Astronomy...
Things Both Near and Far

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Welcome to the Universe in 3D

A Visual Tour

Neil deGrasse Tyson, Michael A. Strauss,
J. Richard Gott, and Robert J. Vanderbei

Neil deGrasse Tyson with Stephen Colbert

April 19, 2022

Parallax

Parallax

Left Eye View

Parallax

Right Eye View

My Finger – Parallax

My Finger – Left Eye

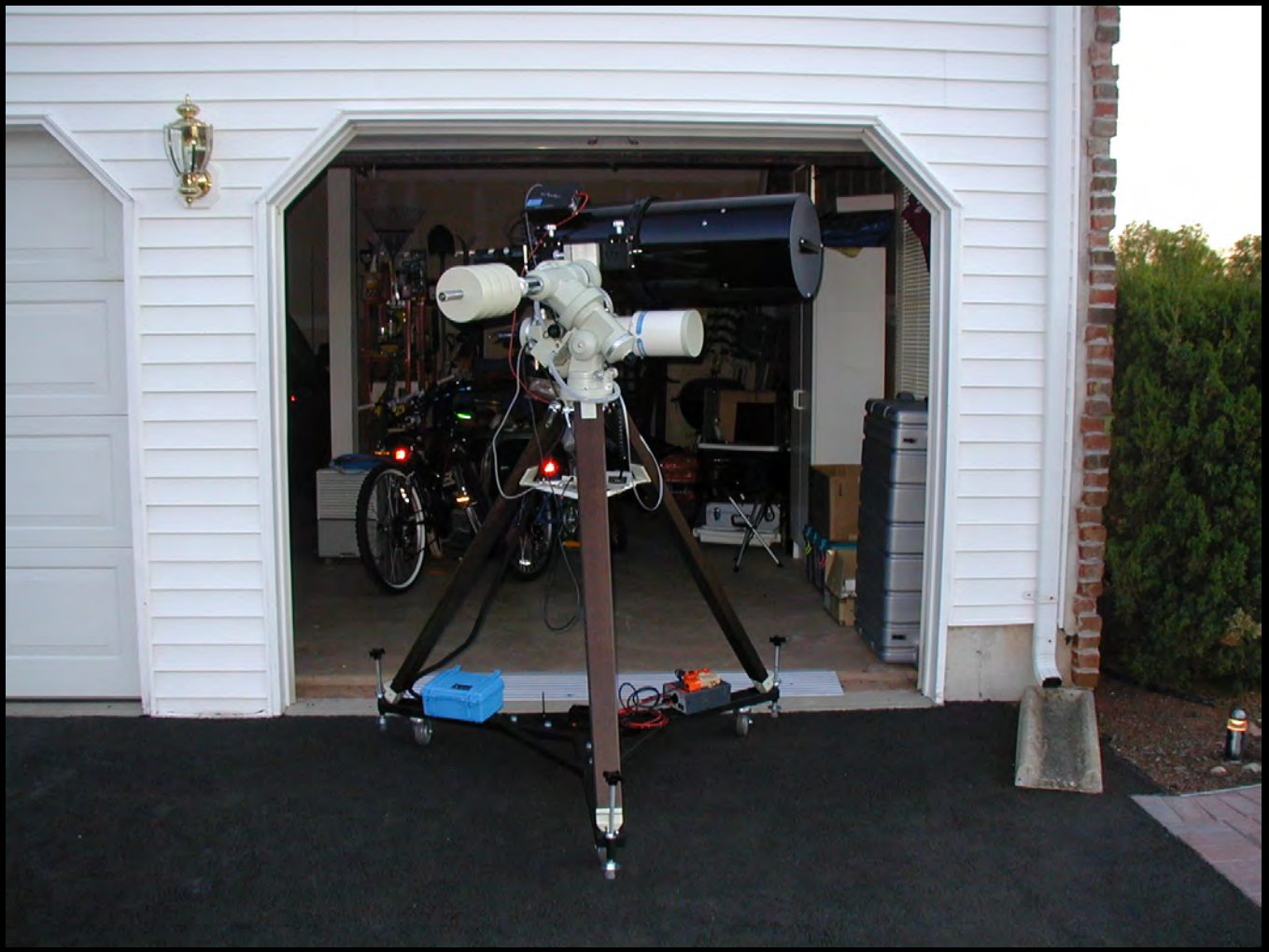
My Finger – Right Eye

My Finger – Both Eyes

Let's Go Astro

10” Reflector, 4” Refractor, Telephoto Lens

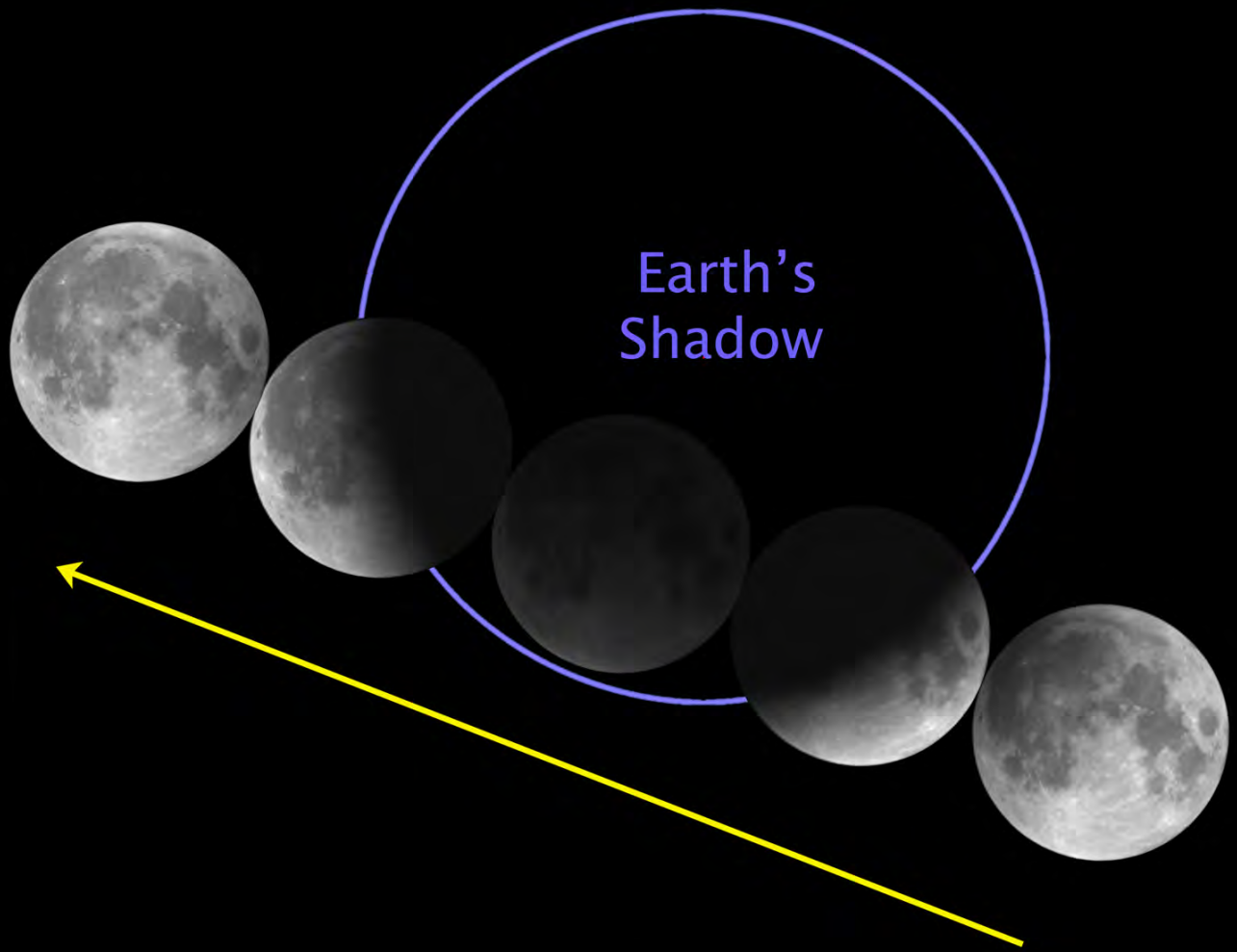
Move equipment outside.



