



Astronomy...

Things Both Near and Far

Robert Vanderbei

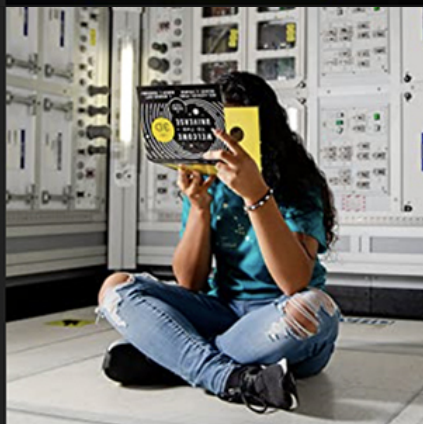
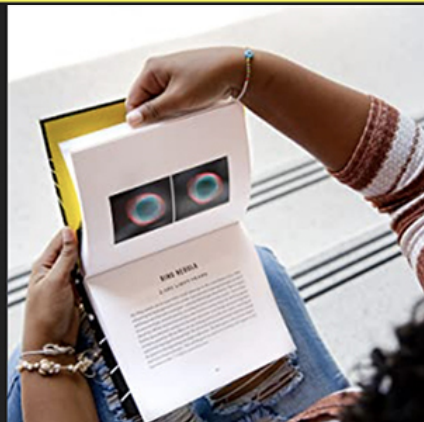
SOAL U @ Princeton University

<http://vanderbei.princeton.edu>



Welcome to the Universe in 3D *A Visual Tour*

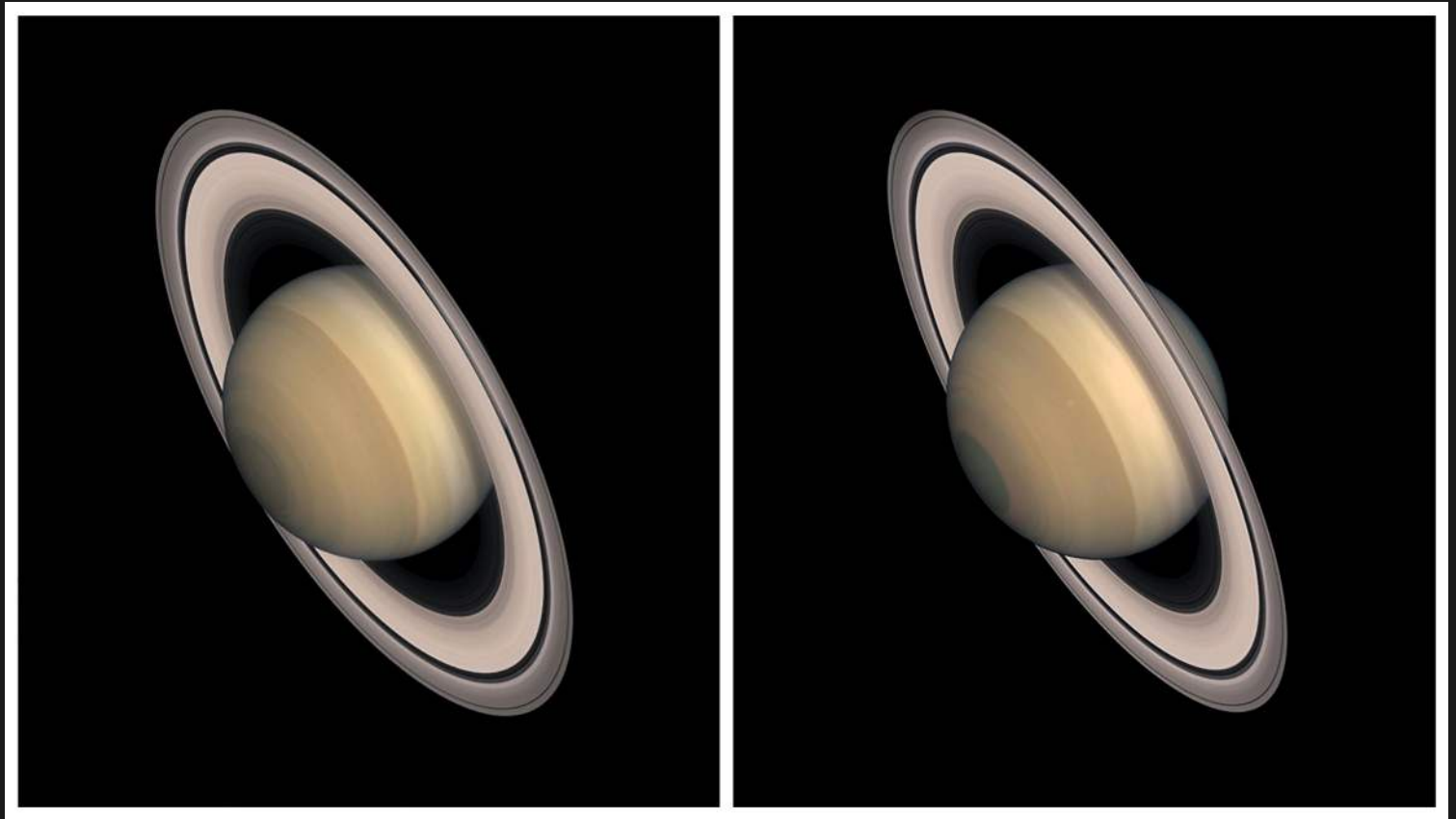
Neil deGrasse Tyson, Michael A. Strauss,
J. Richard Gott, and Robert J. Vanderbei



