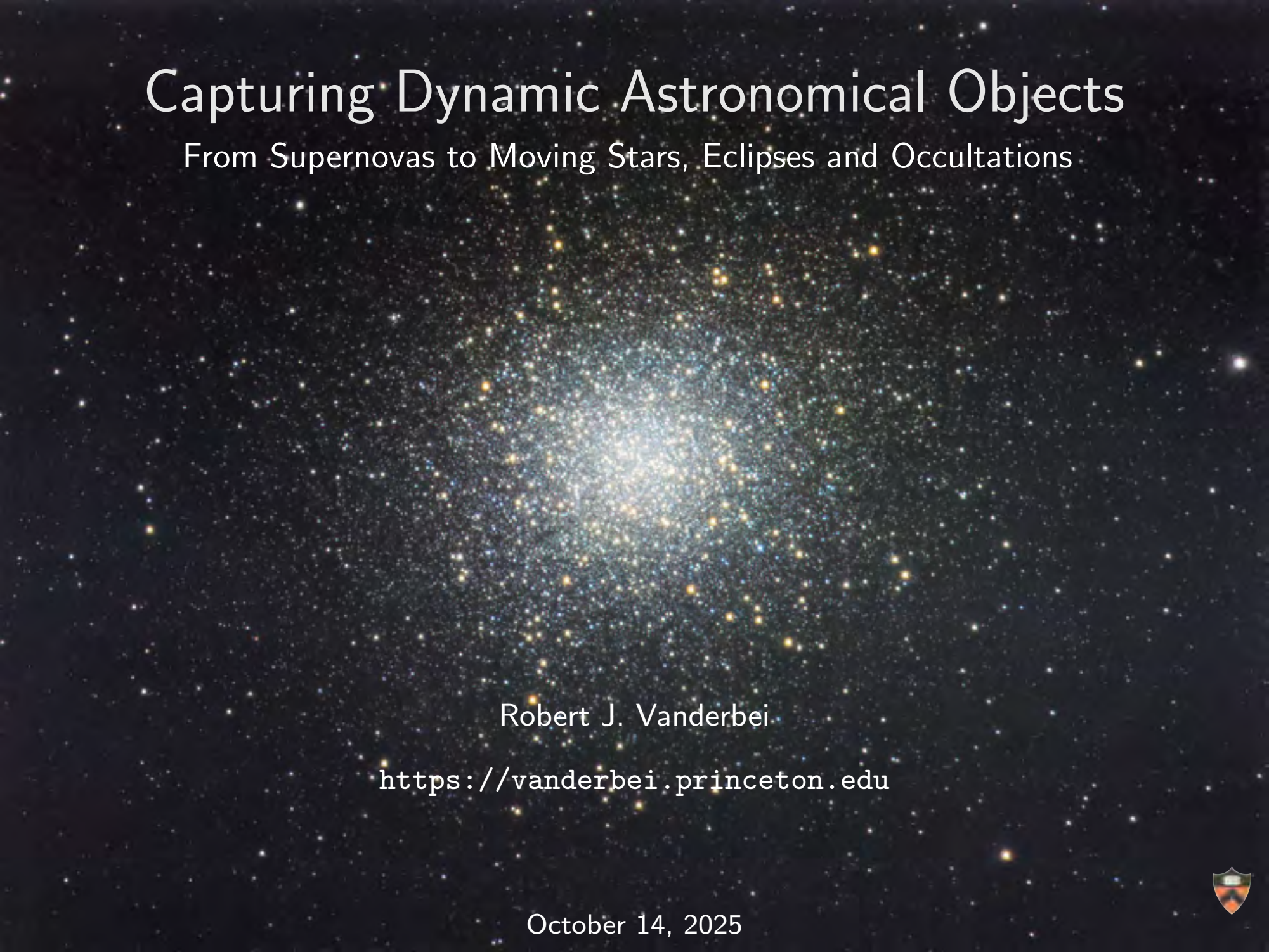
Capturing Dynamic Astronomical Objects

From Supernovas to Moving Stars, Eclipses and Occultations



Robert J. Vanderbei

https://vanderbei.princeton.edu

October 14, 2025

Me and My Telescopes

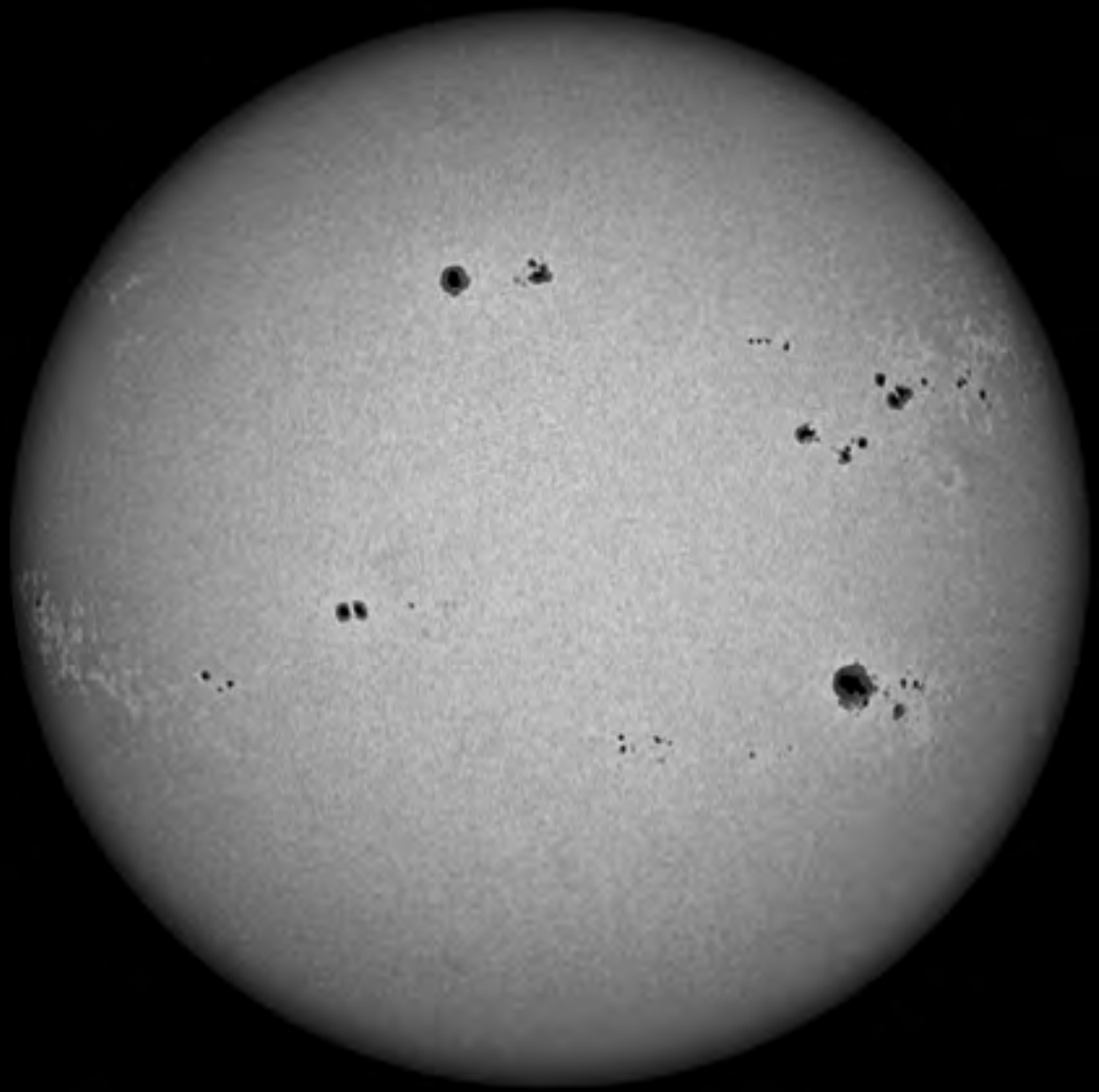
Move equipment outside.