Ready To Go...

Is The Earth Flat?

A Picture's Worth a Thousand Words...



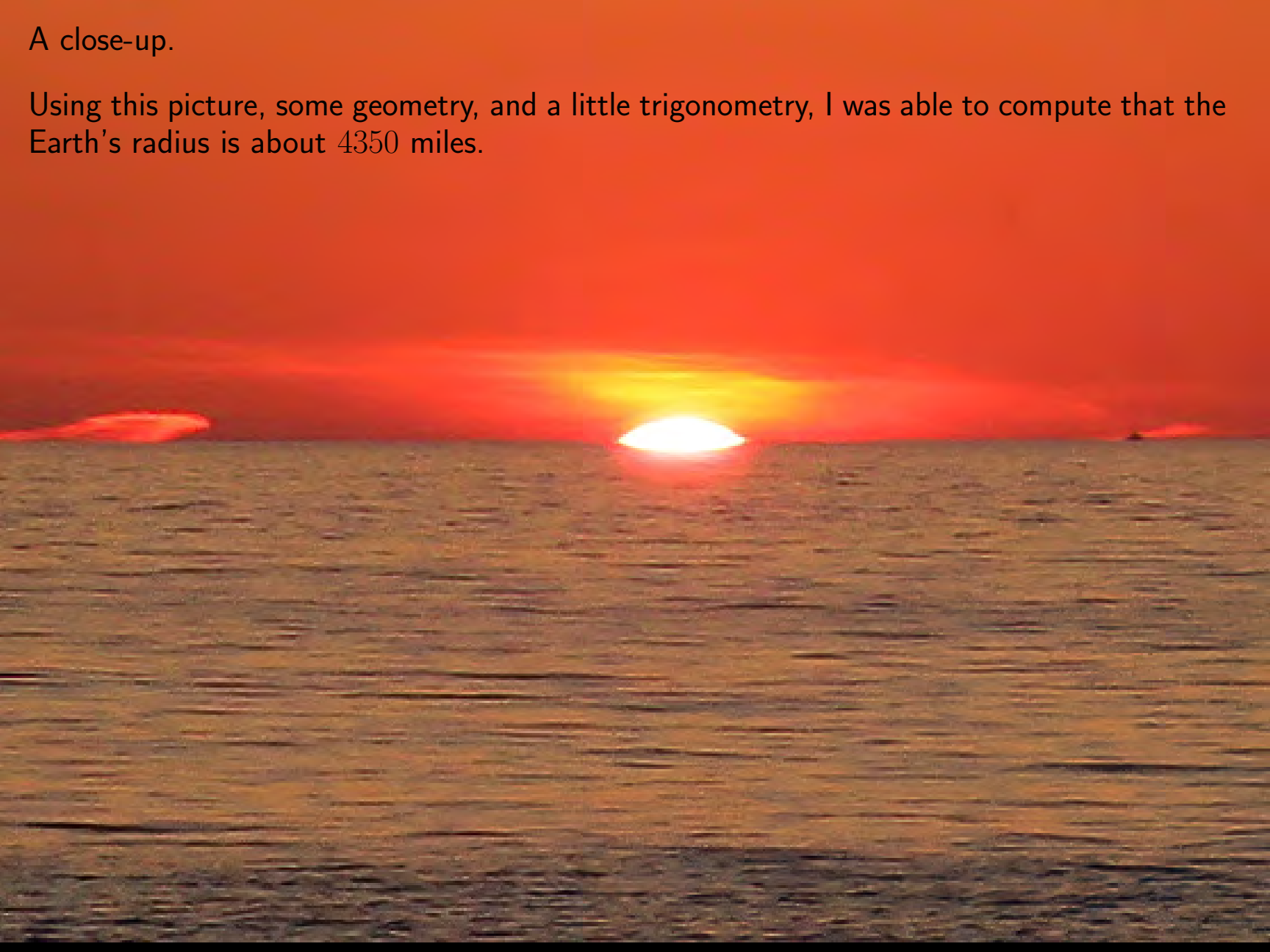
How Aristarchus measured the size of the Moon.

How Big Is Earth?