Neil deGrasse Tyson with Stephen Colbert

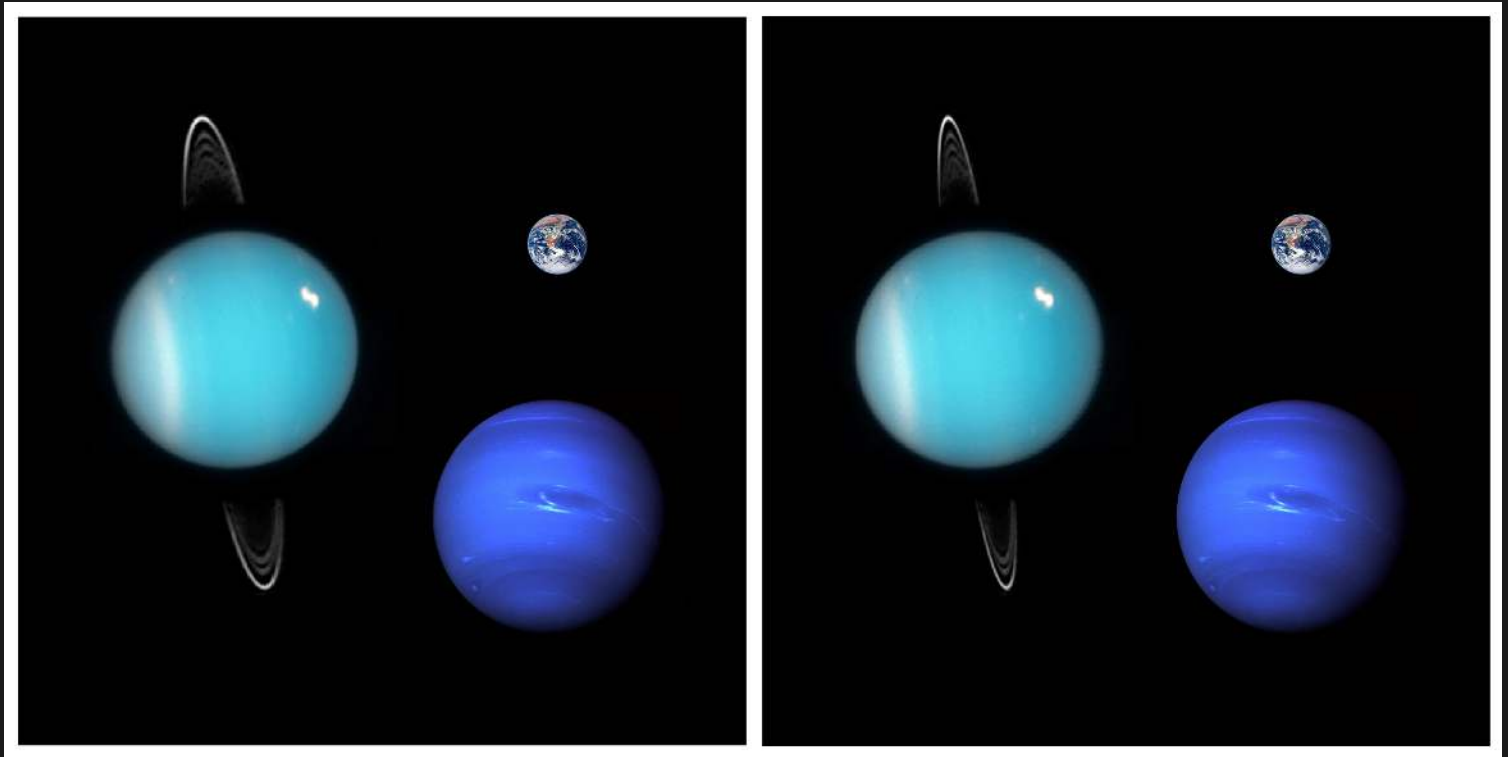


April 19, 2022



Uranus, Neptune, Earth

pg.69



Pluto, Charon

pg.71



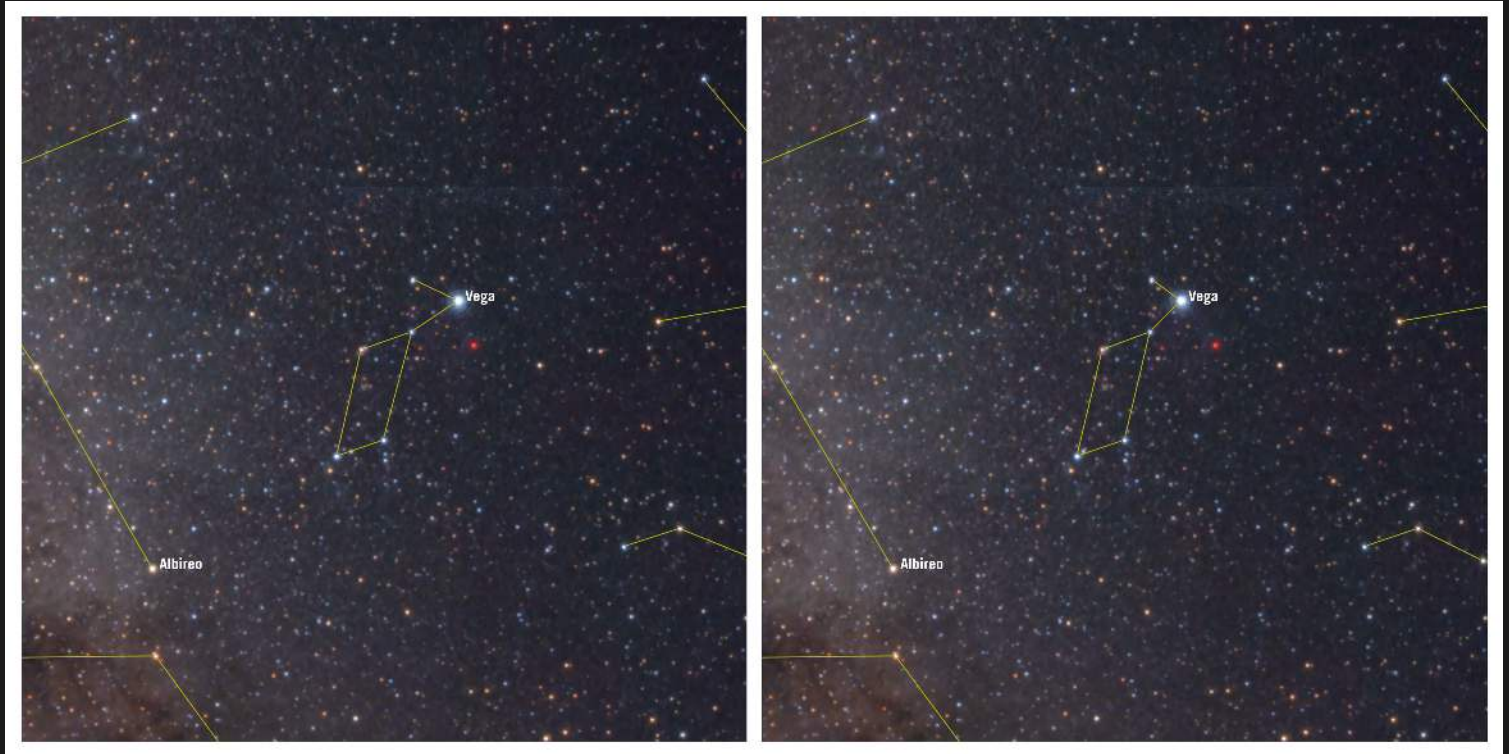
Our Solar Neighborhood

pg.73



Constellation of Lyra

pg.79



The Big Dipper



Constellation of Orion

pg.85



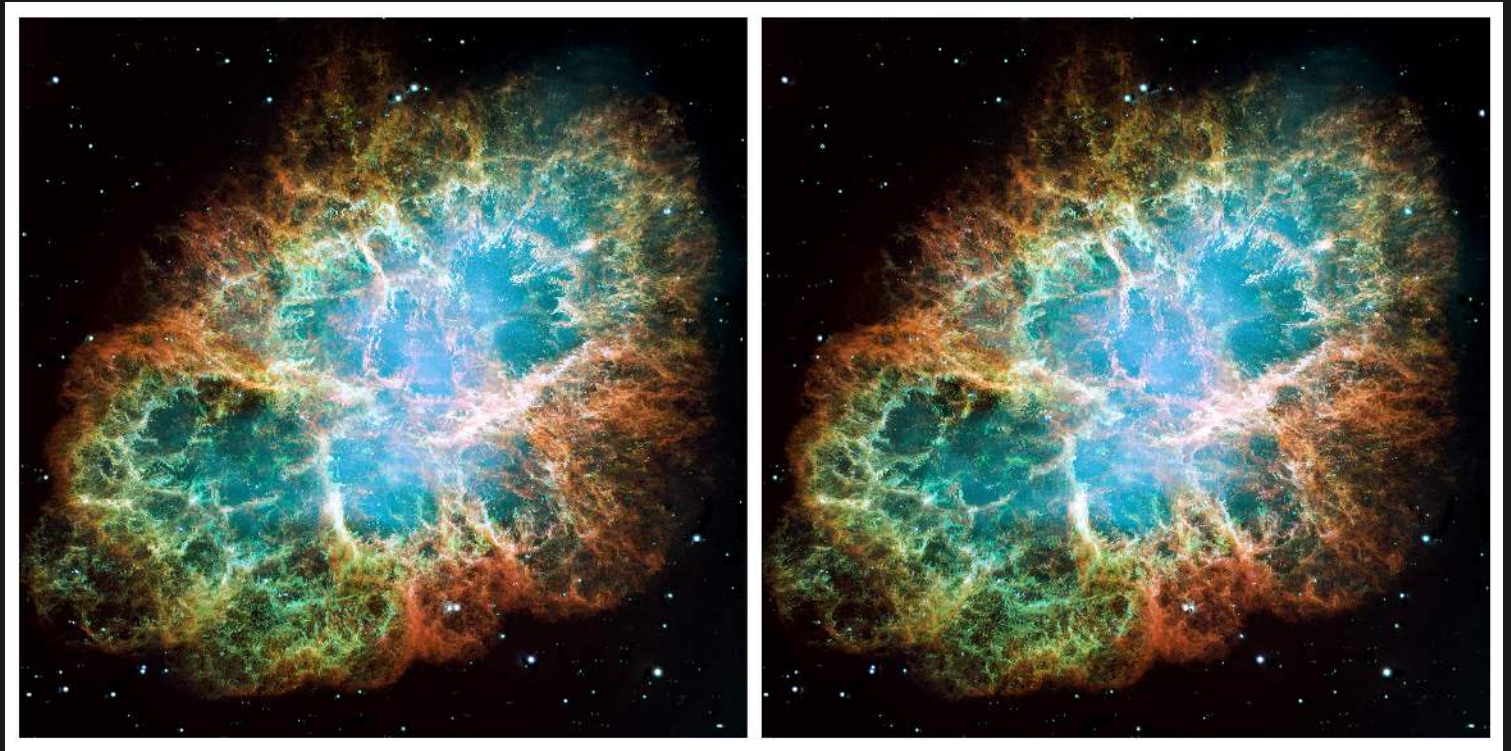