Ready To Go...

10" Reflector, 4" Refractor, Telephoto Lens

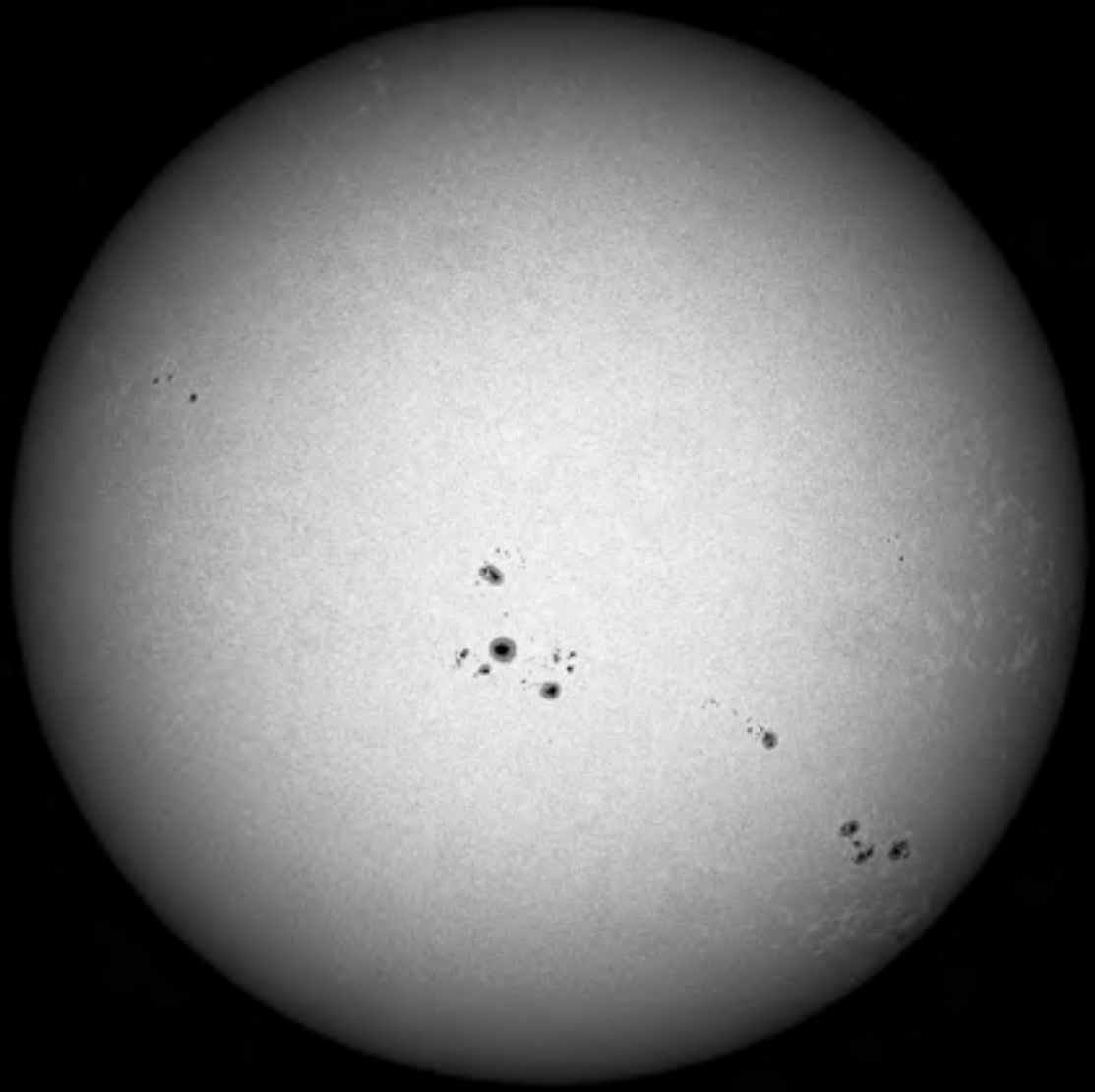
Sun with Sunspots

Jan 16, 2023



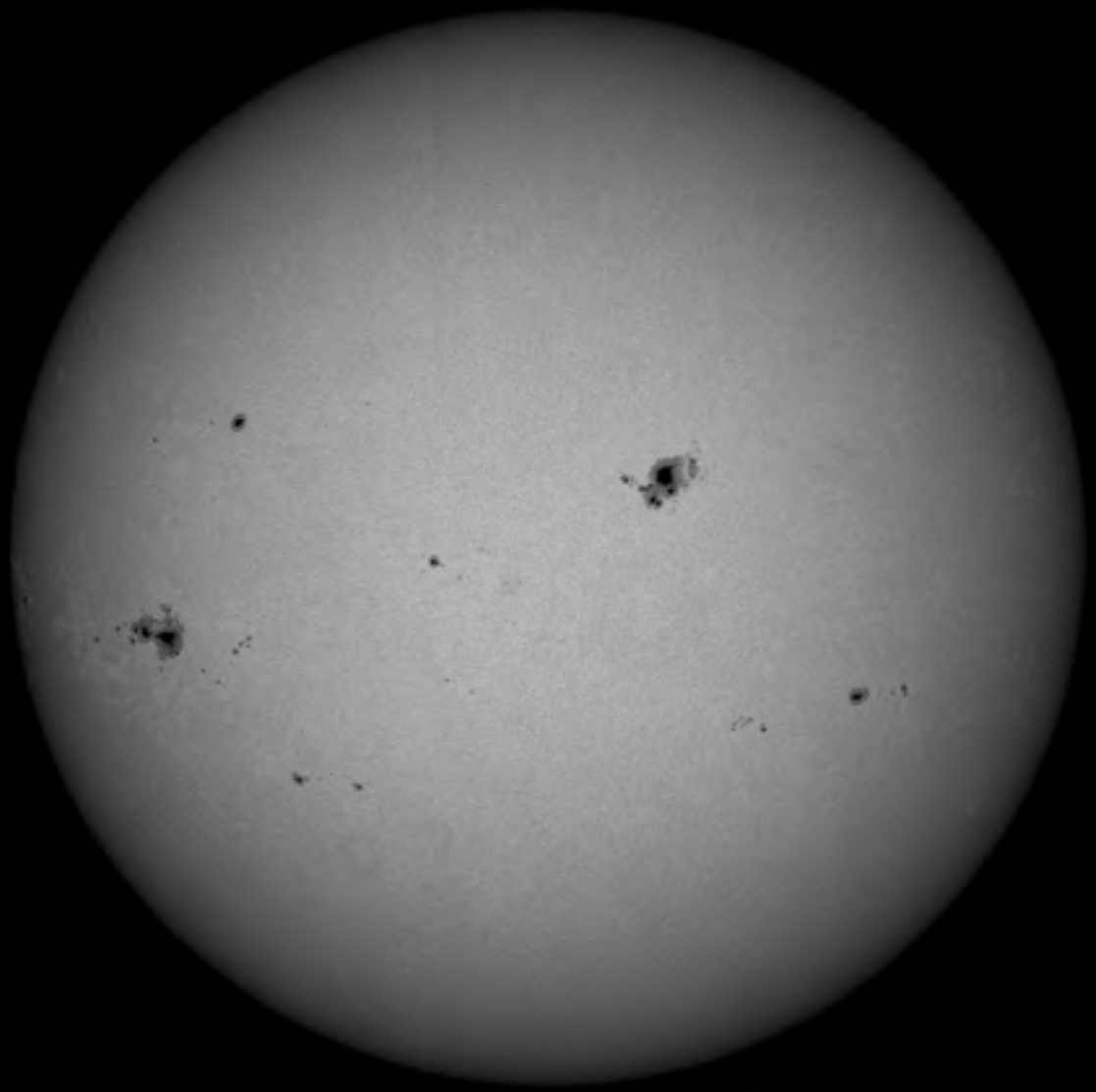
Sun with Sunspots

May 22, 2024

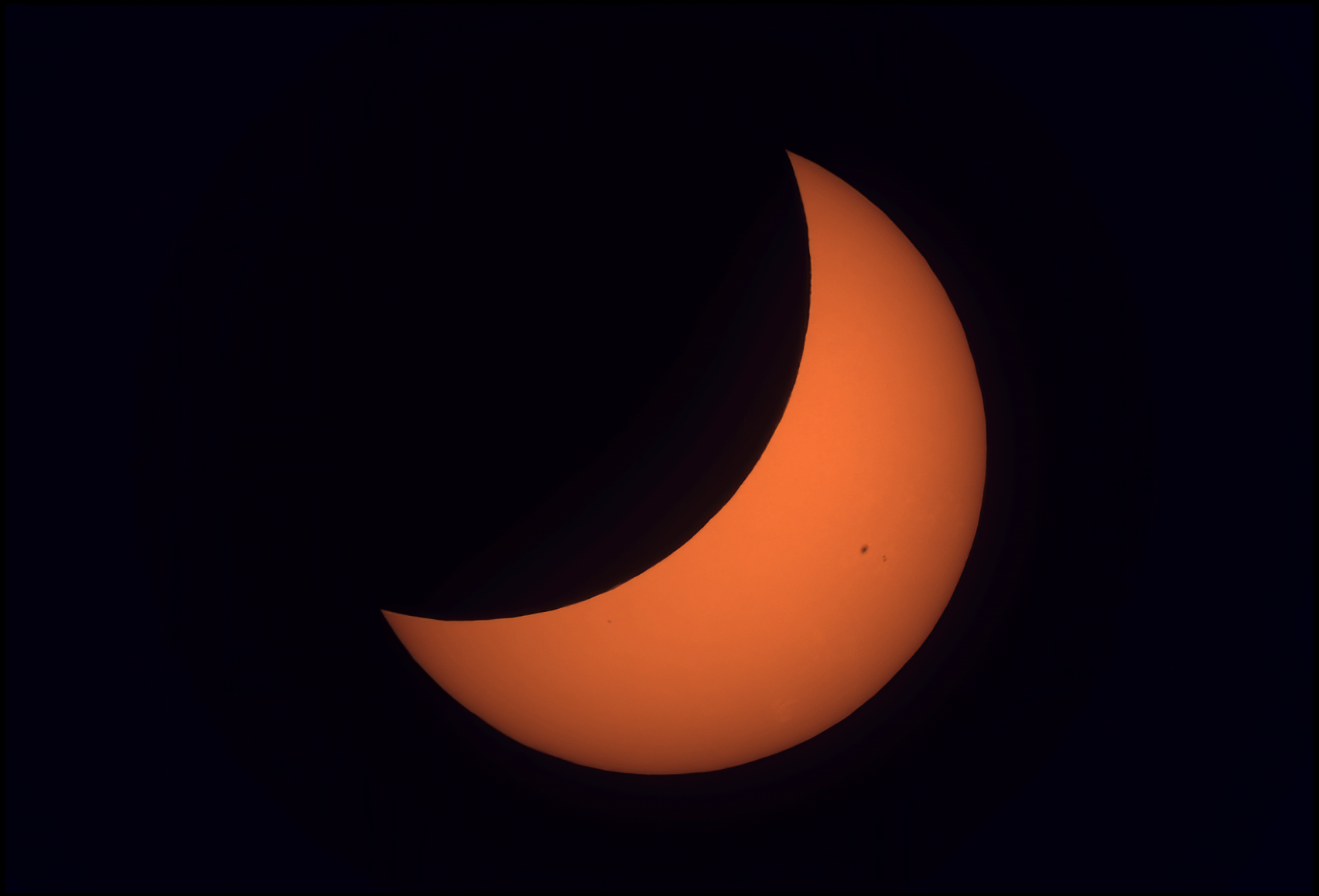


Sun with Sunspots

Aug 13, 2024



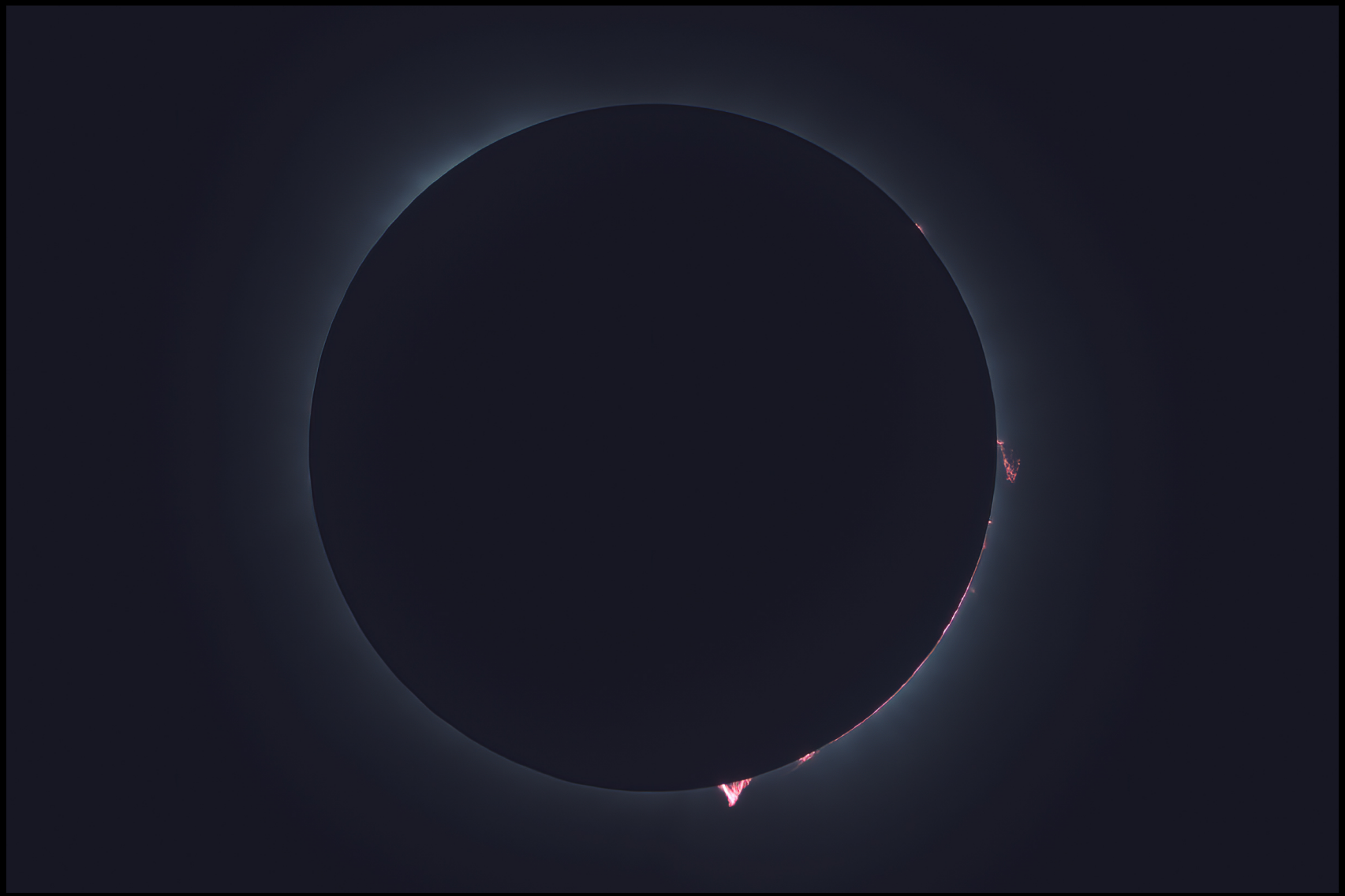