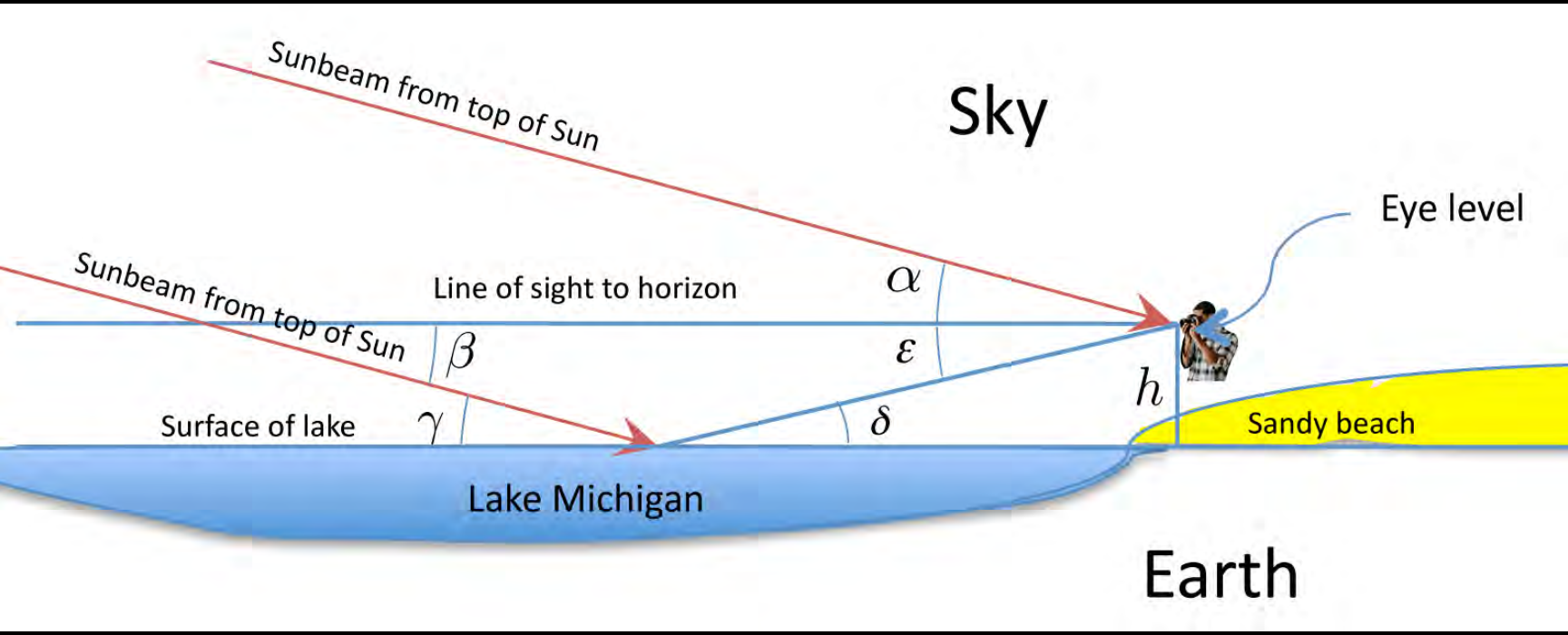
A picture I took of a sunset over Lake Michigan.

A close-up.

Using this picture, some geometry, and a little trigonometry, I was able to compute that the Earth's radius is about 4350 miles.



Geometry — If the Earth Were Flat!



$\alpha = \beta$ alternate interior angles are equal

$\beta = \gamma$ alternate interior angles are equal

$\gamma = \delta$ angle of incidence equals angle of reflection (from Physics!)

$\delta = \epsilon$ alternate interior angles are equal

Therefore,

$$\alpha = \epsilon.$$

The reflection dips just as far below the horizon as the Sun stands above the horizon.

Geometry — The Earth Is Not Flat

Draw a picture.

Label everything of possible relevance.

Identify what we know:

α Angle between horizon and top of Sun (measured from photo)

β Angle between horizon and "top" of Sun in reflection (measured)

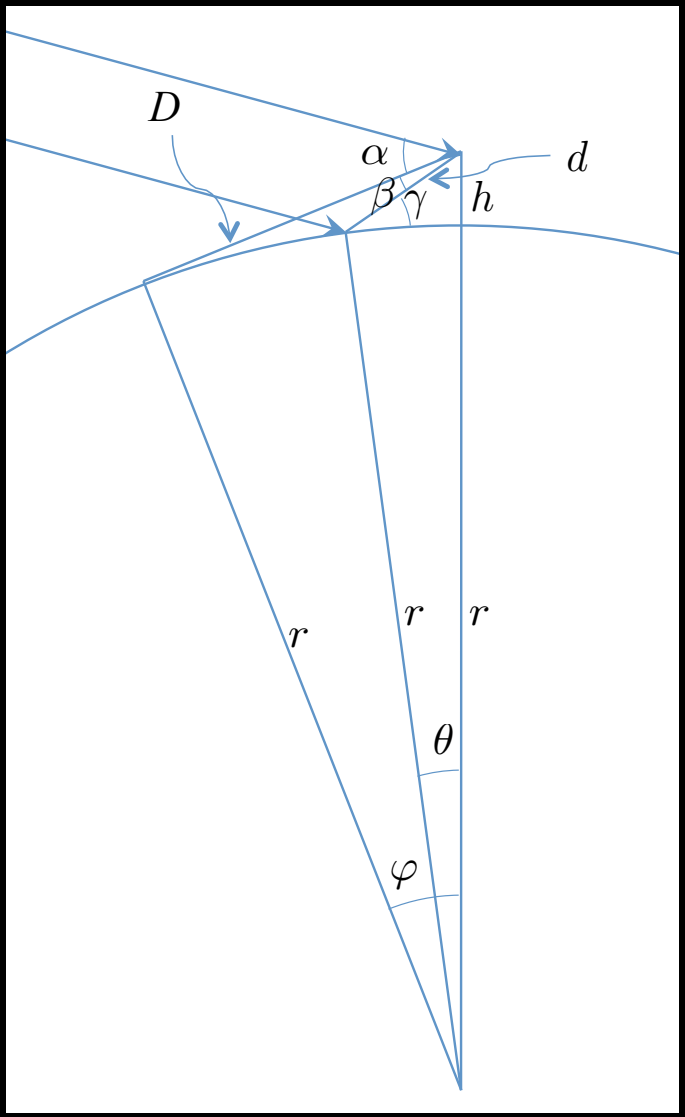
h Height of "eye-level" above "water-level".

