National Aeronautics and Space Administration

The Heliophysics Big Year

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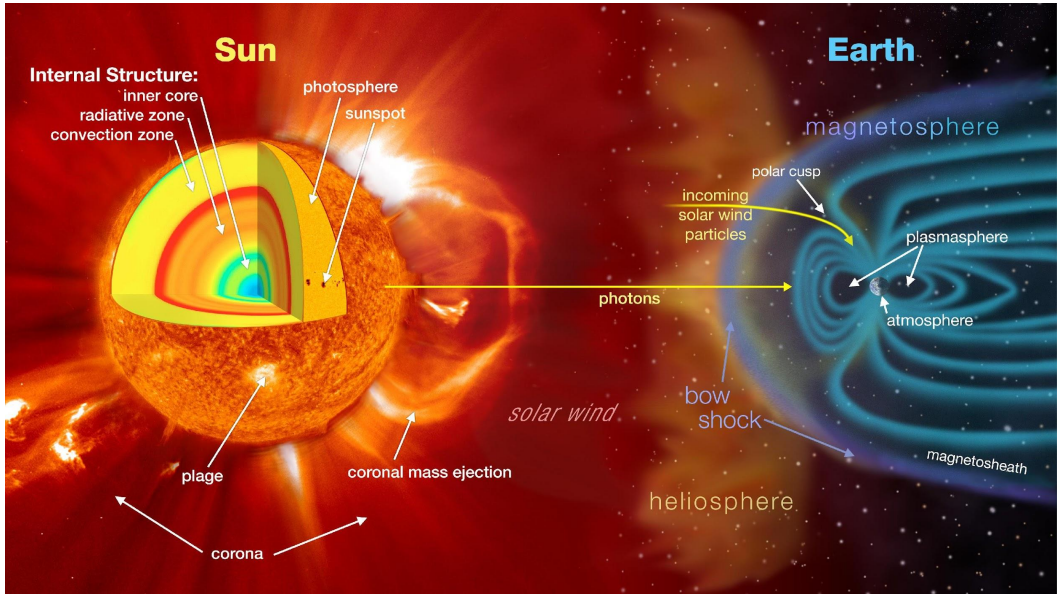
NASA Heliophysics Education Activation Team

July 2024: What is Heliophysics?

Heliophysics is the discipline in space science that deals with the matter and energy of our Sun and its effects on the solar system.

It also studies how the Sun varies and how those changes pose a hazard to humans on Earth and in space



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Heliophysics Big Year Timeline

Annular Eclipse

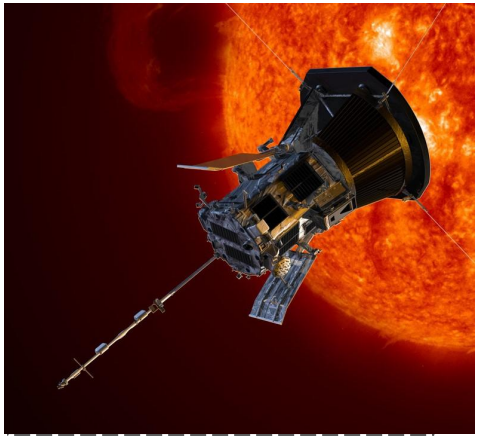
October 14, 2023

Total Eclipse

April 8, 2024

Solar Parker Probe Perihelion

December 24, 2024



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Heliophysics Big Year Themes

2023

- ☑ **October-** Annular Solar Eclipse
- ☑ **November-** Mission Fleet
- ☑ **December-** Citizen Science

2024

- ☑ **January-** The Sun Touches Everything
- ☑ **February-** Fashion
- ☑ **March-** Experiencing the Sun
- ☑ **April-** Total Solar Eclipse
- ☑ **May-** Visual Art
- ☑ **June-** Performance Art
- ☑ **July-** Physical and Mental Health
- **August-** Back to School
- **September-** Environment / Sustainability
- **November-** Bonus Science
- **December-** Parker's Perihelion

https://www.nasa.gov/science-research/heliophysics/nasa-announces-monthly-themes-to-celebrate-the-heliophysics-big-year/

August 2024 : NASA's Big Questions

1. What causes the Sun to vary?
2. How do the Earth and the heliosphere respond?
3. What are the impacts on humanity?

These Big Questions form the basis for the

Framework for Heliophysics Education

https://science.nasa.gov/learn/heat/big-ideas/

How to Teach Heliophysics

Framework for Heliophysics Education

3 Heliophysics Investigatory Questions

↓

3 NGSS-aligned Big Ideas per Question

↓

3 Guiding Questions per Idea
-1 Question per Level-

↓

Heliophysics Resource Database

1. What causes the Sun to vary?

1.1 The Sun is really big and its gravity influences all objects in the solar system. (PS2, ESS1)
1.2 The Sun is active and can impact technology on Earth via space weather. (PS1,PS2, PS4, ESS2, ESS3)
1.3 The Sun's energy drives Earth's climate, but the climate is in a delicate balance and is changing due to human activity. (PS1, PS2, PS3, LS4, ESS2, ESS3)