Solar Eclipse: Partial Phases – 2024



Solar Eclipse: Jet Stream

Video taken by Aram Friedman

Solar Eclipse: Totality – 2024



Crescent Moon

Crescent Moon

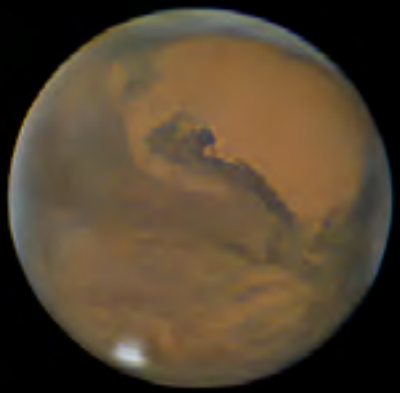
Crescent Moon

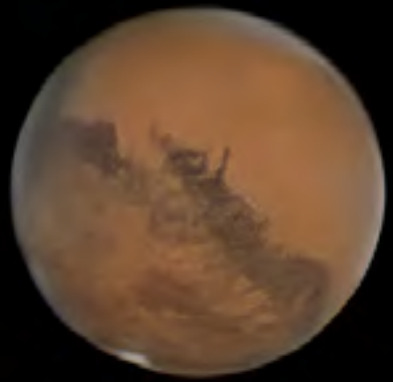
Full Moon

1.2 sec

Mars

Oct. 6 and 18, 2020



