



The Heliophysics Big Year

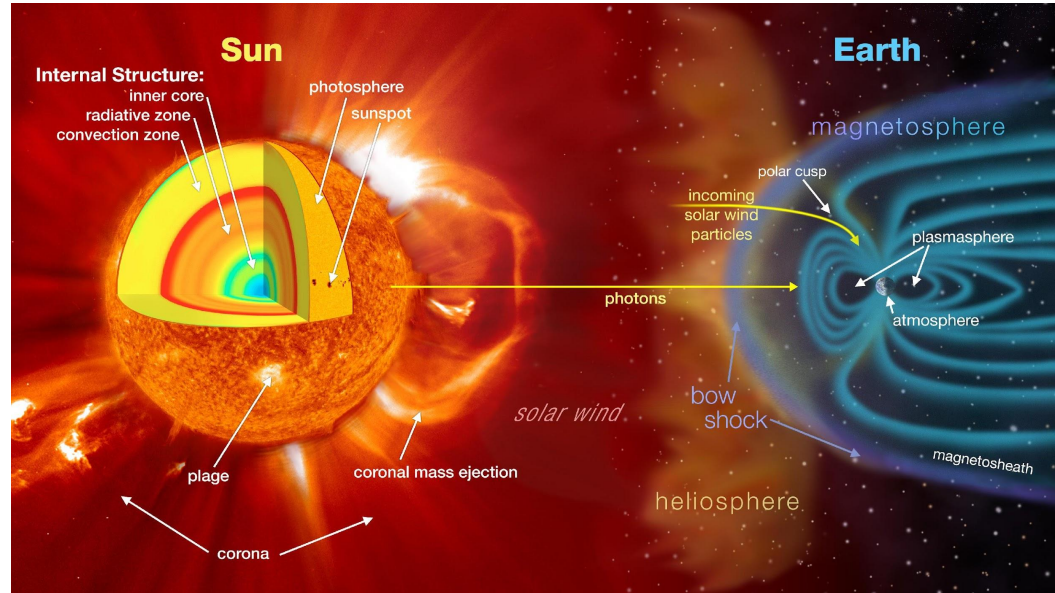
Dr. Sten Odenwald, Astronomer



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 over time and how those changes can sometimes pose a hazard to humans on Earth and in space.



Heliophysics Big Year Timeline

Annular Eclipse

October 14, 2023



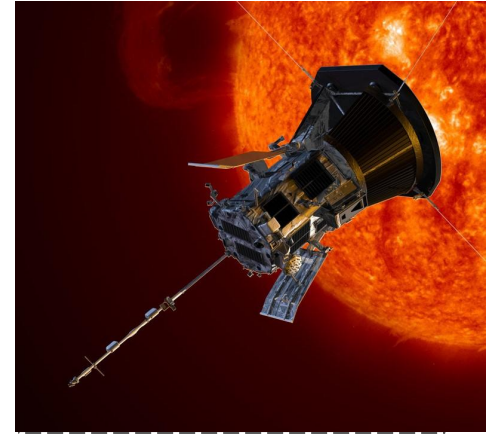
Total Eclipse

April 8, 2024



**Solar Parker
Probe Perihelion**

December 24, 2024



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/>

July 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)

1. 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)

1. 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)

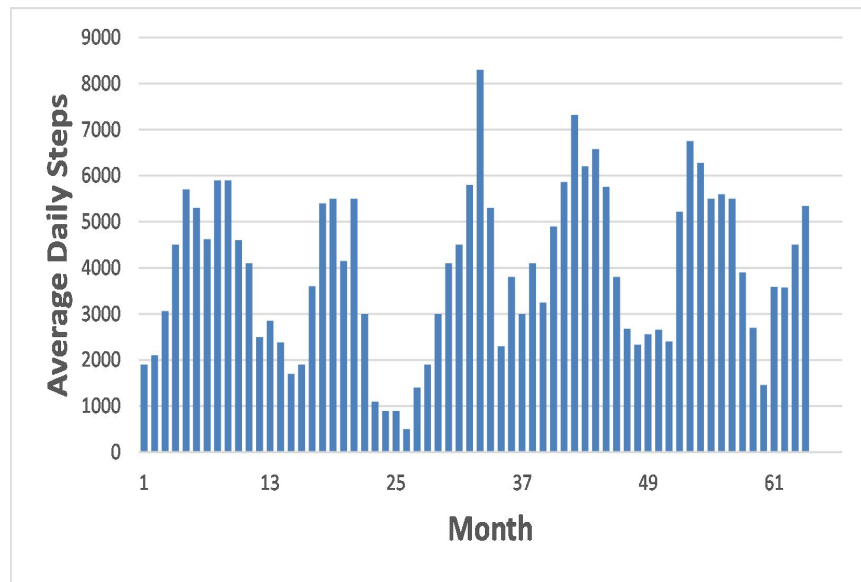
3.3 Our Sun, like all stars, has a life cycle. (PS1, LS1, ESS1)

July 2024: Physical and Mental Health

We are all familiar with the idea of accumulating 10,000 steps each day to keep active. This level of fitness wards off many different physical and even mental illnesses.