Ring Nebula

pg.91



Crab Nebula

pg.93



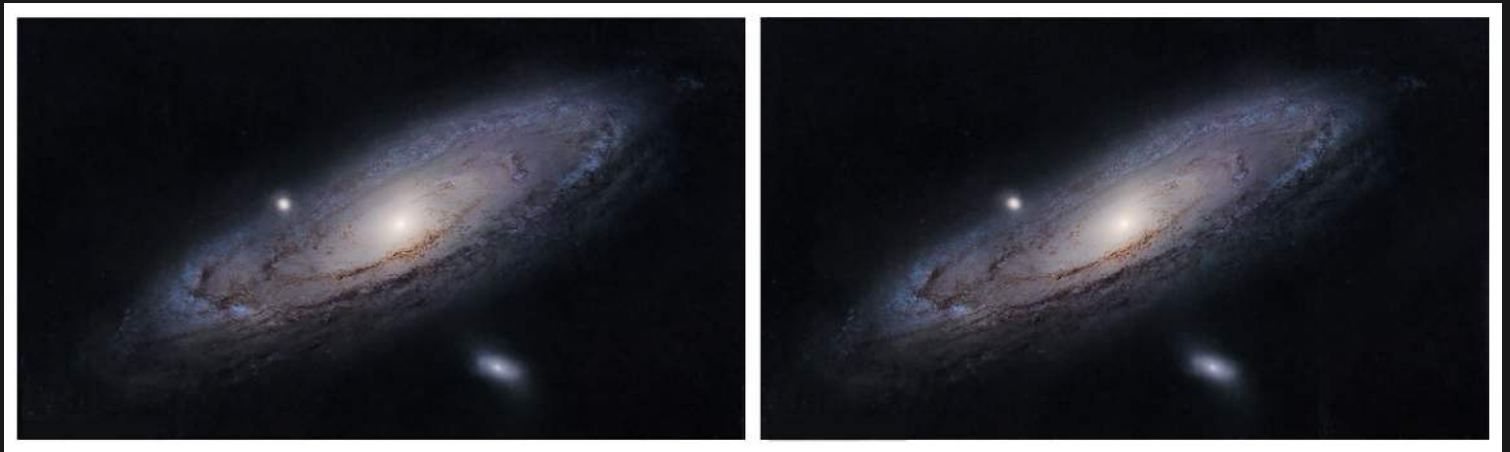
Great Globular Cluster in Hercules

pg.109



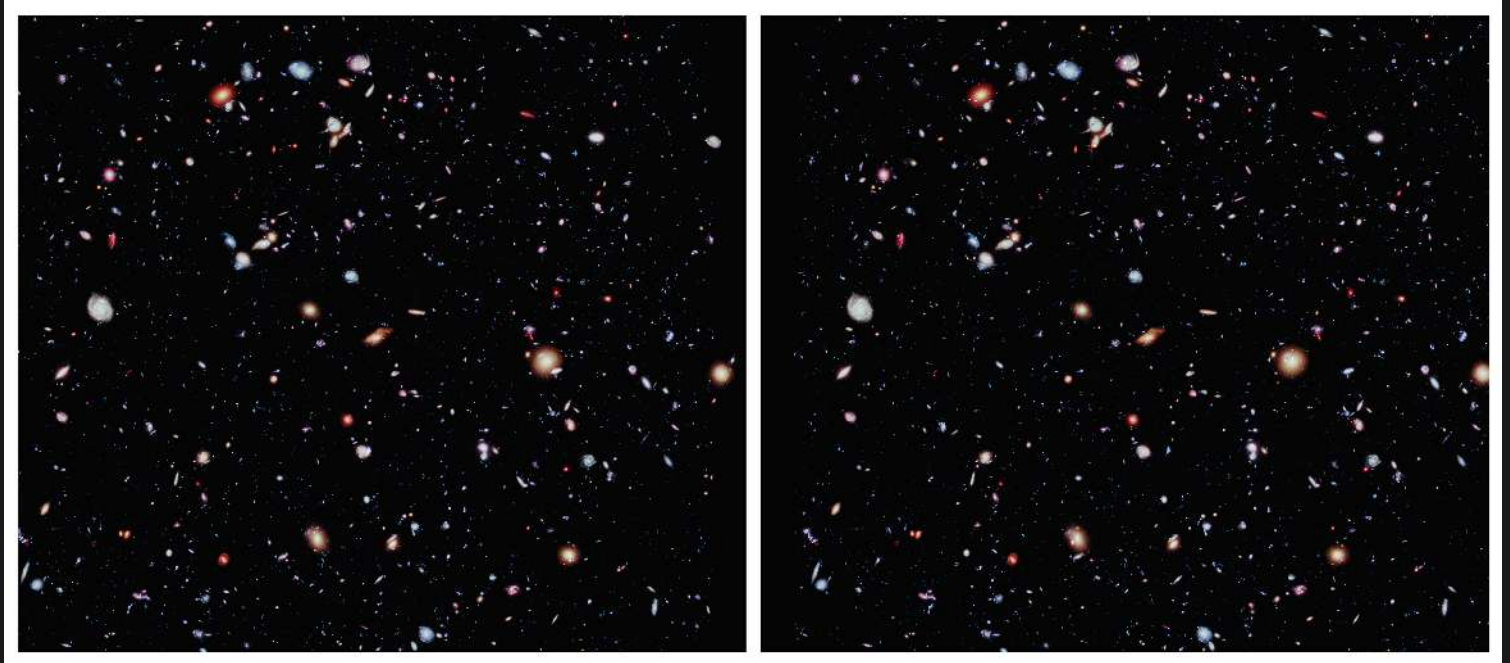
Andromeda Galaxy

pg.111



Hubble Ultra Deep Field

pg.125



Let's Go Astro

SeeStar S30 Smart Telescope



Attach the Tripod



Take outdoors and put on the table (or the floor)