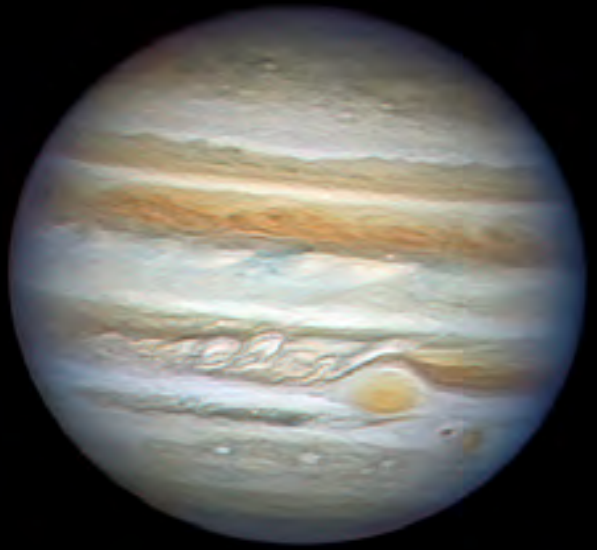


Moon and Mars

Jan. 13, 2025

Jupiter and Saturn

32 and 67 min



Comet 103P / Double Cluster

1.2 min / 7460 and 7640 yrs

Comet 103P / Double Cluster

55 minutes in 10 seconds

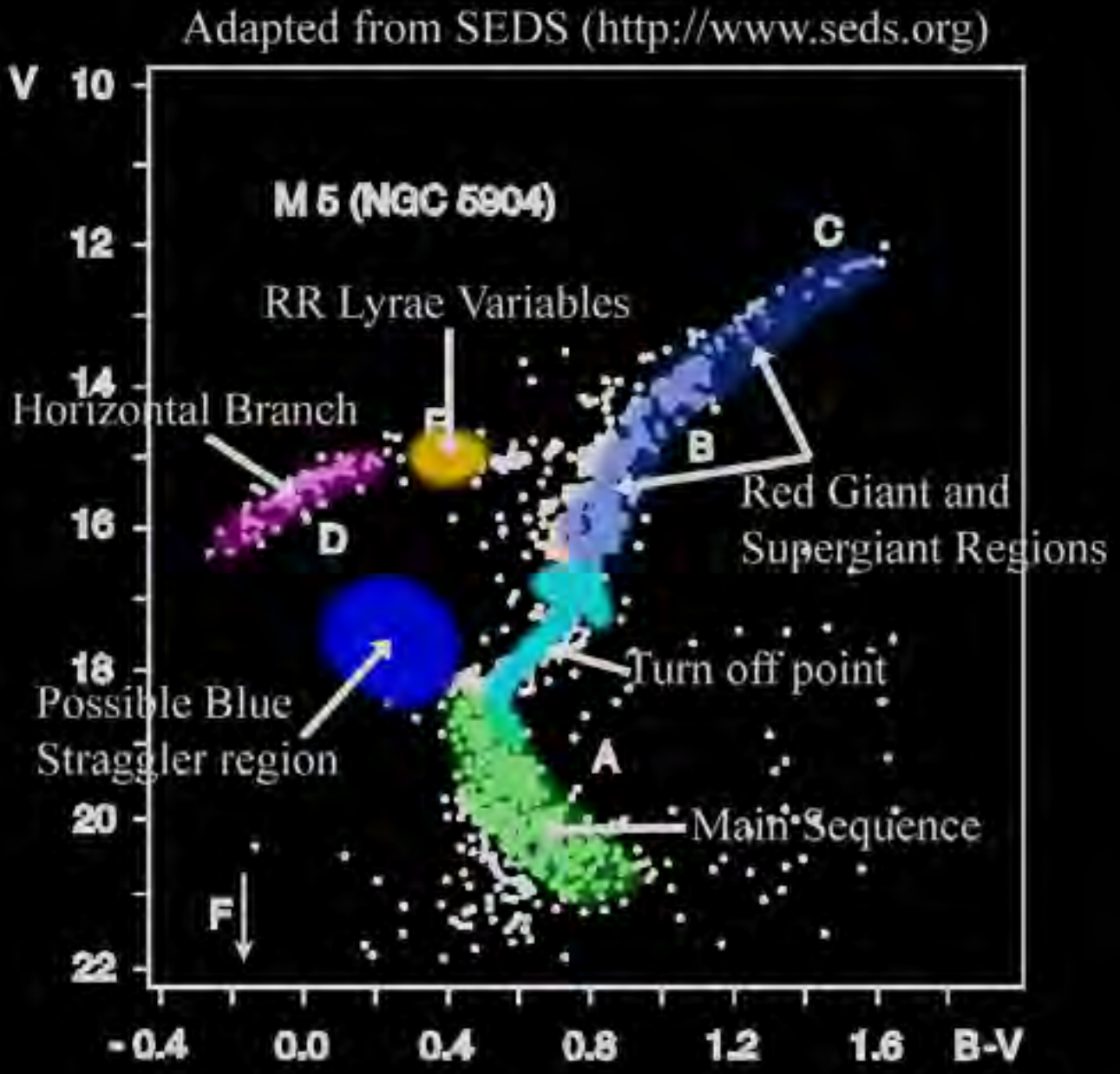
Comet Tsuchinshan 7:17 pm, Oct. 15 2024 4.1 min