Doing a bunch of trigonometry and algebra we get

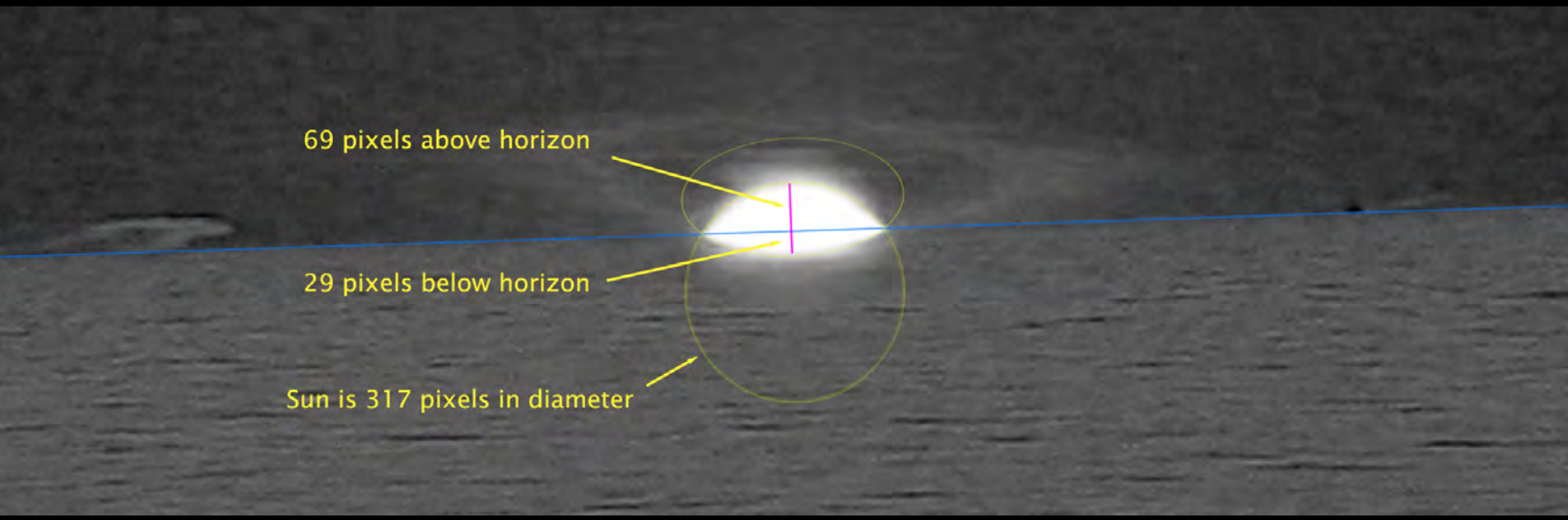
$$r = \frac{h}{\frac{\sqrt{1 - 2\cos\beta\cos\gamma + \cos^2\gamma}}{\sin\beta} - 1}$$

where

$$\gamma = (\alpha + \beta)/2$$



What We Know (Measure!)



The Sun is $1/2^\circ$ in diameter. Therefore, 1° equals $2 \times 317 = 634$ pixels.
And so,

$$\alpha = 69 \text{ pixels} \times \frac{1 \text{ degree}}{634 \text{ pixels}} = 0.1088 \text{ degrees}$$

and

$$\beta = 29 \text{ pixels} \times \frac{1 \text{ degree}}{634 \text{ pixels}} = 0.0457 \text{ degrees.}$$

And, we assume that eye level is

$$h = 6 \text{ feet}$$

Hence... Earth's radius is about 4,350 miles. Diameter is twice a radius: 8,700 miles.

BETTER ANSWER: Earth's Diameter $\approx 8{,}000$ miles

How Far to the Moon?

Angular Size of the Moon.

Using my iPhoneX, I took 16 pics to make a 360° panorama from the middle of the road in front of my house. I used Photoshop to assemble the pics:

Here's a closeup of my neighbor's car as seen at the left edge and the right edge:

The horizontal pixel distance of the car's rear view mirror as seen on the left and on the right is $38108 - 83 = 38025$ pixels.

Using the same camera I took a picture of the crescent Moon:

Here's a closeup showing that the Moon's diameter is 59 pixels:

Using these pixel measurements, we can compute the angular size of the Moon:

$$\text{Moon Size} = \frac{59}{38025} \times 360^\circ = 0.56^\circ$$
$$\approx 1/2 \text{ deg}$$

From a lunar eclipse, we can determine that the Earth is about 4 times larger than the Moon. Earth's diameter is about $8{,}000$ miles. Hence, Moon's diameter is about $2{,}000$ miles.

Next total lunar eclipse visible from the "east coast" is on March 14, 2025 at 3am.

ANSWER: Distance to the Moon $\approx 240{,}000$ miles

Moon's diameter $= 2{,}000$ miles

Moon's orbital circumference $= 2{,}000$ miles $\times \frac{360 \text{ deg/circumference}}{1/2 \text{ deg/Moon diameter}}$

Moon's distance $= \frac{\text{Moon's orbital circumference}}{2\,\pi} \approx \frac{\text{Moon's orbital circumference}}{6} = \frac{2{,}000 \times 720}{6} = 240{,}000$ mi