Pictures Taken With The SeeStar S30 Telescope

Super Moon

10:04pm Nov. 4, 2025

1.17 secs



Crescent Moon

9:53pm June 4, 2025

1.33 secs



Comet Lemmon - C/2025 A6

5.0 min



Comet PanSTARRS - C/2025 R3

6.3 min



Looking Out Beyond Our Solar System

The Pleiades (Subaru): M45

Nov. 28, 2025

444 yrs



Beehive Star Cluster: M44

May 11, 2026

610 yrs



California Nebula: NGC1499

Dec. 12, 2025 1,250 yrs



Orion Nebula: M42

Mar. 1, 2025

1,267 yrs



Dumbbell Nebula: M27

Sept. 22, 2025

1,360 yrs



Horsehead Nebula: IC434

Sept. 27, 2025

1,375 yrs



Pelican Nebula: IC5070

June 9, 2026

1,800 yrs



Bubble Nebula and M52

Oct. 26, 2025

4,600, 9,100+/-2,000 yrs



Owl Nebula: M97

Apr. 23, 2026

2,030 yrs



Veil Nebula: NGC6960, NGC6992

June 20, 2026

2,200 yrs



North America Nebula: NGC7000

July 3, 2026

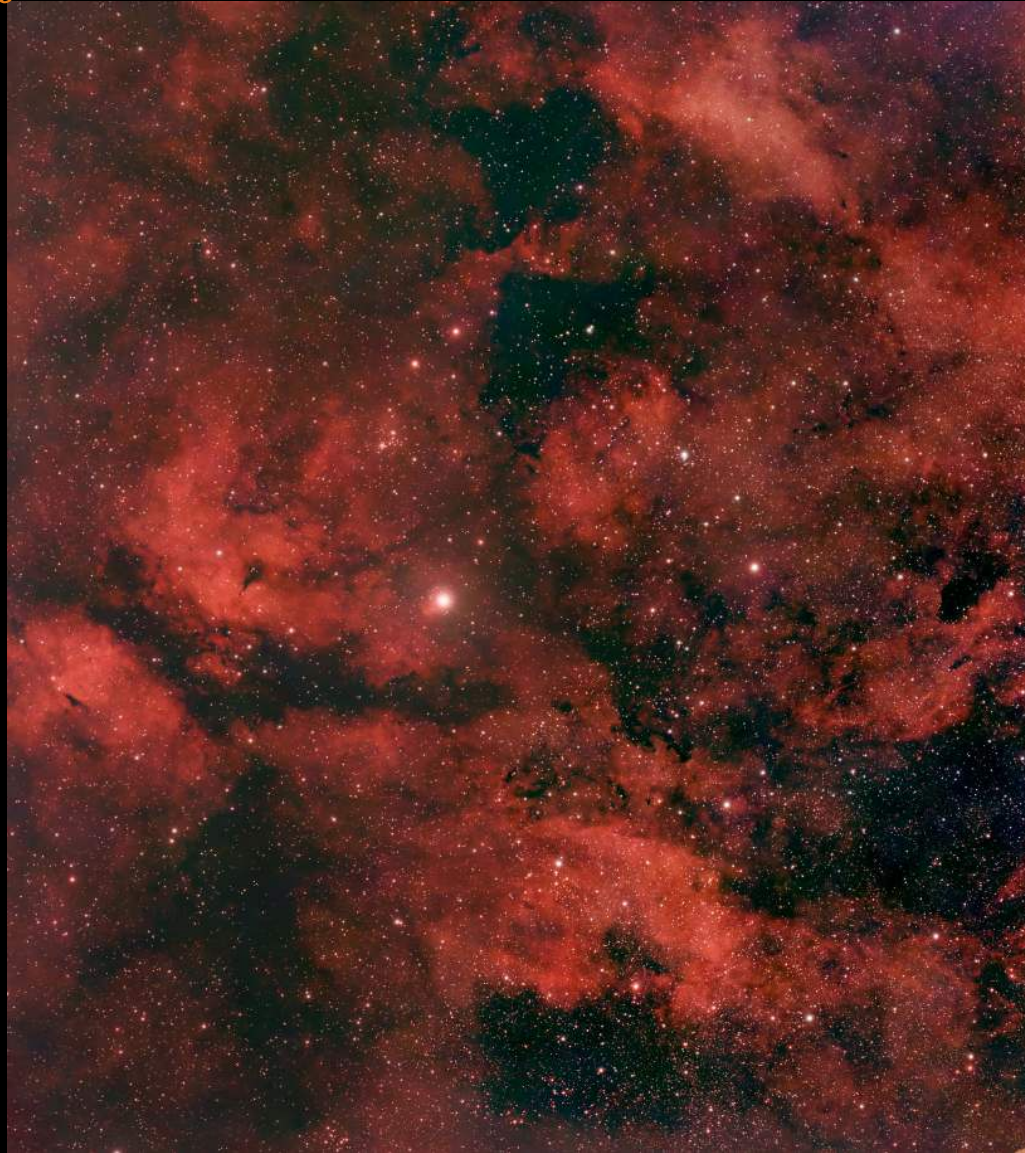