Aurora Borealis (aka Northern Lights)

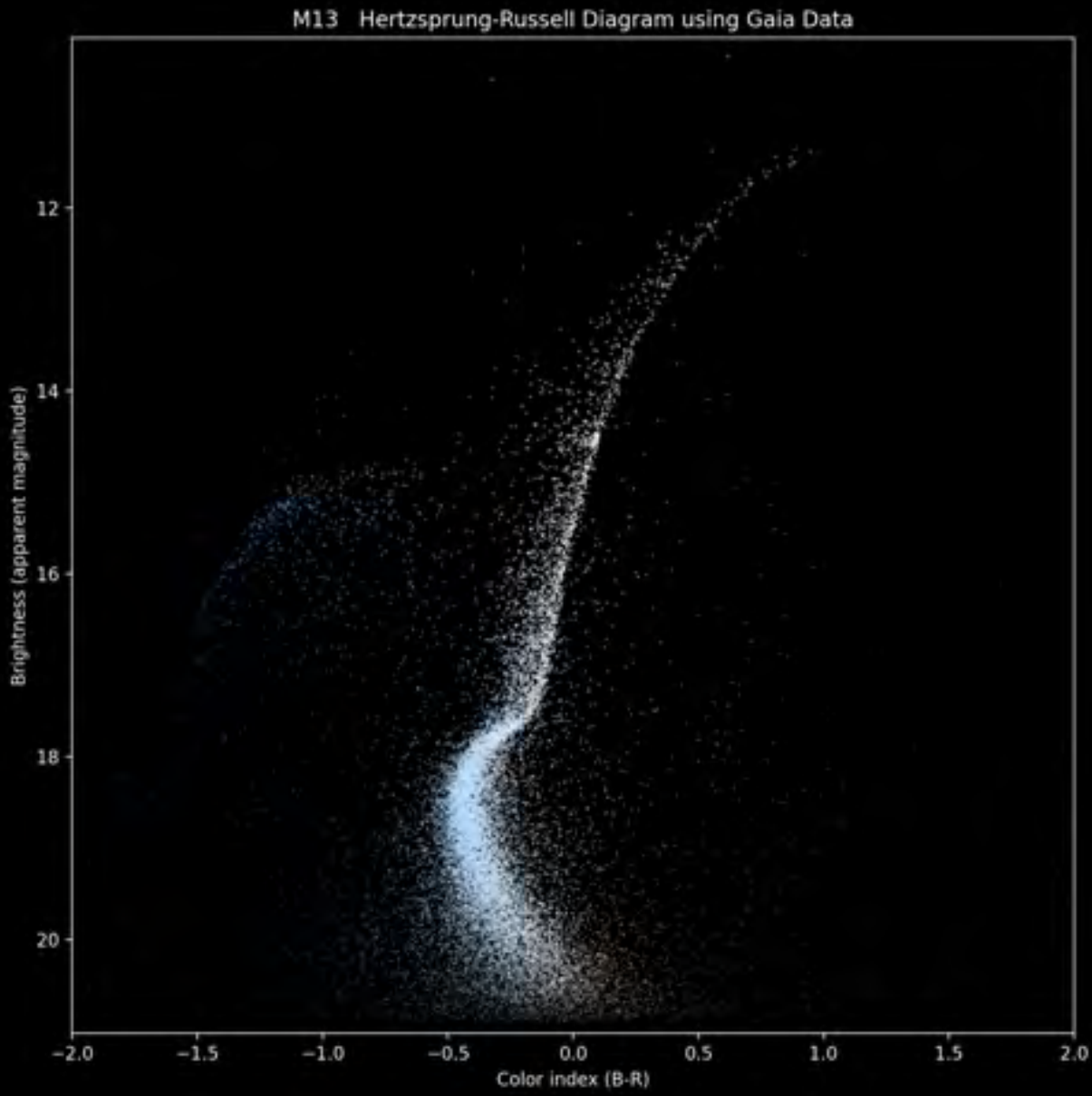
7:20pm, Oct. 11 2024

Looking Out Beyond Our Solar System

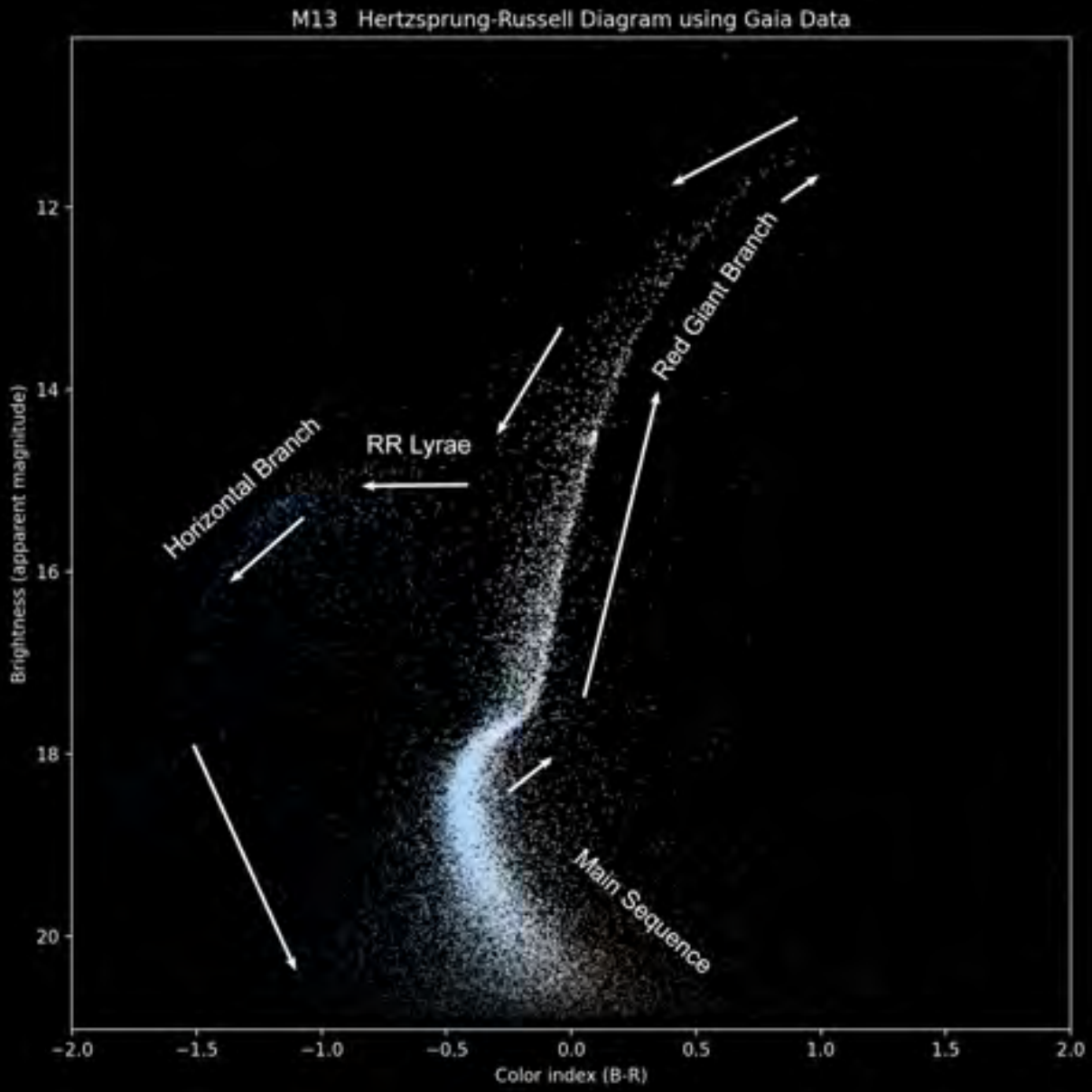
Variable Stars



HR-Diagram Using Gaia Data



HR-Diagram Using Gaia Data

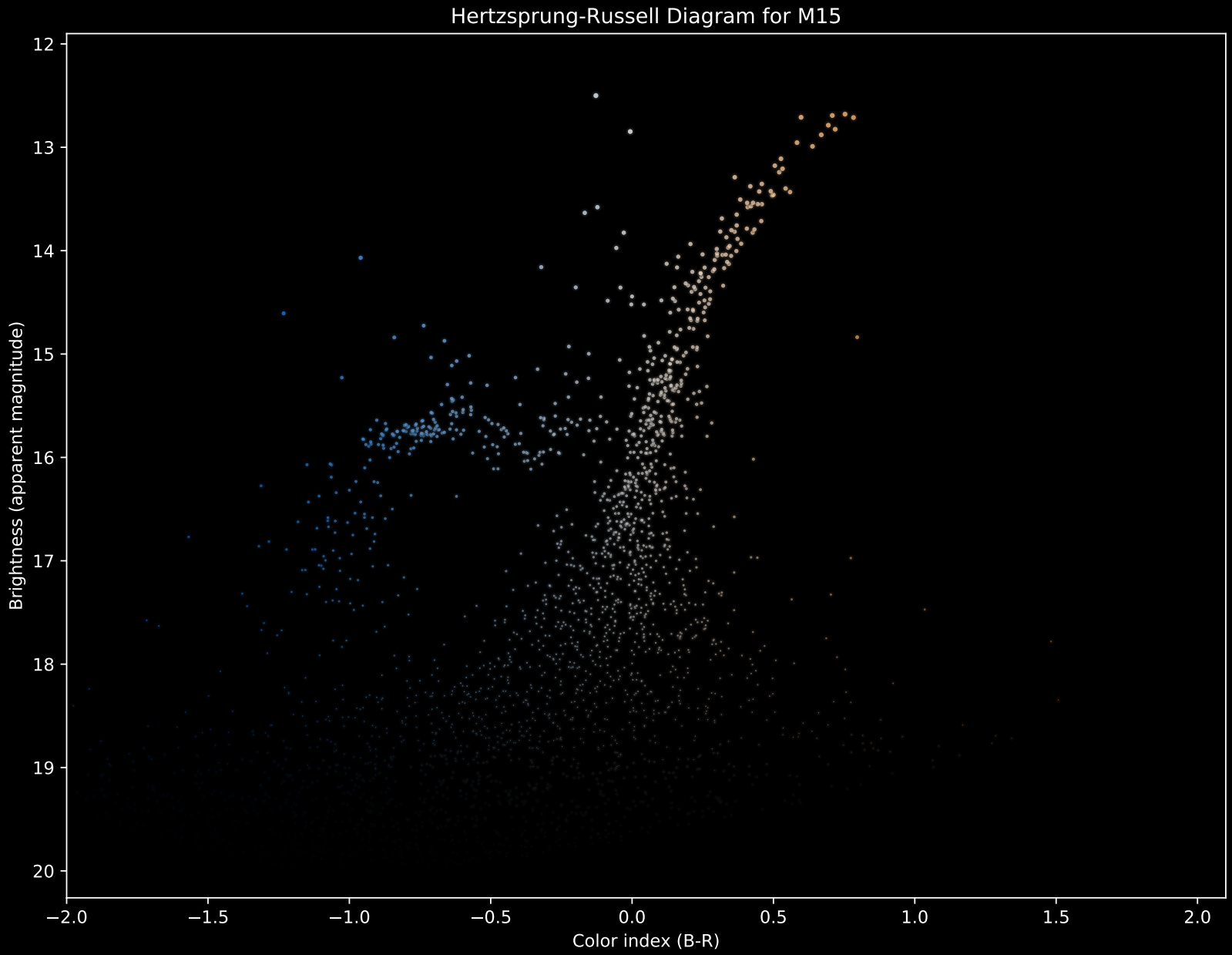


Globular Cluster M15

Click to see it

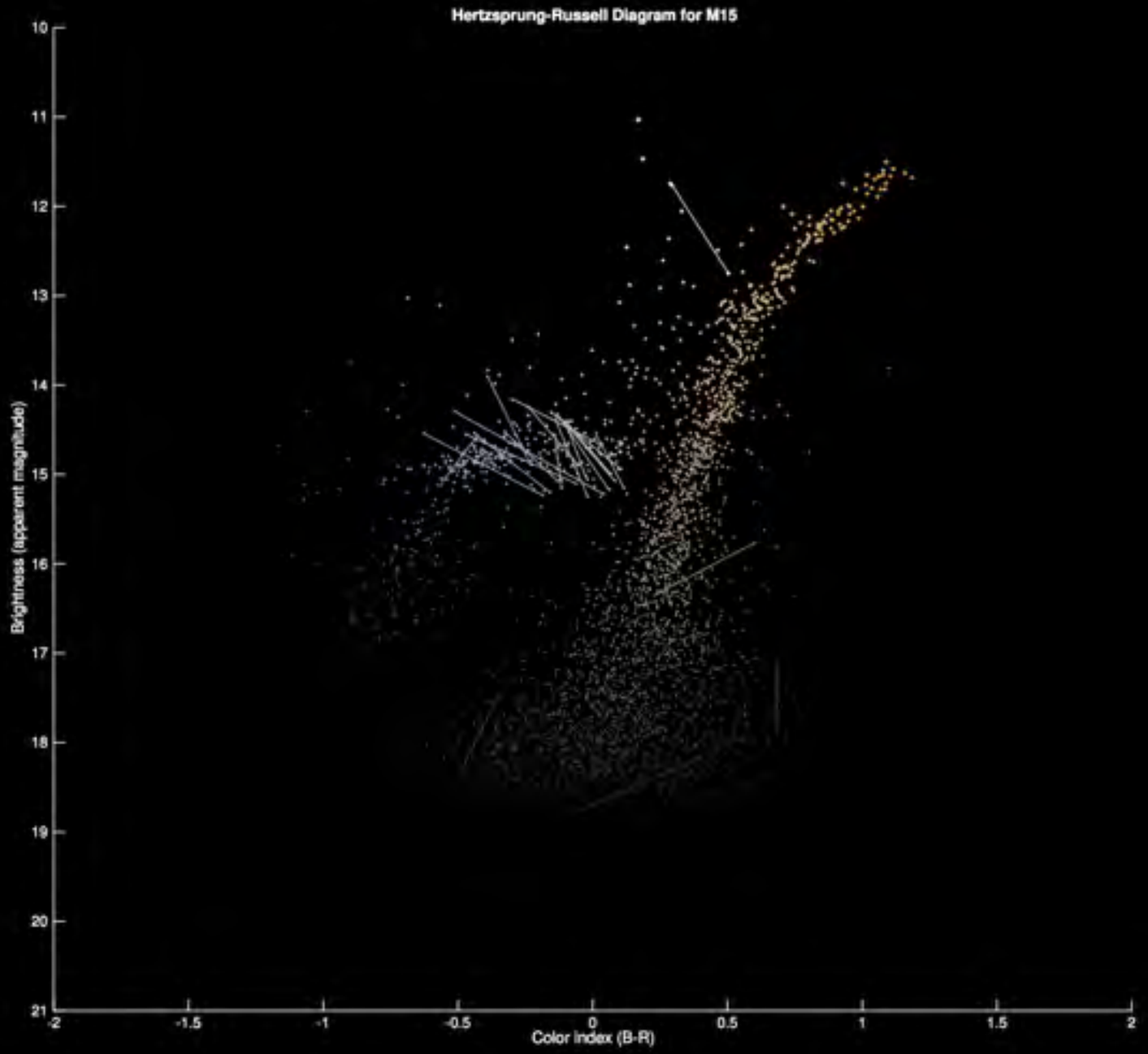
HR-Diagram for M15

Click to see it



HR-Diagram Showing RR-Lyrae Stars

Click to see it



RR-Lyrae distance: 258 parsecs

RR-Lyrae distance: 258 parsecs

Dumbbell Nebula: M27

Dumbbell Nebula: M27

Proper Motion and Parallax

Barnards Star – Click To See Motion

Data from StackImages.py

Date	t (years)	x (pixels)	y (pixels)
2012-06-21	-0.494	758.95	649.41
2013-06-06	0.461	758.24	665.87
2013-09-05	0.715	756.69	669.24
2014-04-10	1.307	758.11	679.03
2014-07-05	1.547	756.82	684.50
2014-10-27	1.844	756.31	690.32

$$x(t) = x_0 + v_x t + a \sin(2\pi t)$$

$$y(t) = y_0 + v_y t + b \cos(2\pi t)$$

- t is time in years
- Unknowns: x_0, v_x, a, y_0, v_y, and b
- 1 pixel = 0.575 arcseconds
- a = parallax
- $\sqrt{{v_x}^2 + {v_y}^2}$ = proper motion
- $\tan^{-1}(b/a)$ = orbital inclination

$$\text{distance} = 1/\text{parallax} = 1.90 \text{ parsec}$$