2. How do Earth, the solar system, and the heliosphere respond to changes on the Sun?

2.1 Life on Earth has evolved with complex diversity because of our location near the Sun. It is just right! (PS3, PS4, LS1, LS2, ESS2)
2.2 The Sun defines the space around it, which is different from interstellar space. (PS2, ESS1, ESS2)
2.3 The Sun is the primary source of light in the solar system. (PS1, PS2, PS3,PS4, ESS1)

3. What are the impacts of changes on the Sun on humans?

3.1 The Sun is made of churning plasma, causing the surface to be made of complex, tangled magnetic fields. (PS1, PS2, ESS1, ESS2)
3.2 Energy from the Sun is created in the core and travels outward through the Sun and into the heliosphere. (PS1, PS3, PS4, ESS1, ESS2, ESS3)
3.3 Our Sun, like all stars, has a life cycle. (PS1, LS1, ESS1)

August 2024: Back to School

Many things are controlled by cycles, such as every September we start a new school year.

There is also the ‘Cycle of Life’ that begins at birth and ends at death.

This month we will explore our sun’s life cycle and how Today’s Sun is different from yesterday’s and tomorrow’s.

https://sciencephotogallery.com/featured/life-cycle-of-the-sun-mark-garlickscience-photo-library.html

August 2024 – Beginning – Cloud Collapse

A proto-stellar nebula has a radius of 1 light year (6 trillion km).

If the infall speed is 0.5 km/sec, about

how long will it take for the star to form?

https://keystagewiki.com/index.php/File:Protostar.png#mw-jump-to-license

August 2024 – Beginning – Cloud Collapse

Distance = 1 light year

Speed = 0.5 km/s

Time = Distance/speed

Time = $6x10^{12}$ km/(0.5 km/s)

Time = $1.2x10^{13}$ seconds

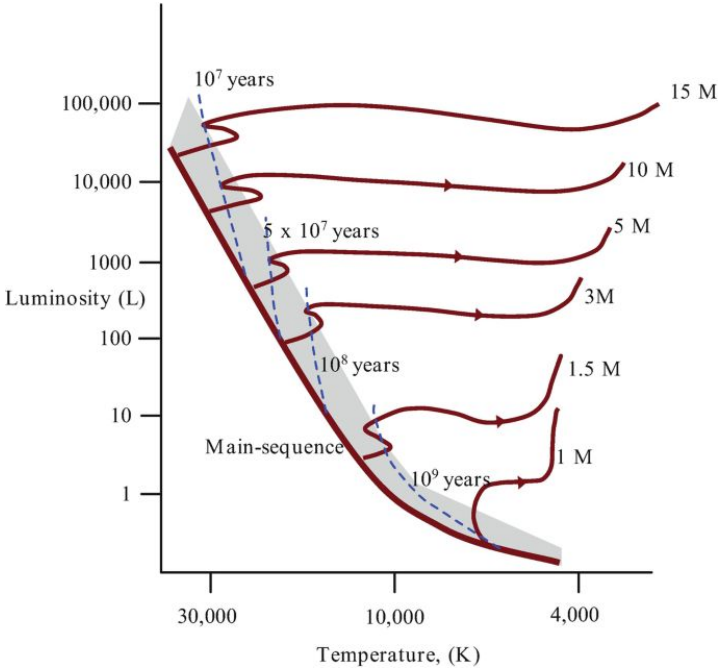
Time = 400,000 years.

https://keystagewiki.com/index.php/File:Protostar.png#mw-jump-to-license

August 2024 – Intermediate – The Main Sequence

The star is now stable and is fusing hydrogen into helium to maintain internal pressure and prevent further collapse. This is the longest phase of a star's life cycle. The duration of this phase is given by the simple formula

$$T = 10 \text{ billion years} \times \frac{1}{\text{Mass}^{2.5}}$$



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August 2024 – Intermediate – The Main Sequence

Compare the lifetimes of three stars:

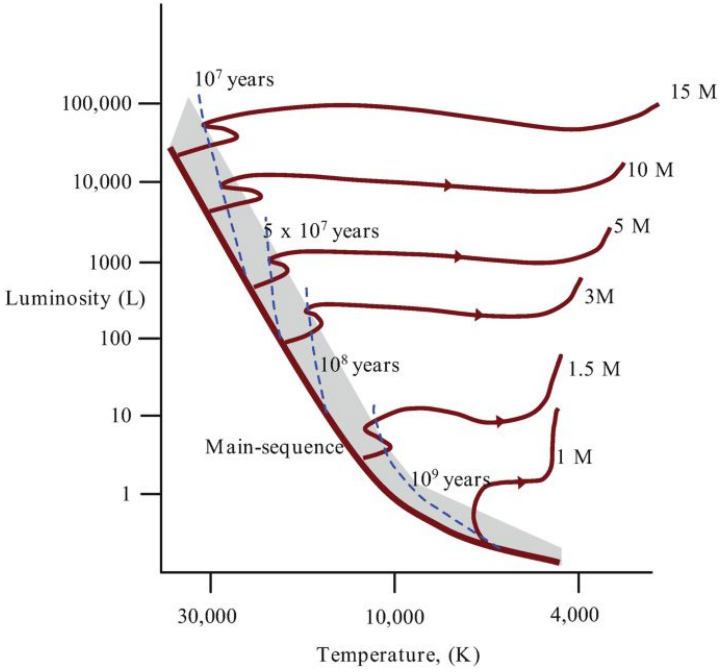
Proxima Centauri M = 0.1 msun Red Dwarf

The Sun M = 1.0 msun Main Sequence

Betelgeuse M = 20 msun Red Supergiant

Which star is the most likely to vanish tomorrow?

$$T = 10 \text{ billion years} \times \frac{1}{\text{Mass}^{2.5}}$$



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August 2024 – Intermediate – The Main Sequence

Proxima Centauri M = 0.1 msun

T = 10 billion / $(0.1)^{2.5}$ = 3 trillion years.

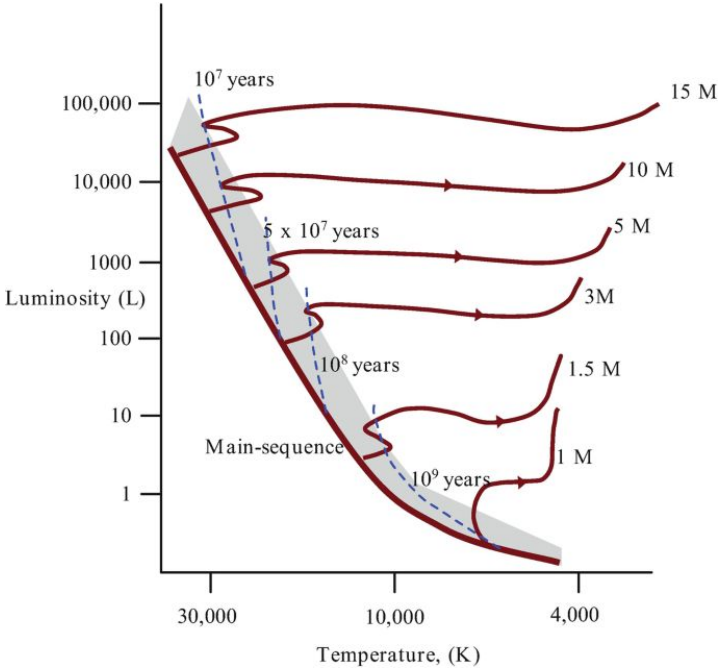
The Sun M = 1.0 msun

T = 10billion / $(1)^{2.5}$ = 10 billion years

Betelgeuse M = 20 msun

T = 10billion / $(20)^{2.5}$ = 1.8 billion years.

Which star is the most likely to vanish tomorrow? Probably Betelgeuse.



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August 2024 – Advanced – Stellar Remnants

What is left behind after a star ‘dies’ depends on its mass.

Stars like our sun:

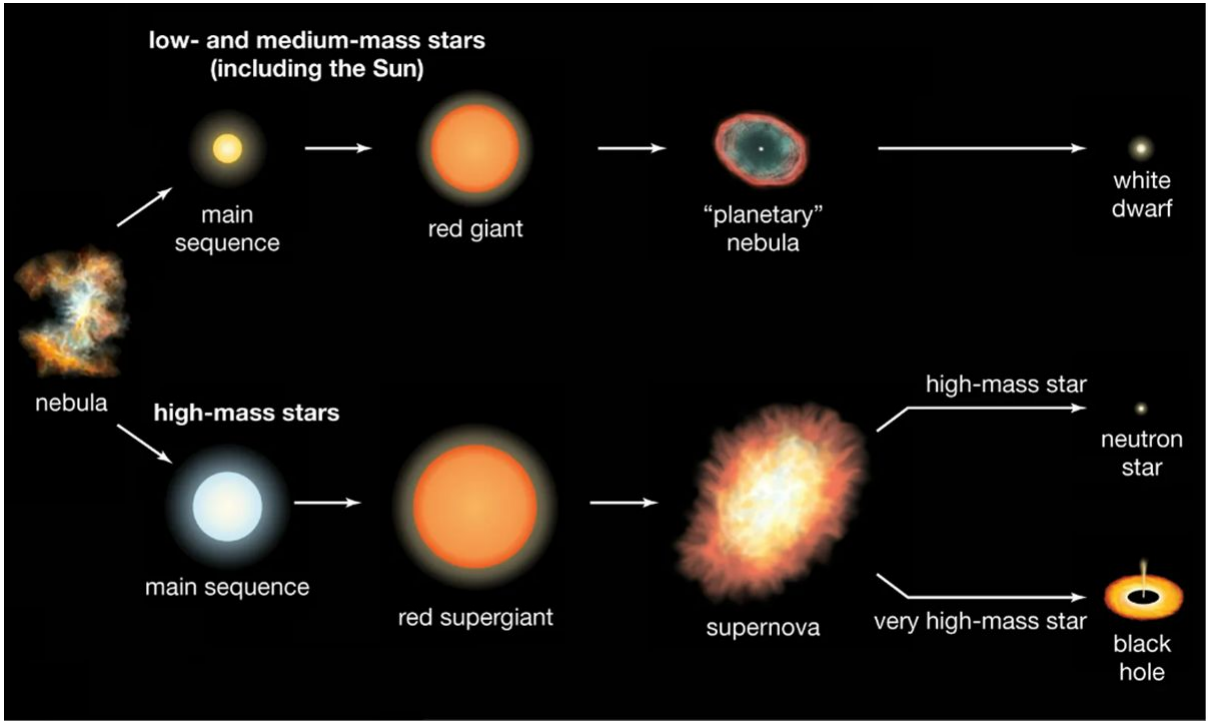
0.1 to 5 suns = **White Dwarfs**

Stars with intermediate masses:

6-20 suns = **Neutron Stars**

Stars with high masses:

> 20 suns = **Black Holes**.



https://explainingscience.org/2023/05/07/the-end-of-the-universe/

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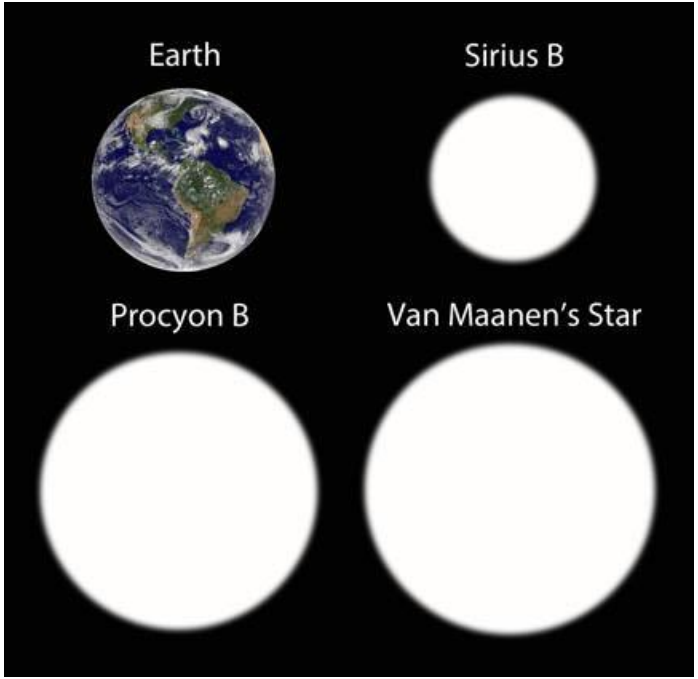
August 2024 – Advanced – Stellar Remnants

A **white dwarf** has a size comparable to Earth (radius: 6000km) with a mass equal to our sun ($2x10^{30}$ kg).

What is its density?

How much would a 1cm sugar cube weigh in tons?



Bob King; Earth photo: NASA

August 2024 – Advanced – Stellar Remnants

A **Neutron Star** has a radius of 12 km with a mass equal to our sun ($2x10^{30}$ kg).

What is its density?

How much would a 1cm sugar cube weigh in tons?

Credit: NASA

August 2024 – Advanced – Stellar Remnants

A **Neutron Star** has a size of 12 km with a mass equal to our sun ($2x10^{30}$ kg).