2,590 yrs



Butterfly Nebula: IC1318

June 5,16 2025

3,100 yrs



Trifid/Lagoon (M20/M8) Nebulae

July 9, 2026

4,100 yrs



Crescent Nebula: NGC6888

June 2, 2026

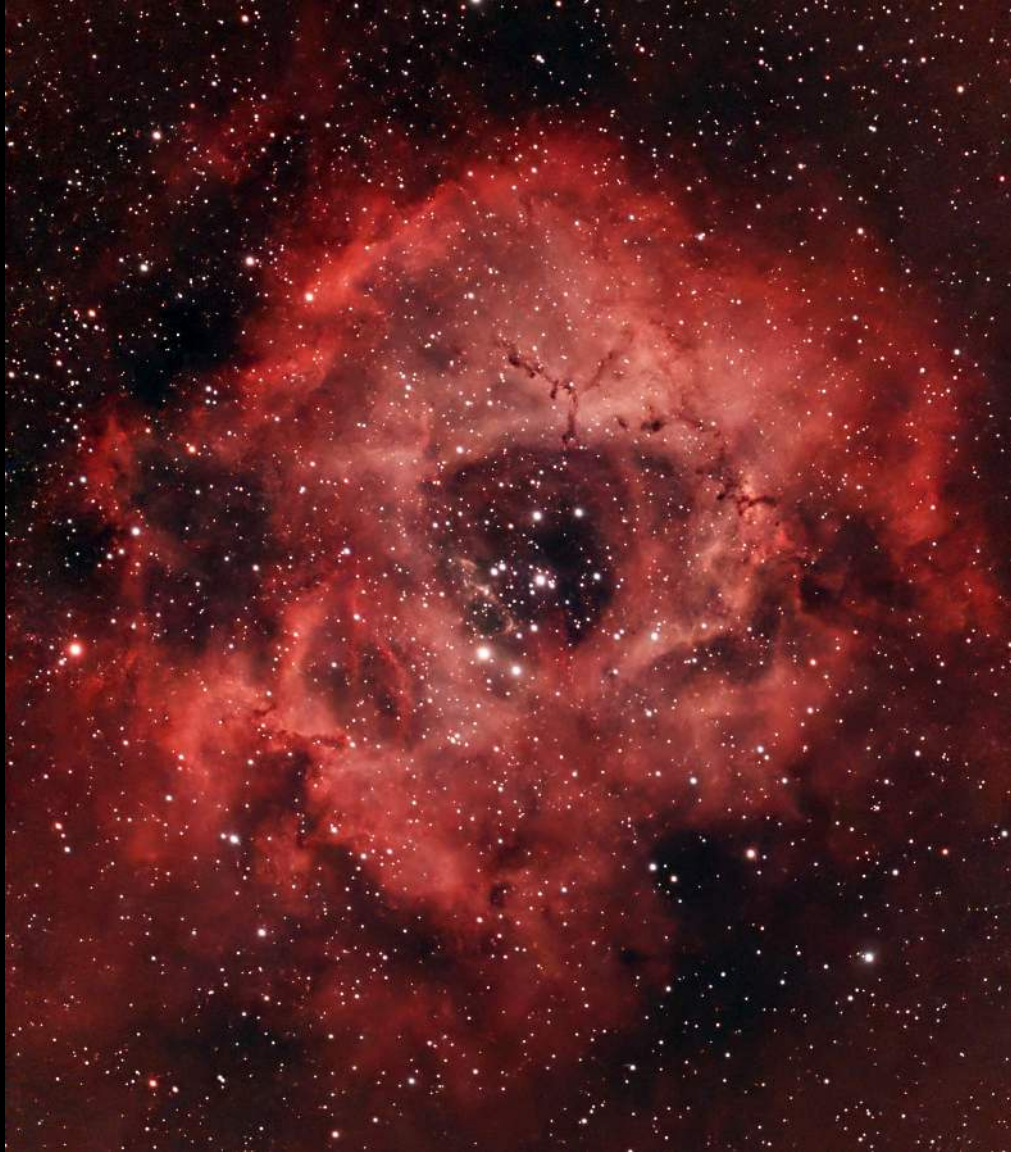
4,800 yrs



Rosette Nebula: NGC2238

March 9, 2026

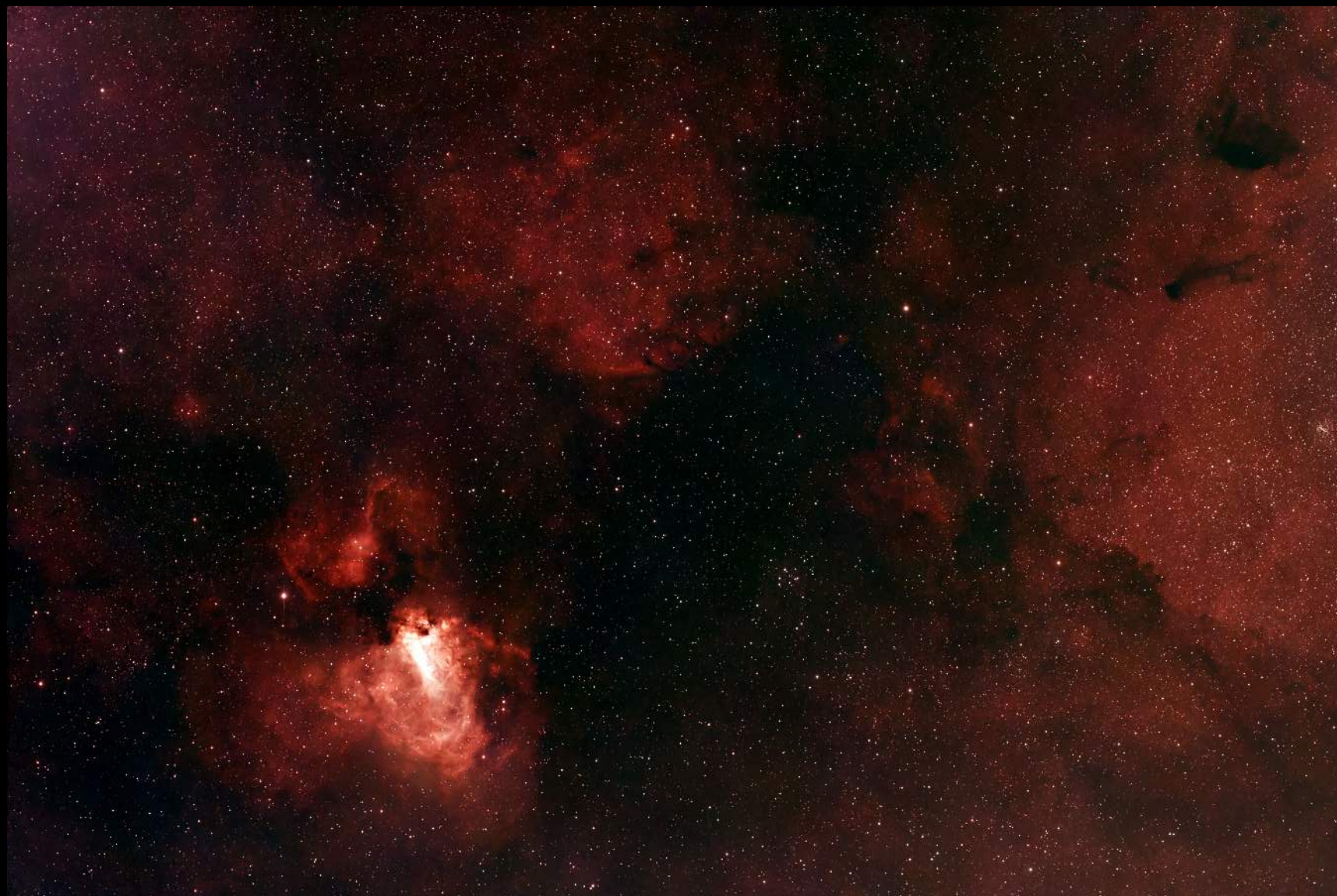
5,100 yrs



Swan Nebula: M17

July 20, 2026

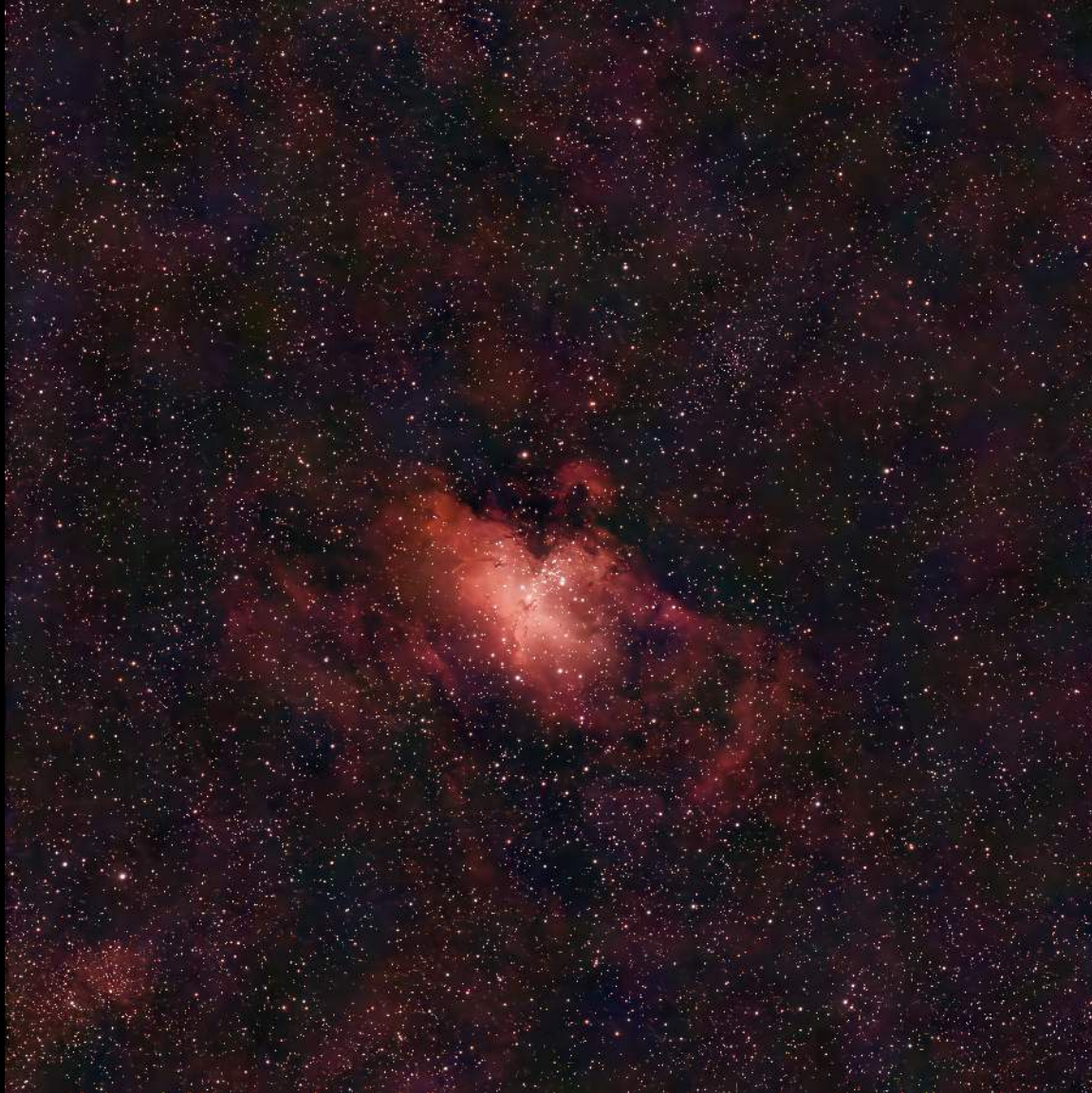
5,500 yrs



Eagle Nebula: M16

July 15, 2026

5,700 yrs



Crab Nebula: M1

Feb. 28, 2026

6,500 yrs



Double Cluster: NGC884, NGC869

Sept. 12, 2025 7,500 yrs



Heart Nebula: IC1805

Apr. 27, 2026

7,500 yrs



The Owl Cluster: NGC457

Sept. 14, 2025

8,000 yrs



Great Globular Cluster: M13

June 4, 2025

22,200 yrs

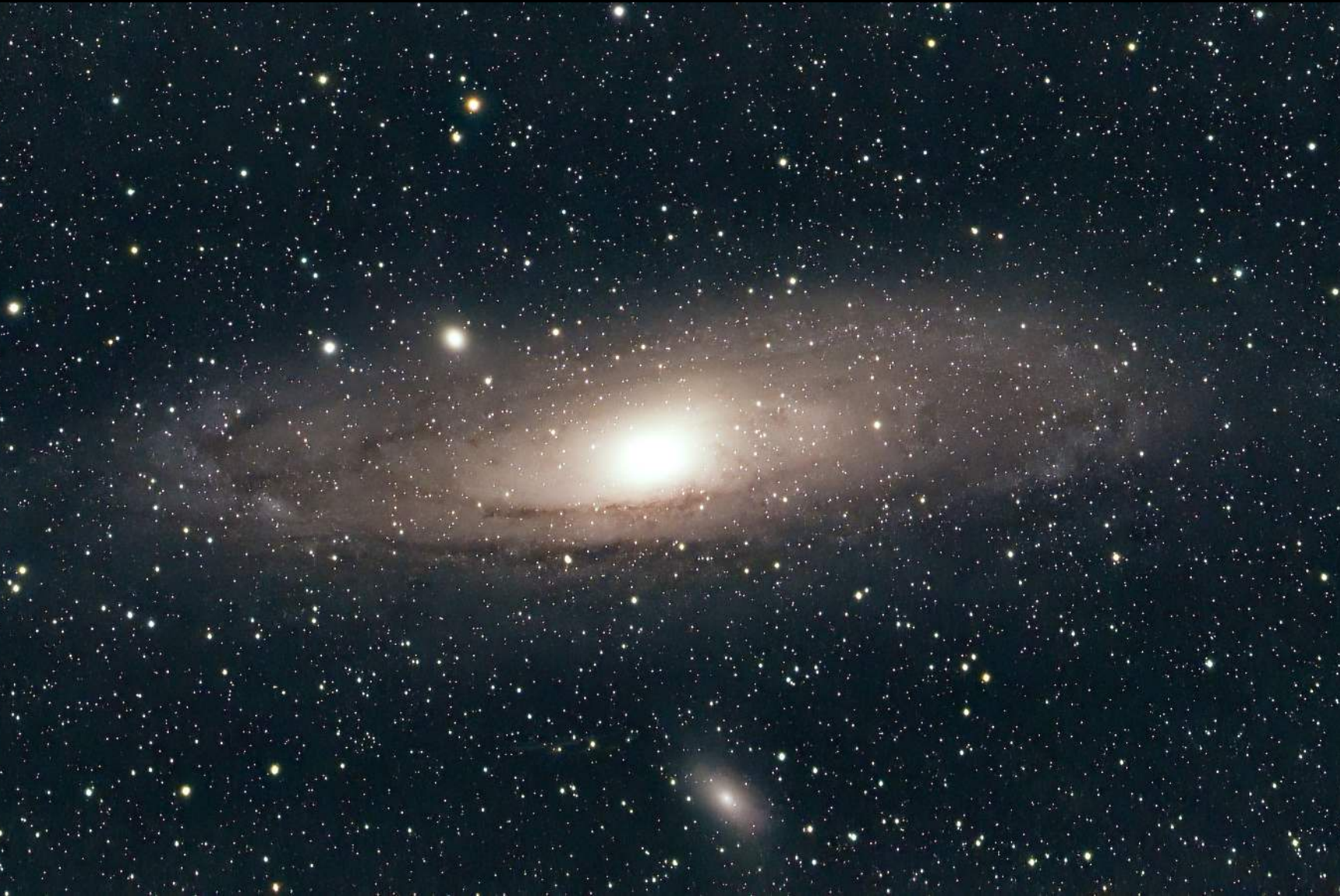


Looking Out Beyond Our Milky Way

Andromeda Galaxy: M31

Oct. 18, 2025

2,450,000 yrs



Triangulum Galaxy: M33