$$\text{proper motion} = 9.9 \text{ arcsec/yr}$$

Year: 5405

Resume Now

FOV: 90°

Max magnitude: 10.0

Show Constellation Lines Show Star Labels

Stars Moving Over Time

Use the sliders to change year & FOV. Click anywhere in the view to re-center.

Click here to see a stereoscopic 3D rendition.

To change the view point, either type an Object Name (M, NGC, IC, or HD):

Barnards Star

or give a Direction to Look: Select

or enter RA and Dec coordinates

RA: 269.450 , Dec: 4.693

or just click somewhere.

Note: Barnard's Star is being shown as magnitude 1 when in reality it is magnitude 9.5.

Supernovas

Crab Nebula: M1

Oct. 27, 2006

6500 yrs

Crab Nebula: M1

Mar. 26, 2019

6500 yrs

Crab Nebula – Analysis

First picture was taken Oct. 27, 2006.

Crab Nebula – Analysis

First picture was taken Oct. 27, 2006.

Second picture was taken Mar. 26, 2019.

Crab Nebula – Analysis

First picture was taken Oct. 27, 2006.

Second picture was taken Mar. 26, 2019.

The expansion factor is 1.288%. The time interval is 4533 days.

Crab Nebula – Analysis

First picture was taken Oct. 27, 2006.

Second picture was taken Mar. 26, 2019.

The expansion factor is 1.288%. The time interval is 4533 days.