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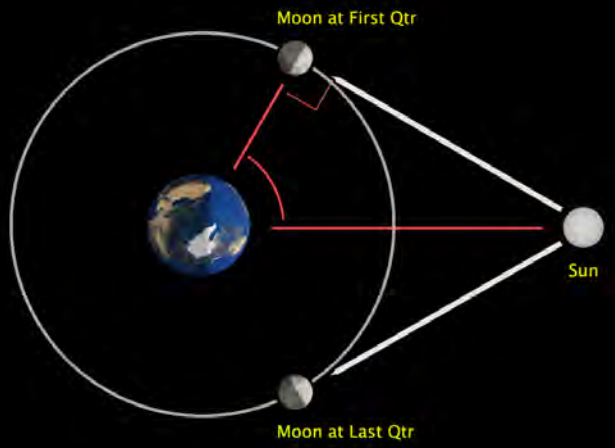
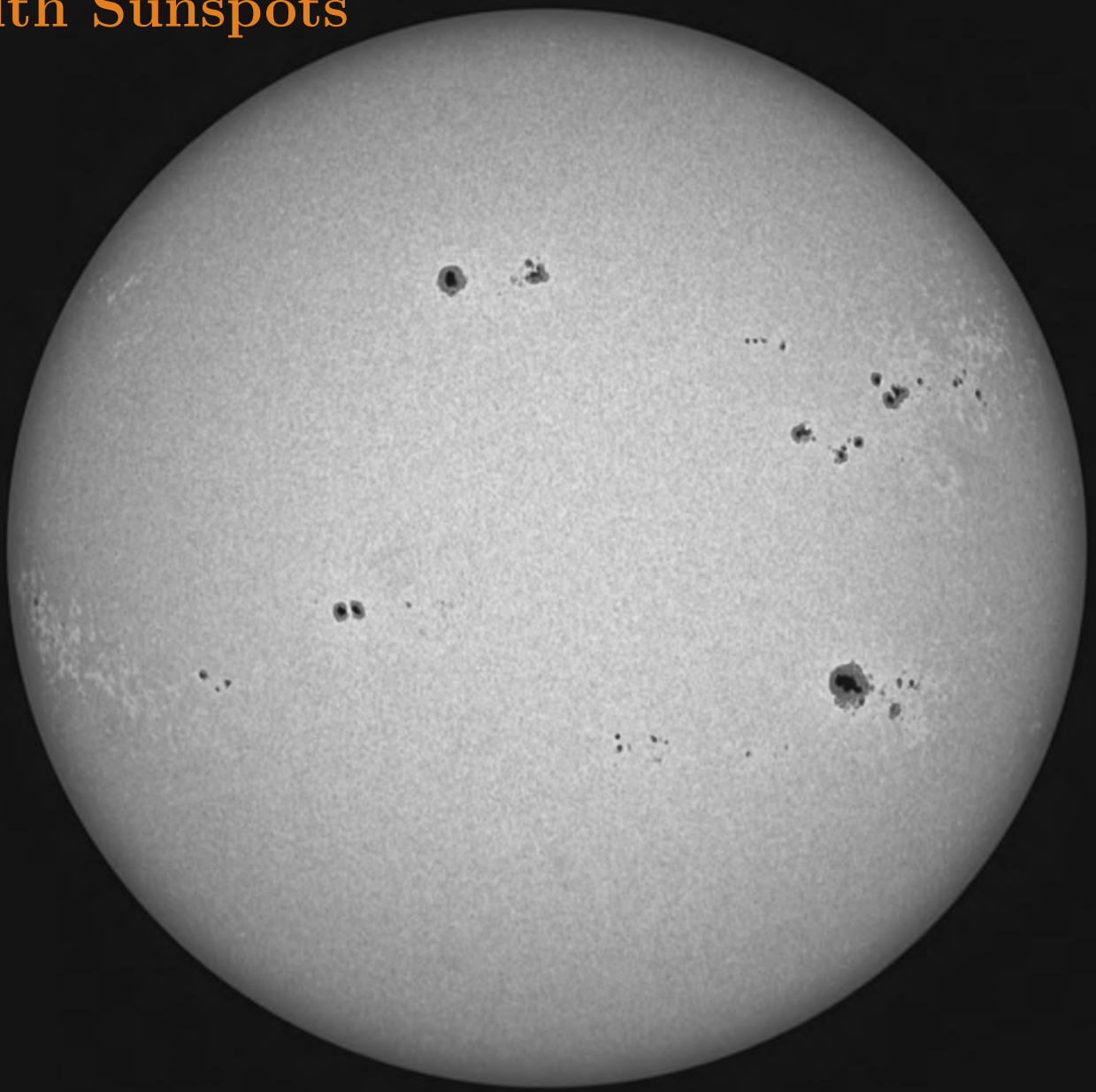
Which Is Further Away... Sun or Moon?

The Sun is about 400 times further away...



Sun with Sunspots

8 minutes



Halloween's Blue Moon

Oct. 31, 2020

Crescent Moon

4:07pm Nov. 5, 2021

Moon

1.2 sec

Moon and Mars

Moon and Mars

1.2 sec and 3.3 min

Mars

Oct. 6 and 18, 2020

Jupiter and Saturn

32 and 67 min

Comet 2022/E3 ZTF

Comet 103P / Double Cluster

1.2 min / 7,460 and 7,640 yrs

Looking Out Beyond Our Solar System

Distance Measurements

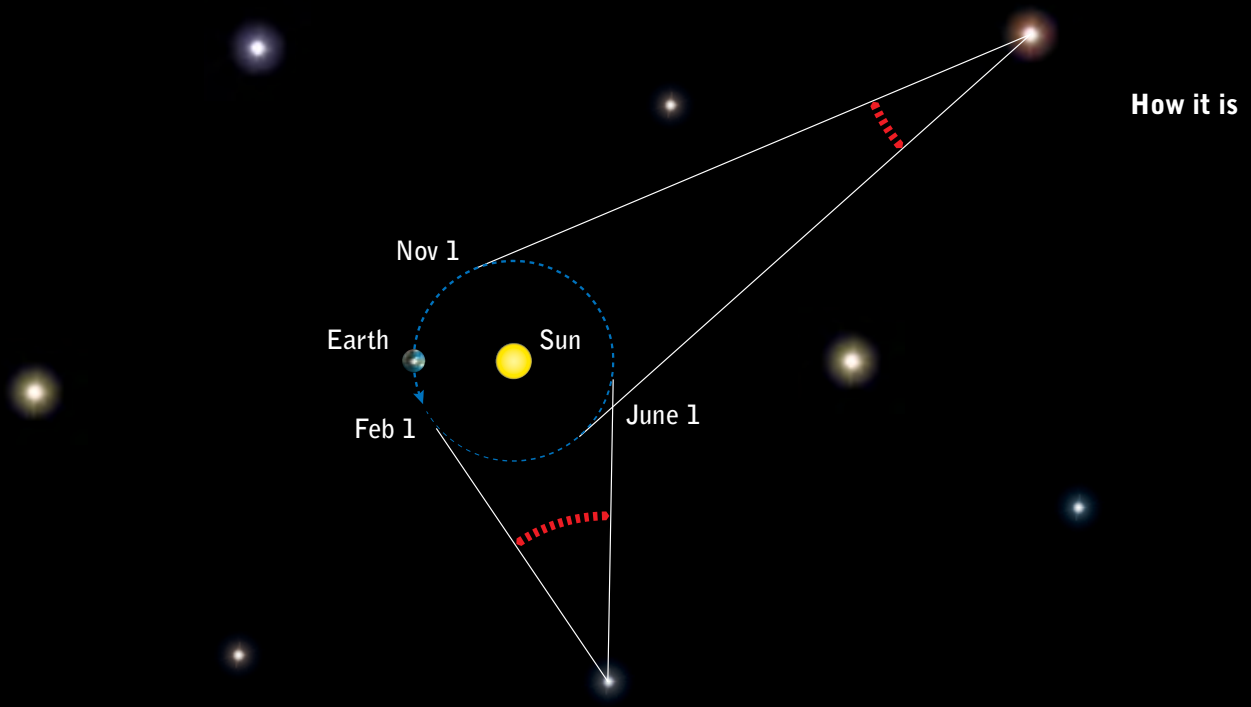
There are various ideas/methods for measuring distances.

The simplest is called *parallax*.

Using parallax, we can measure the distance to nearby stars.

For things further away, we need more clever/subtle methods.