Nov. 28, 2025

2,880,000 yrs



Galaxy Pair: M81, M82

Mar. 18, 2026

12,000,000 yrs



Pinwheel Galaxy: M101

May 18, 2026

23,000,000 yrs



Whirlpool Galaxy: M51

Apr. 30, 2025

23,500,000 yrs



Leo Trio: M65, M66, NGC3628

Apr. 9, 2026

35,000,000 yrs



My more expensive equipment

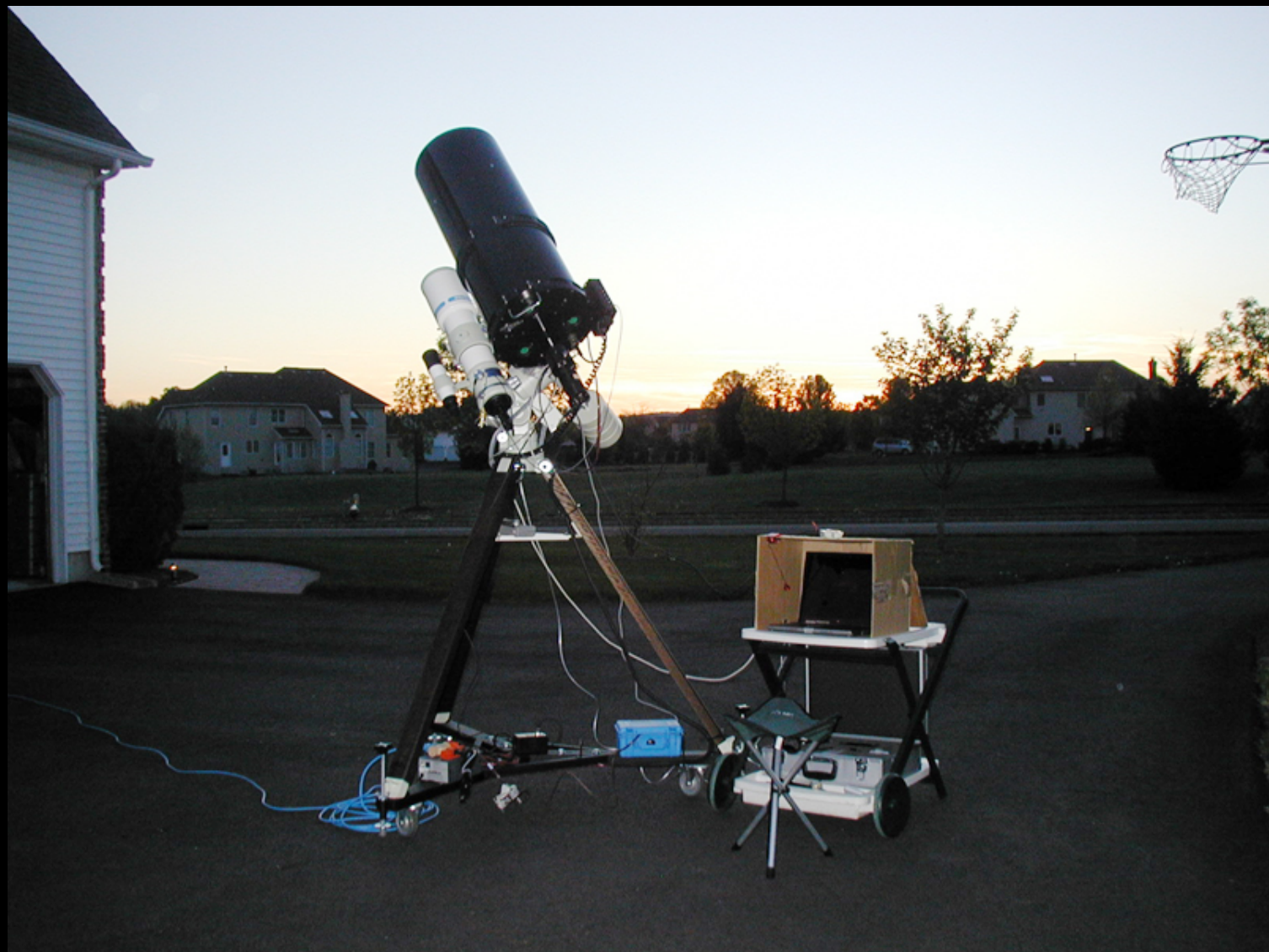
10" Reflector, 4" Refractor, Telephoto Lens



Move equipment outside.

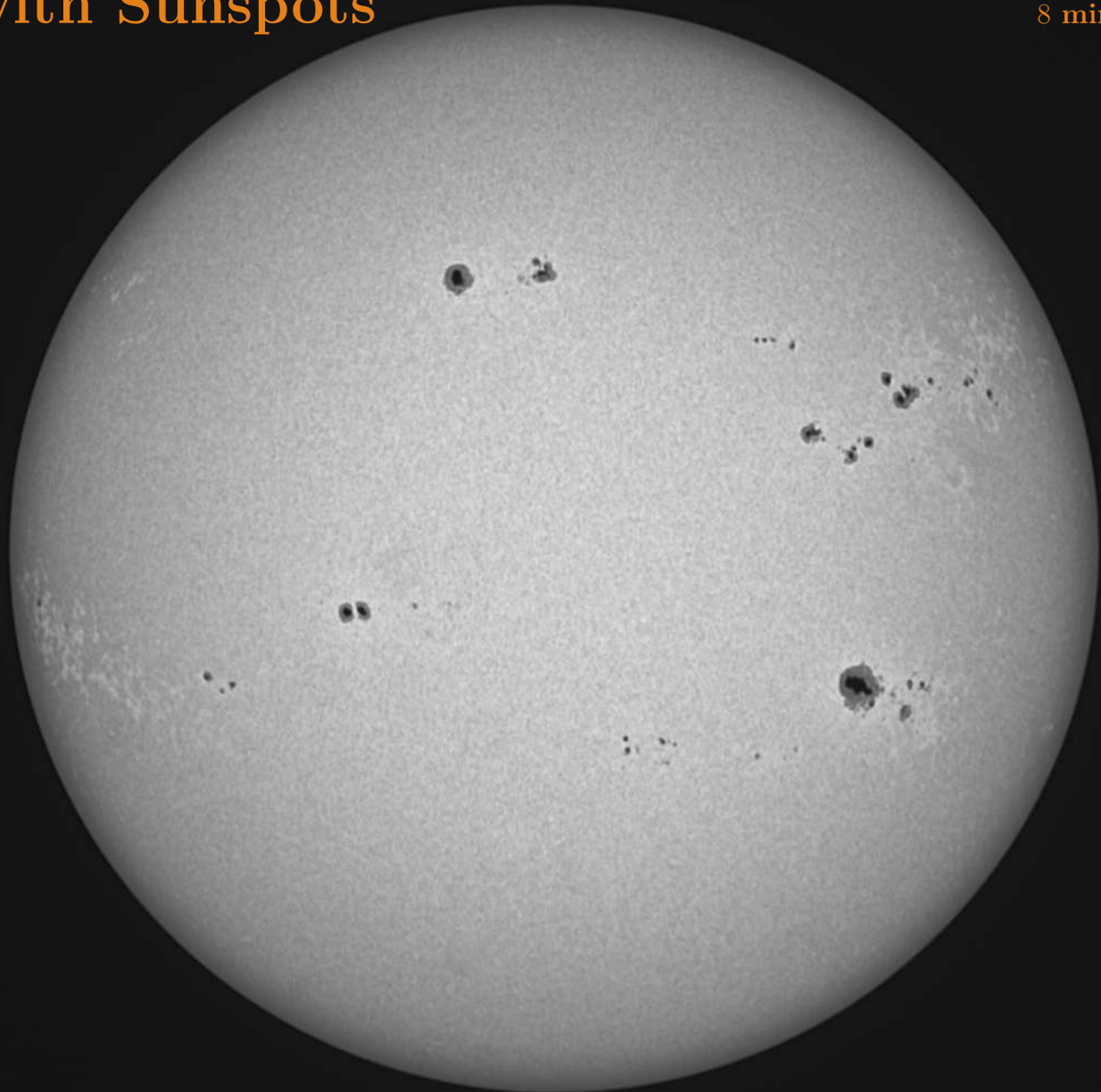


Ready To Go...



Sun with Sunspots

8 minutes (pg 21)



Crescent Moon

4:07pm Nov. 5, 2021



Full Moon

1.2 sec



Moon and Mars



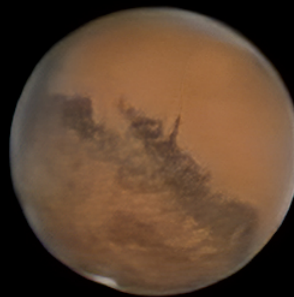
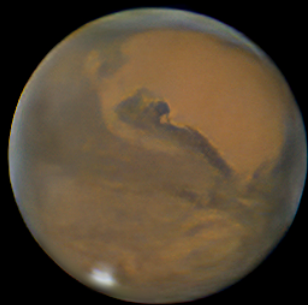
Moon and Mars

1.2 sec and 3.3 min



Mars

Oct. 6 and 18, 2020 (pg 33)



Jupiter and Saturn

32 and 67 min (pgs 51,59)



Comet 103P / Double Cluster

1.2 min / 7,460 and 7,640 yrs (pg 47)