If we denote the expansion factor by x and we assume a constant linear rate of expansion, then the formula for computing the date at which the supernova explosion took place is

$$\text{date} = 2019 - \frac{4533}{365.25}\,\frac{1}{1-\frac{1}{1+x}}$$

Crab Nebula – Analysis

First picture was taken Oct. 27, 2006.

Second picture was taken Mar. 26, 2019.

The expansion factor is 1.288%. The time interval is 4533 days.

If we denote the expansion factor by x and we assume a constant linear rate of expansion, then the formula for computing the date at which the supernova explosion took place is

$$\text{date} = 2019 - \frac{4533}{365.25}\,\frac{1}{1-\frac{1}{1+x}}$$

Putting $x = 0.01288$, we get

$$\text{date} = 1045$$

Crab Nebula – Analysis

First picture was taken Oct. 27, 2006.

Second picture was taken Mar. 26, 2019.

The expansion factor is 1.288%. The time interval is 4533 days.

If we denote the expansion factor by x and we assume a constant linear rate of expansion, then the formula for computing the date at which the supernova explosion took place is

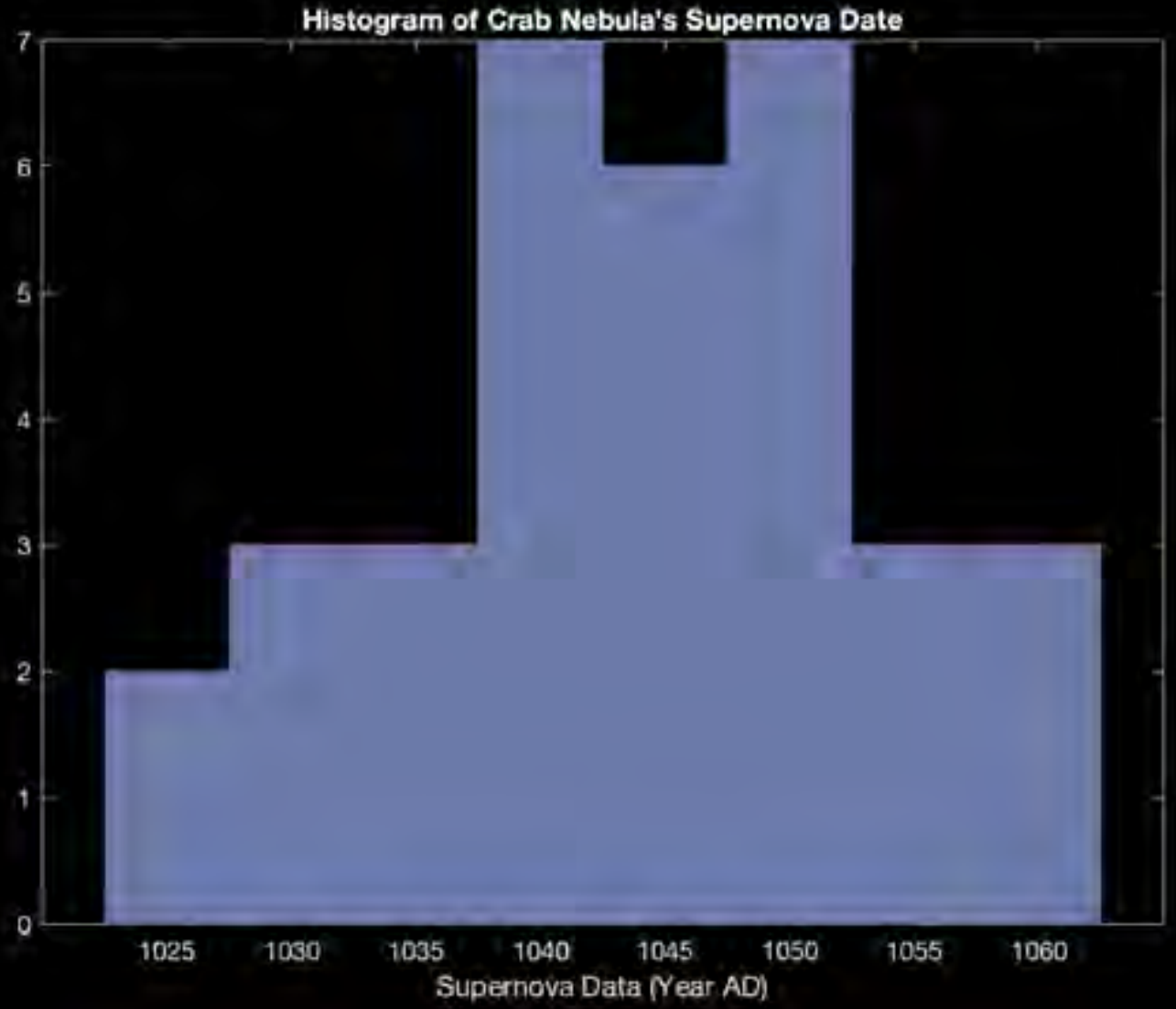
$$\text{date} = 2019 - \frac{4533}{365.25}\,\frac{1}{1-\frac{1}{1+x}}$$