Parallax: Distance to the Stars



Barnard's Star

Barnard's Star

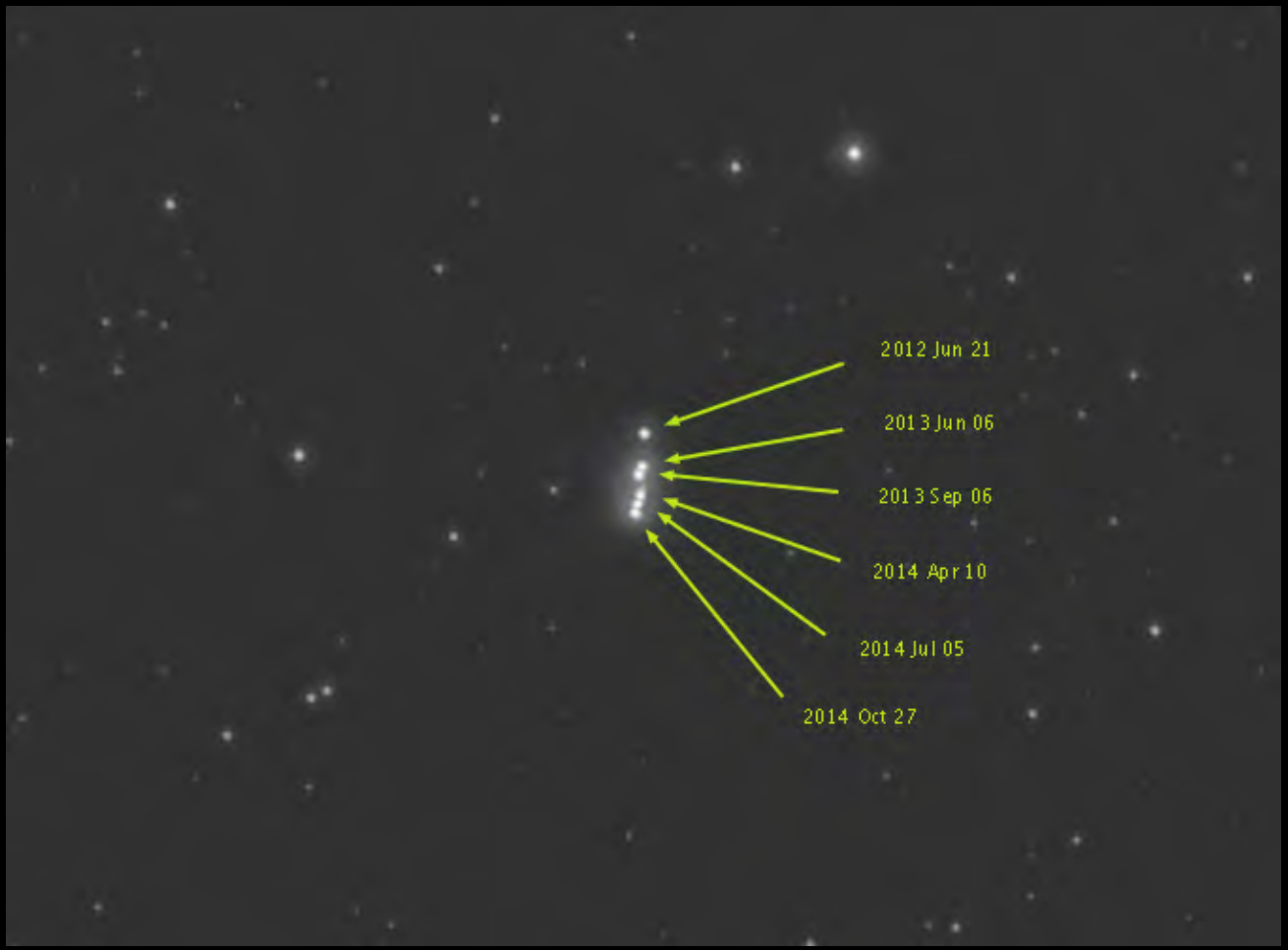
Barnard's Star

Barnard's Star

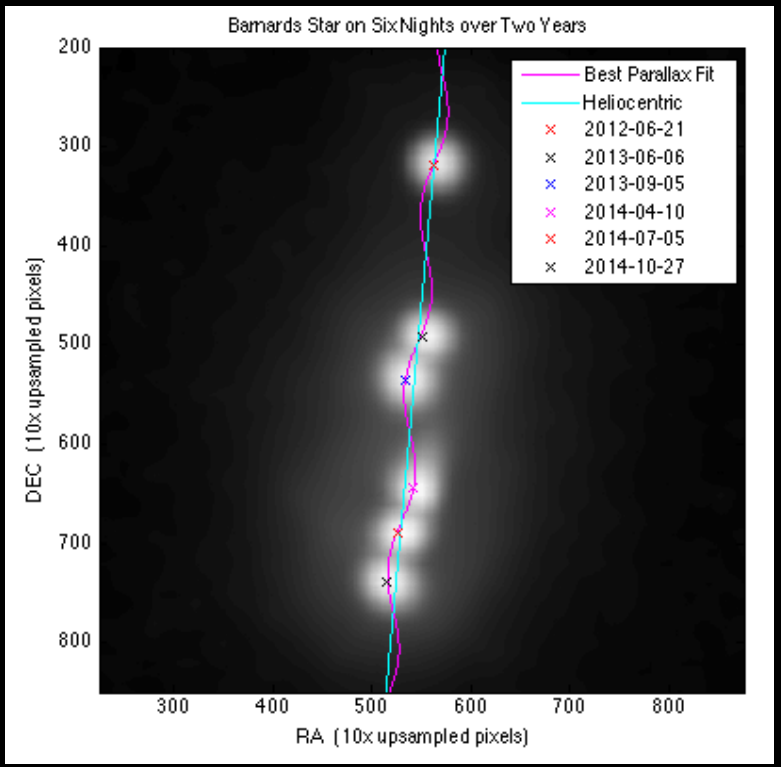
Barnard's Star

Barnard's Star

Barnard's Star Overlay



Barnard's Star Closeup



The measured parallax is 0.5478 arcsecs. Corresponds to a distance of 5.97 lightyears.

