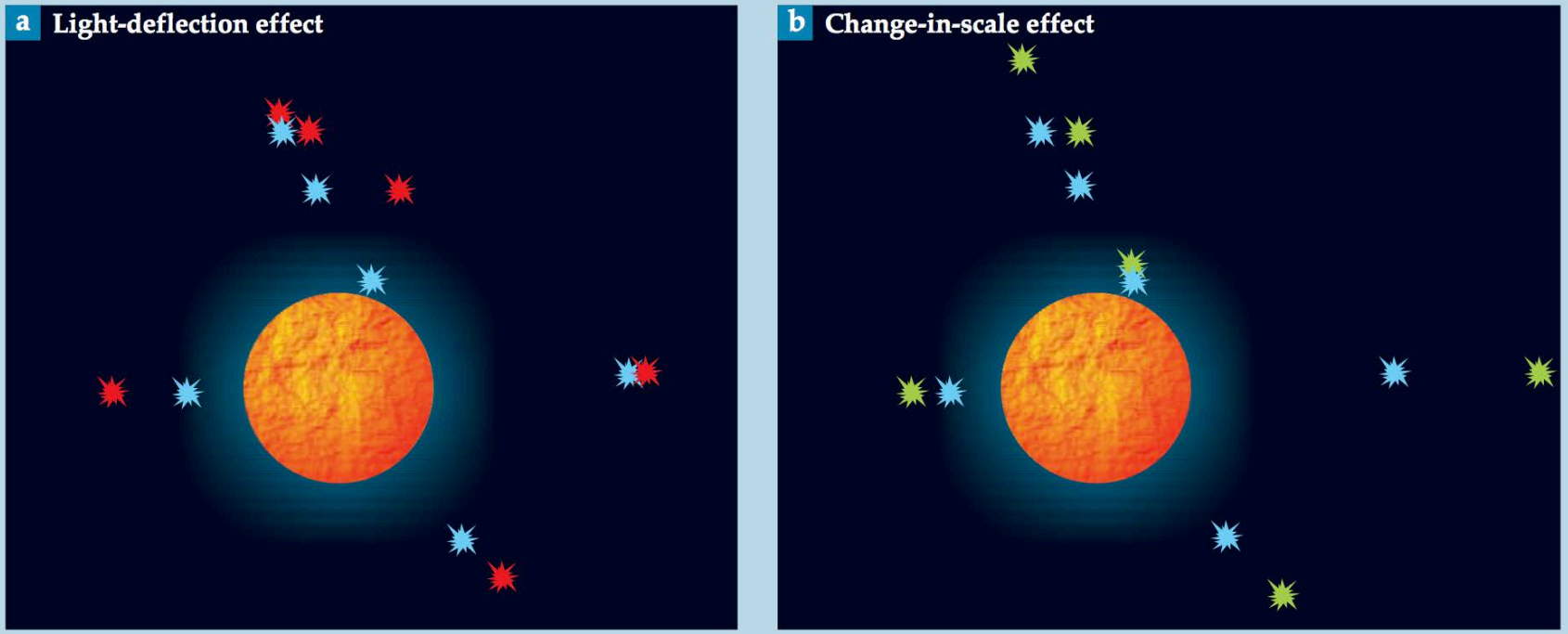
Summary

- Why perform the MEE? Win the ROSES SMD grant?
- Space Grant Involvement
- Preparation for 2024 eclipse
- Fabulous opportunity for Faculty, Students and Citizen Scientists
- tdittric@pcc.edu toby.dittrich@gmail.com

QUESTIONS?


The Great American Eclipse
of August 21, 2017
9:56 a.m. PDT
10:56 a.m. MDT
11:56 a.m. CDT
12:56 p.m. EDT

Temperature Magnification Effect



An unusual number of bright stars from the Hyades cluster conveniently filled the sky on all sides of the Sun during the 1919 eclipse. **(a)** In this artist's rendering, deflection of starlight from the Sun's gravity shifts the original stellar positions (blue) radially away from the center of the Sun; those closest to the center suffer the greatest shift. **(b)** A change in scale between one exposure and another shifts stellar positions radially away from the center of the image; those far from the center show the greatest shifts.