Putting $x = 0.01288$, we get

$$\text{date} = 1045$$

According to the historical record, the supernova took place in the year 1054.

I recomputed the estimate by subsampling the measurements 34 different ways. Here's the histogram showing the range of dates obtained:



The Whirlpool Galaxy: M51

May 9, 2005

The Whirlpool Galaxy: M51

July 10, 2005

The Whirlpool Galaxy: M51

June 7, 2011

The Pinwheel Galaxy: M101

May 25, 2023

The Pinwheel Galaxy: M101

May 25, 2023

No More Dynamics. Just Pictures.

Helix Nebula: NGC 7293

200 yrs

The Pleiades (Subaru): M45

444 yrs

Pacman Nebula: NGC 281

950 yrs

Horsehead Nebula: IC 434

1260 yrs

Orion Nebula: M42

1344 yrs

Running Man Nebula: NGC 1977

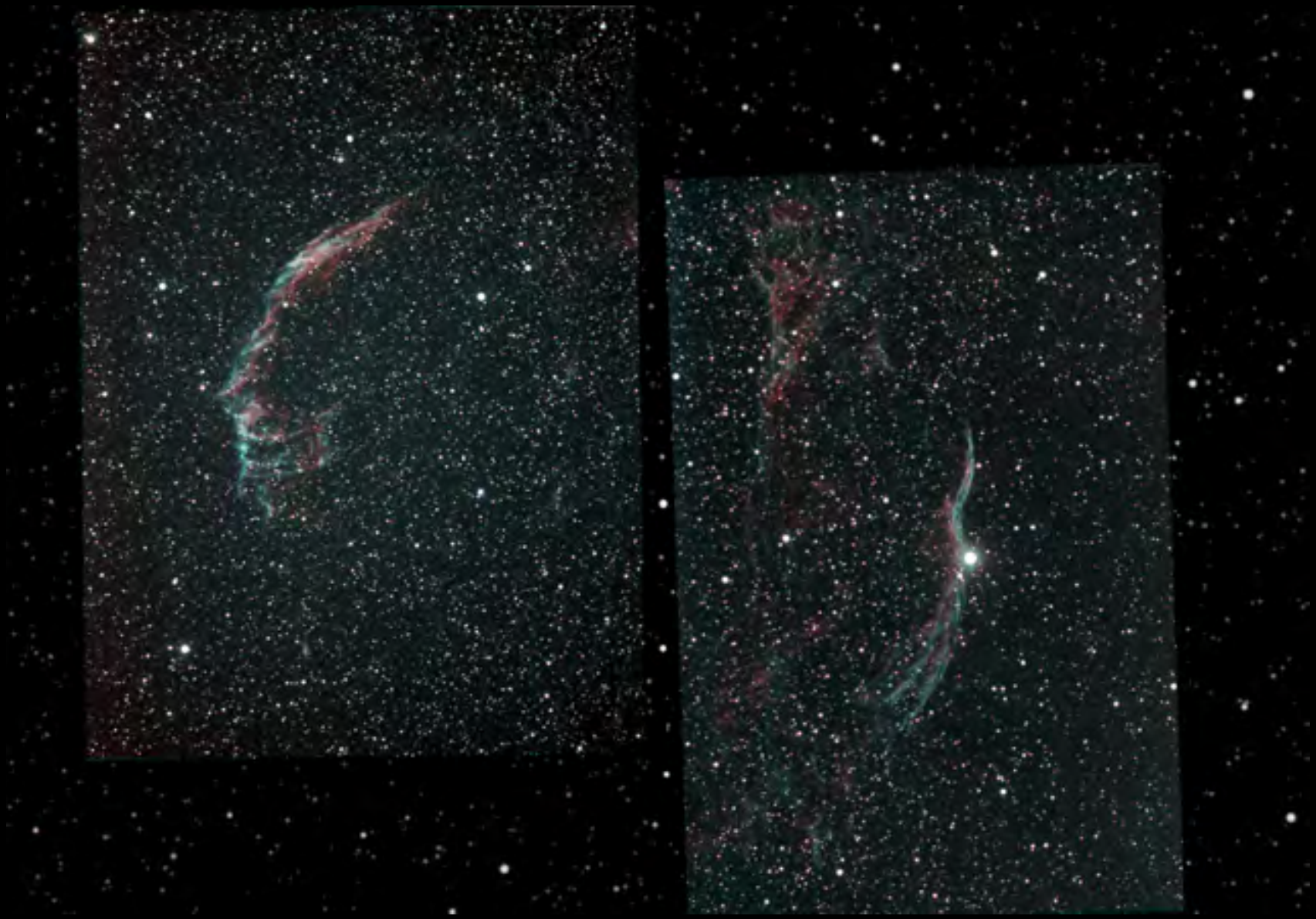
1500 yrs

Crystal Ball Nebula: NGC 1514

1520 yrs

Veil Nebula: NGC 6960 and 6992

2400 yrs



Western Veil: NGC 6960

2400 yrs

Eastern Veil: NGC 6992

Owl Nebula: M97

2400 yrs

Ring Nebula: M57

2567 yrs

The Lagoon Nebula: M8

4100 yrs

Trifid Nebula: M20

4100 yrs

Crescent Nebula: NGC 6888

5000 yrs

Jellyfish Nebula: IC 443

5000 yrs

Rosette Nebula: NGC 2237

5200 yrs

Eagle Nebula: M16

5700 yrs

NGC 6820

6000 yrs

Eskimo Nebula: NGC 2392

6520 yrs

Bubble Nebula: NGC 7635

9100 $\pm$ 2000 yrs

Globular Cluster: M13

22200 yrs

Looking Out Beyond Our Milky Way

The Andromeda Galaxy: M31

2450000 yrs

Sombrero Galaxy: M104

9600000 yrs

M81 and M82

11800000 yrs

Cigar Galaxy: M82

12000000 yrs

Galaxy Cluster: M106

24000000 yrs

The Leo Trio: M65, M66, NGC 3628

32000000 yrs

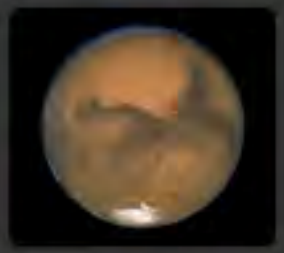
The Needle Galaxy: NGC 4565

42700000 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?