Looking Out Beyond Our Solar System

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



Western Veil: NGC 6960

2,400 yrs



Eastern Veil: NGC 6992



Ring Nebula: M57

2,567 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

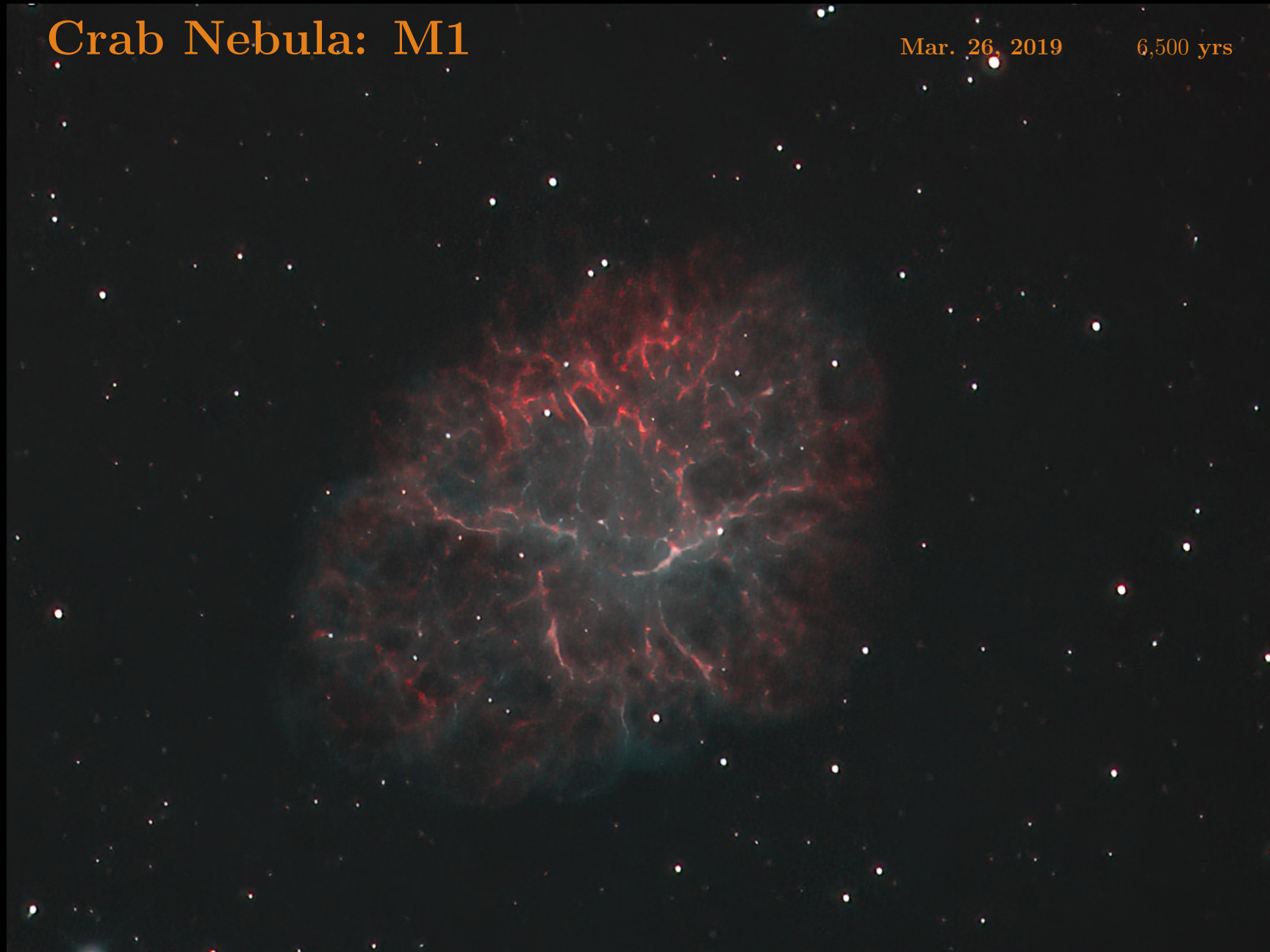
5,700 yrs



Crab Nebula: M1

Mar. 26, 2019

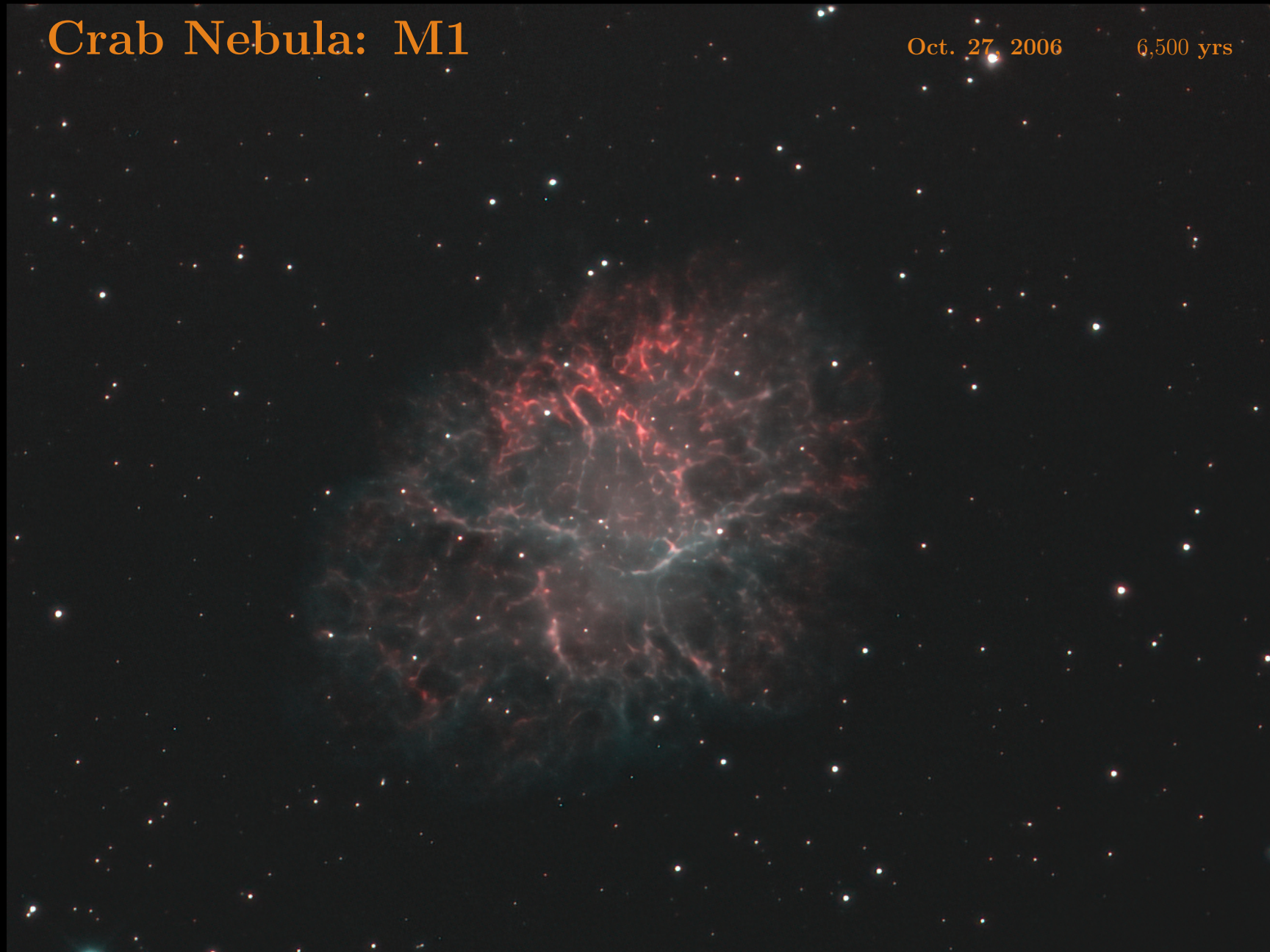
6,500 yrs



Crab Nebula: M1

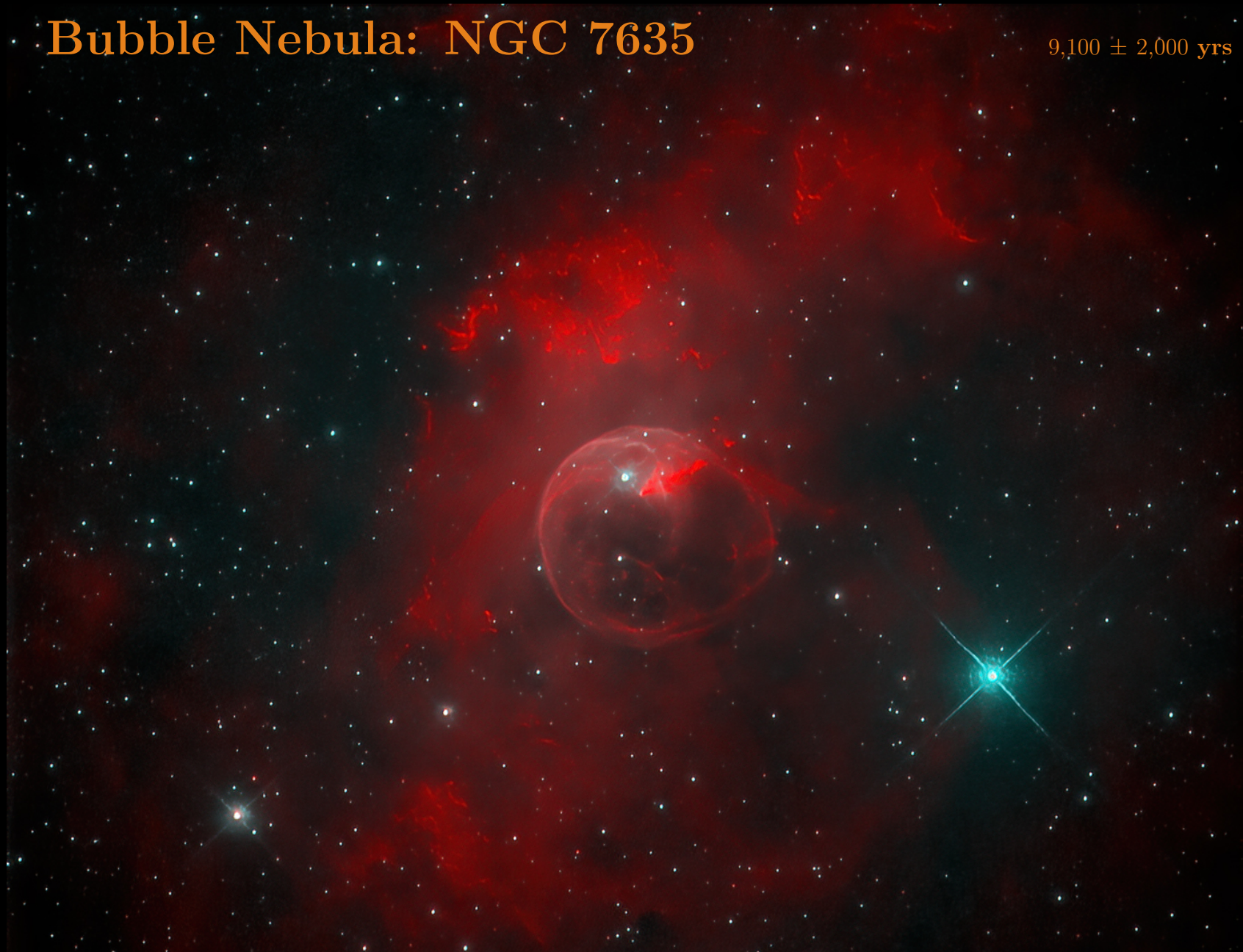
Oct. 27, 2006

6,500 yrs



Bubble Nebula: NGC 7635

$9,100 \pm 2,000$ 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



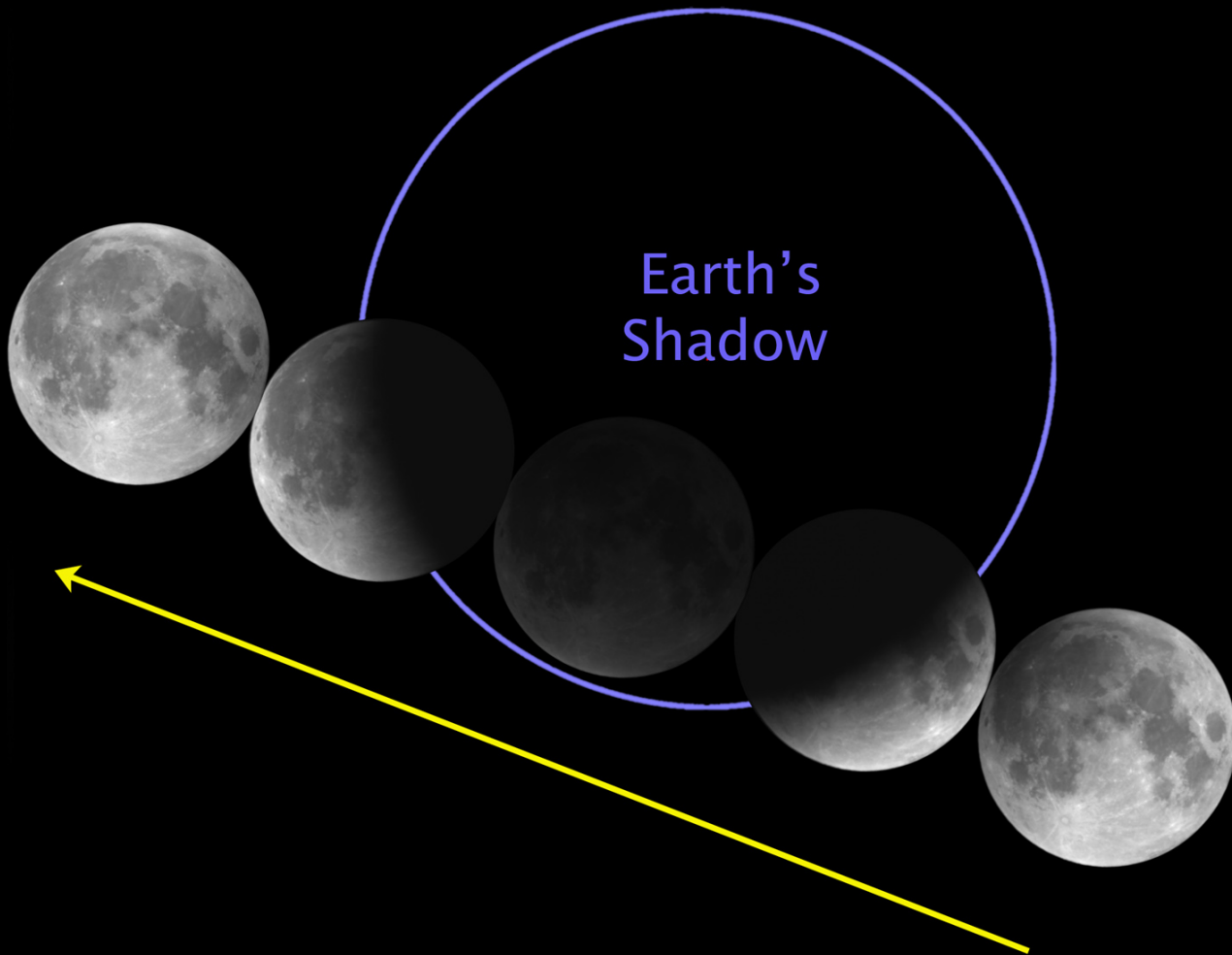
Hubble Ultra Deep Field

Questions?

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.



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:

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