The Pleiades (Subaru): M45

444 yrs


Orion Nebula: M42
1,344 yrs

Dumbbell Nebula: M27

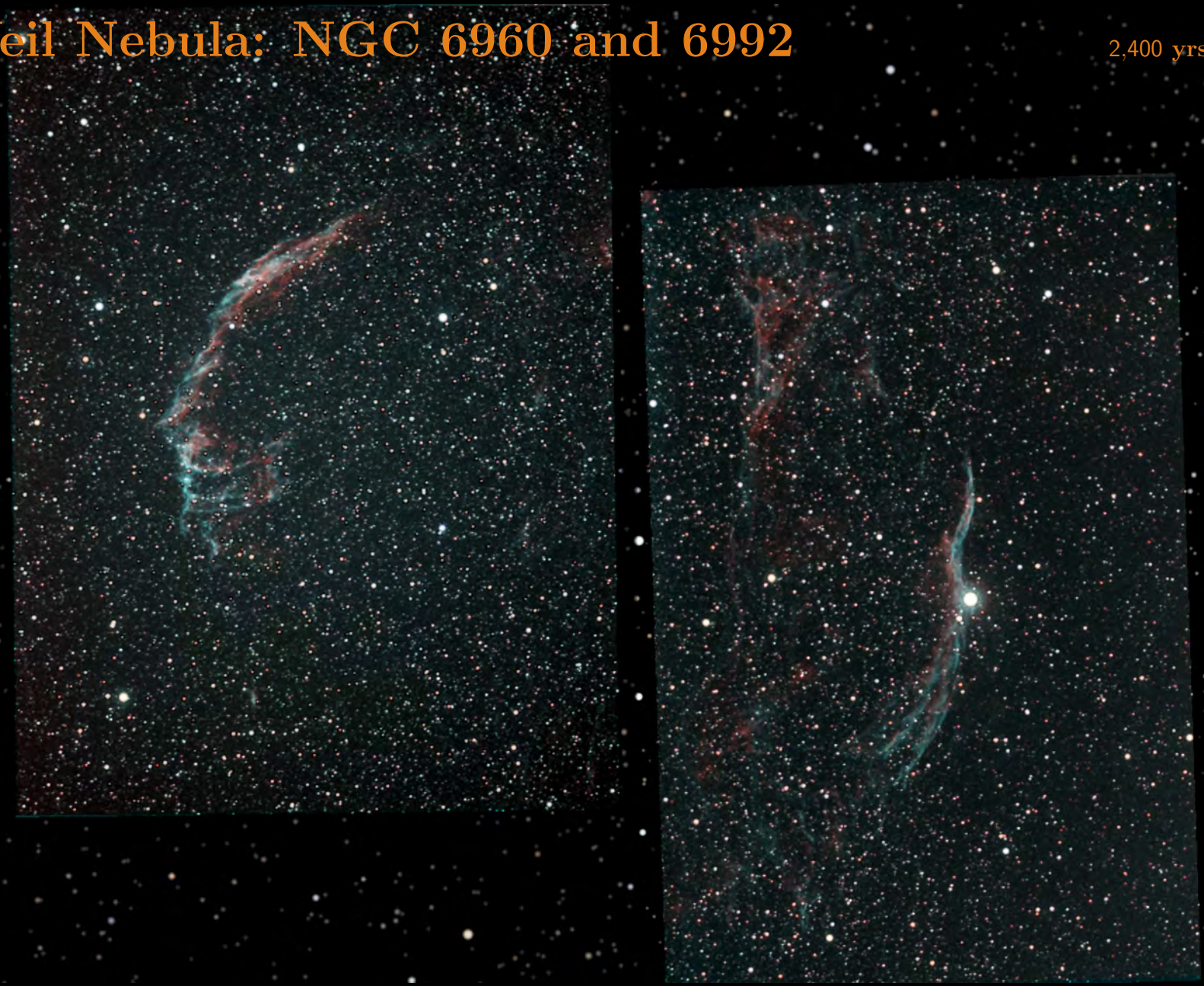
1,360 yrs

Veil Nebula: NGC 6960 and 6992

2,400 yrs

Veil Nebula: NGC 6960 and 6992

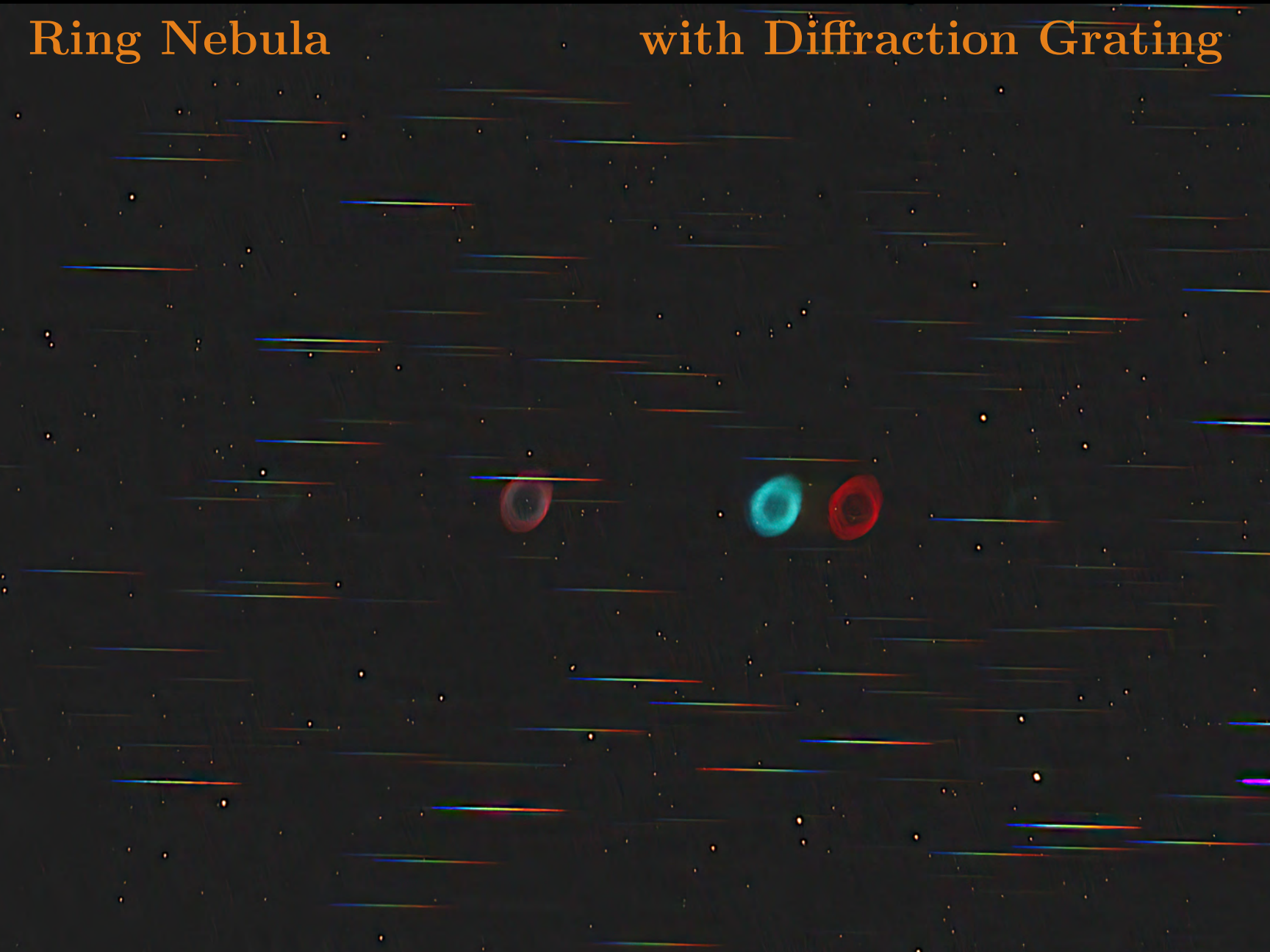
2,400 yrs




Western Veil: NGC 6960
2,400 yrs


Eastern Veil: NGC 6992


Ring Nebula: M57
2,567 yrs


Ring Nebula
with Diffraction Grating

Crescent Nebula: NGC 6888

5,000 yrs


Crescent Nebula: NGC 6888
5,000 yrs

Jellyfish Nebula: IC 443

5,000 yrs

Rosette Nebula: NGC 2237

5,200 yrs

Eagle Nebula: M16

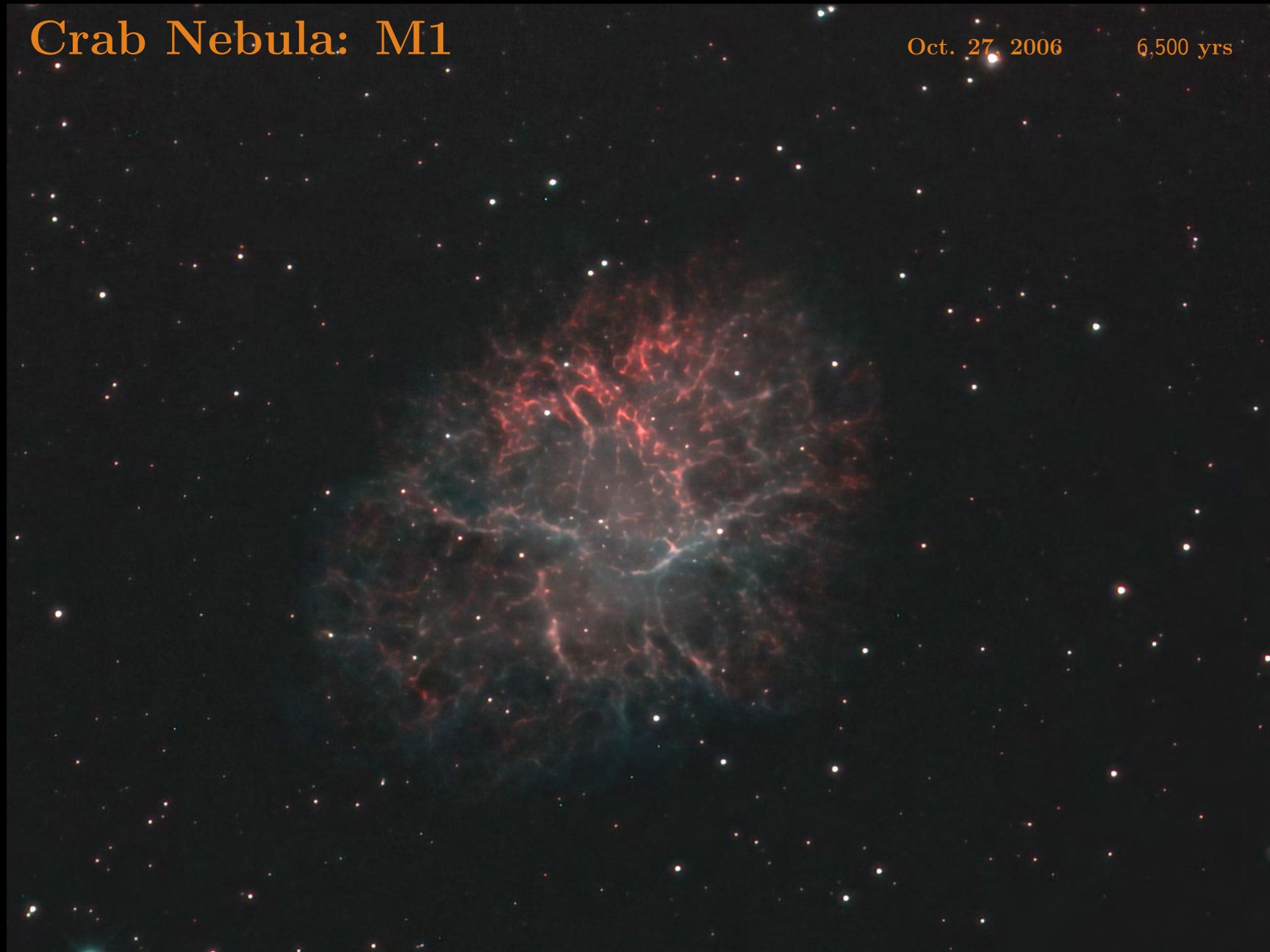
5,700 yrs

Crab Nebula: M1

Feb. 28, 2022

6,500 yrs


Crab Nebula: M1
Mar. 26, 2019
6,500 yrs


Crab Nebula: M1
Oct. 27, 2006
6,500 yrs

Bubble Nebula: NGC 7635

9,100 ± 2,000 **yrs**


Globular Cluster: M13
22,200 yrs

Looking Out Beyond Our Milky Way

The Andromeda Galaxy: M31

2,450,000 yrs

M81 and M82

12,000,000 yrs

The Pinwheel Galaxy: M101

20,900,000 yrs

The Pinwheel Galaxy: M101

20,900,000 yrs

The Whirlpool Galaxy: M51

31,000,000 yrs

The Whirlpool Galaxy: M51

31,000,000 yrs

The Whirlpool Galaxy: M51

31,000,000 yrs

The Leo Trio: M65, M66, NGC 3628

32,000,000 yrs

The Needle Galaxy: NGC 4565

42,700,000 yrs

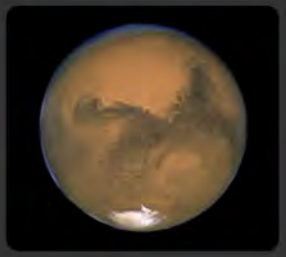
Welcome to the Universe in 3D






3D Pictures from the Book

Moon



Mars

Comet Lovejoy

Jupiter and Ganymede

Mimas

Crab Nebula

Andromeda

Hubble Ultra Deep Field

Questions?