What is its density?

How much would a 1cm sugar cube weigh in tons?

Density of an atomic nucleus is

$2x10^{17}$ kg/m^3.

Volume = $4/3\pi\ (12000)^3 = 7x10^{12}$ m^3

Density = Mass/Volume
= $2x10^{30}$ kg/ $7x10^{12}$ m^3
= $3x10^{17}$ kg/m^3
= 300,000 trillion tons/m^3

Volume = $(1cm/100cm)^3 = 10^{-6}$ m^3.

Mass = $3x10^{17}$ tons/m^3 x 10^{-6} m^3
= 300 billion tons.

August 2024 – Advanced – Stellar Remnants

A **Black Hole** has a size that depends on its mass in multiples of the mass of our sun.

This size is defined by its Event Horizon.

Radius (km) = 2.8 x Mass

What is the Event Horizon radius for a 20-solar mass black hole?

August 2024 – Advanced – Stellar Remnants

Radius (km) = 2.8 x Mass

What is the Event Horizon radius for a 20-solar mass black hole?

Radius = 2.8 x 20 = 5.6 km

August 2024 – Advanced – Stellar Remnants

If Earth became a black hole, what would be its radius?

M = 3×10^{-6} msun

Radius (km) = 2.8 x (3×10^{-6})

= 8.4×10^{-6} km

= 8.4 millimeters

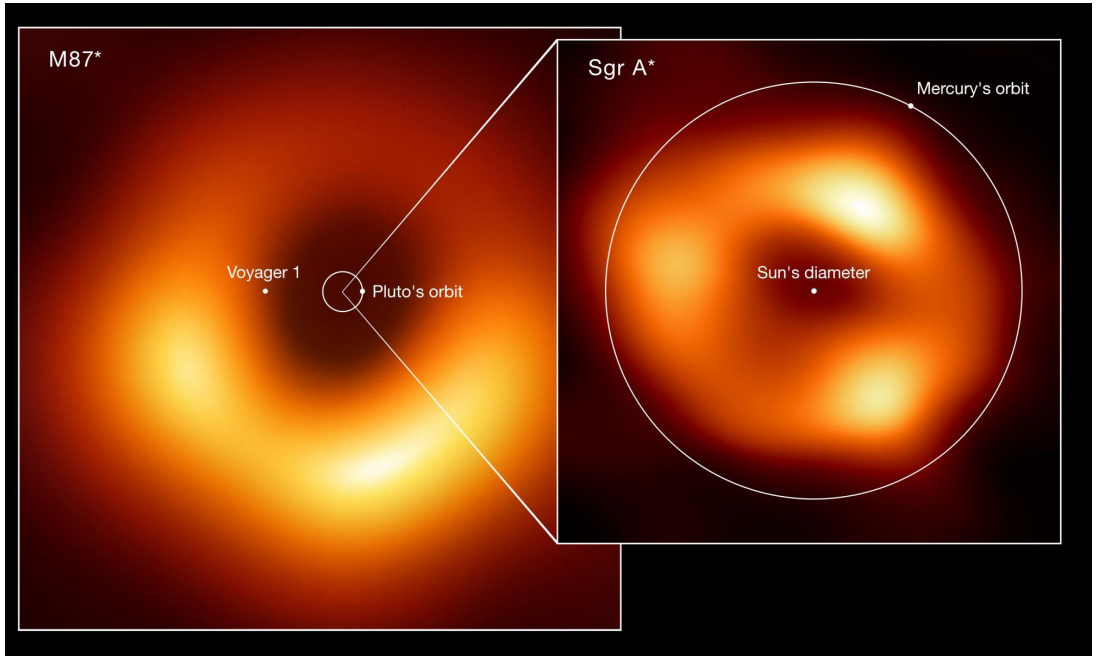
August 2024 – Advanced – Supermassive Remnants

What is the radius of a **supermassive black hole** with a mass of 10 billion suns, like the one in the core of the galaxy Messier 87?

R = 2.8 x 10 billion = 28 billion km

Orbit of Pluto: 5.2 billion km.

M87 would easily swallow our entire solar system.



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September 2024 – Environment and Sustainability

Next Time!

The Sun is a powerful source of energy. In modern times, we now rely on the Sun to produce electricity.

To make this work, we use solar panels to convert sunlight into electricity.

Slides and Recordings

Slides: https://rb.gy/qsgmbr

Previous webinar recordings
https://www.youtube.com/watch?v=lwf8Y_fOOIs&list=PL5mpEj48YwXntxhPvZBgJn0ZG5MRm4UlS