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

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

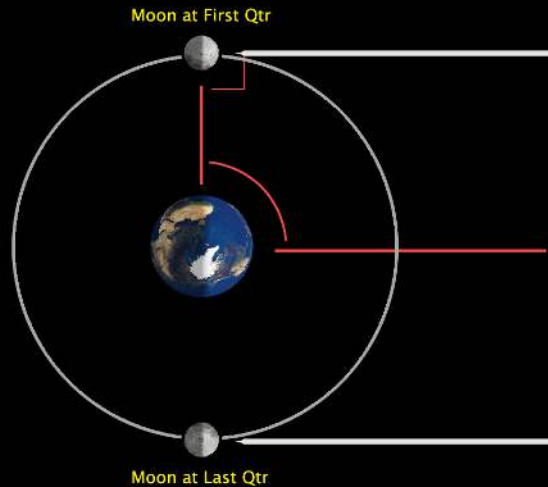
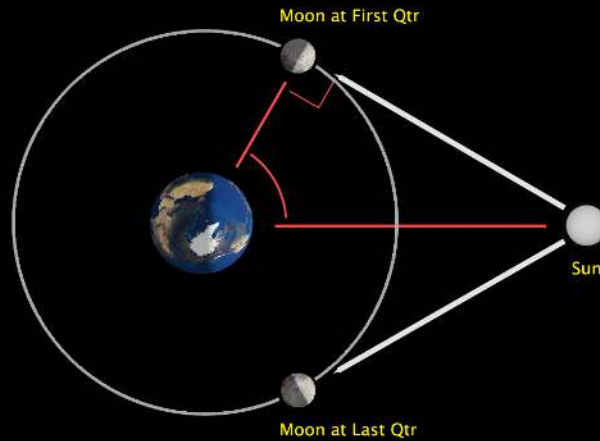
Moon's diameter = 2,000 miles

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

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

Which Is Further Away... Sun or Moon?

The Sun is about 400 times further away...



Parallax



Parallax

Left Eye View



Parallax

Right Eye View



My Finger – Parallax



My Finger – Left Eye



My Finger – Right Eye



My Finger – Both Eyes



Distance Measurements

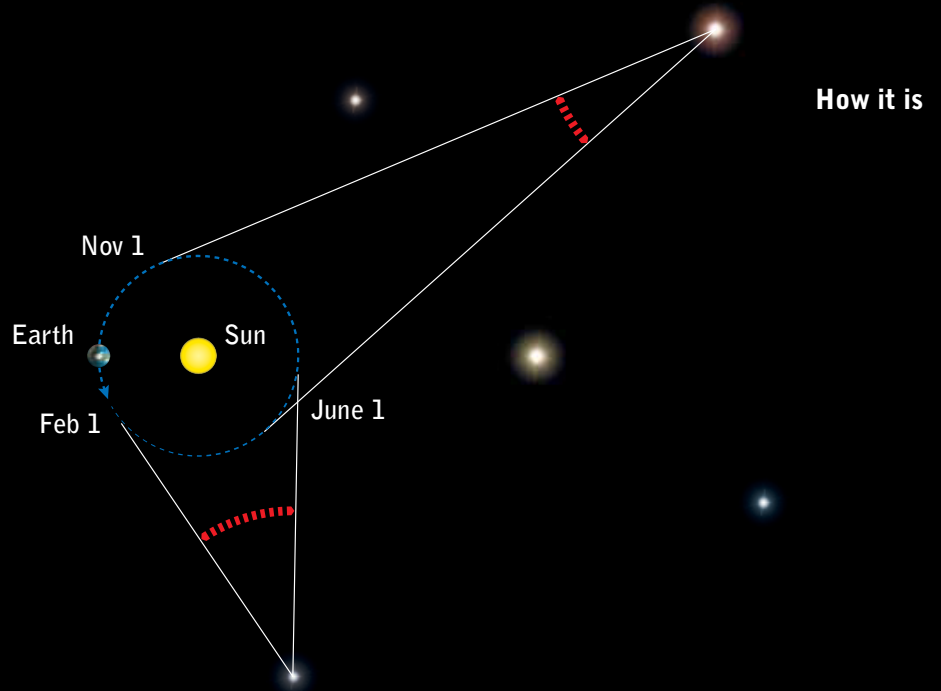
There are various ideas/methods for measuring distances.

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

pg.59



Ring Nebula

with Diffraction Grating