Curiously, there is no evidence that 10,000 is a magic number. It was actually invented in Japan as part of a marketing ploy and 10,000 was literally pulled out of a hat because in Japanese the word for '10,000' rhymed with some other word used in a marketing slogan.

Still, it is better to take 'a lot of steps' rather than to be inactive.



Dr. Odenwald's average daily steps

July 2024 – Beginning – Steps and Time

If you average 5000 steps a day, and each step takes about 1 second, how much time do you spend walking?



Wikipedia – Don DeBold

July 2024 – Beginning – Steps and Time

If you average 5000 steps a day, and each step takes about 1 second, how much time do you spend walking?

$$\begin{aligned} & 5000 \text{ steps/day} \times 1 \text{ second/step} \\ &= 5000 \text{ seconds/day} \\ &= 5000 \text{ seconds} / (3600 \text{ seconds/hr}) \\ &= 1.39 \text{ hours/day} \\ &= 1:23:17 \end{aligned}$$

Some weekend, use the Health app to track your daily steps. How are you doing?



July 2024 – Beginning – Steps and Time

If each step takes about 1 second, and each step is about 24-inches (0.7 meters) how long will it take you to walk to the sun?

Distance to sun = 150 million km.



Wikipedia – Jessie Eastland

July 2024 – Beginning – Steps and Time

1 step = 0.7meter

1 km = 1000 meters

Steps to the sun =

$(150 \text{ million km} \times 1000\text{m}/1\text{km})/0.7\text{m}$

= **214 billion steps**

1 step = 1 second

Time = 214 billion steps x 1 sec/1 step

Time = 214 billion seconds

Time = 2.5 million days

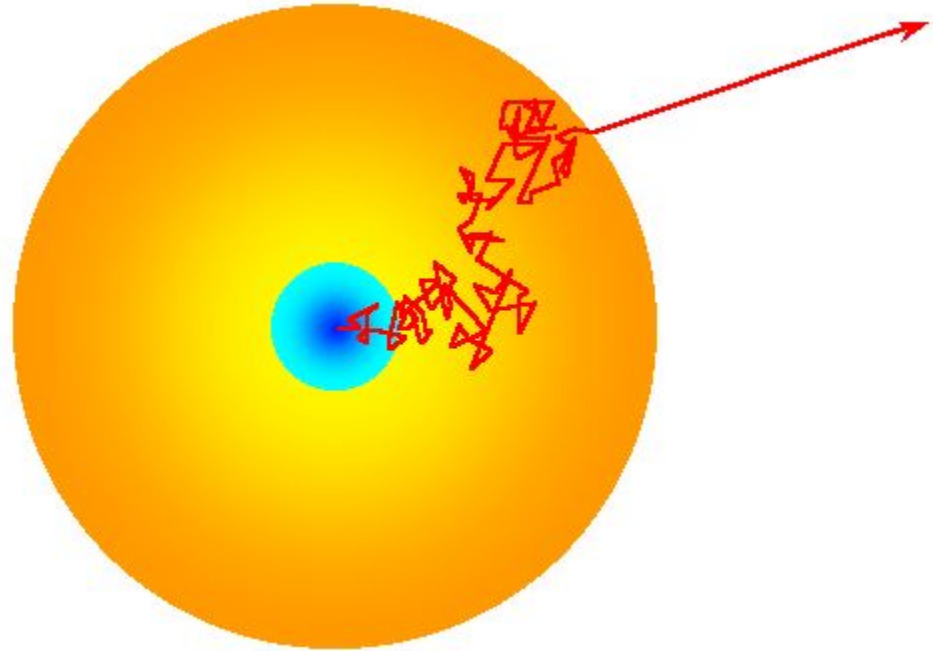
Time = 6,800 years



Wikipedia – Selmane Cherifi

July 2024 – Intermediate – Random Walk

For light to leave the interior of the sun, it does not take a direct route but performs what is called a random walk. A photon scatters from one atom to the next traveling at the speed of light and losing energy along the way.



July 2024 – Intermediate – Random Walk

Mathematically we can model this process.

On a 2-d grid, start at the Origin.

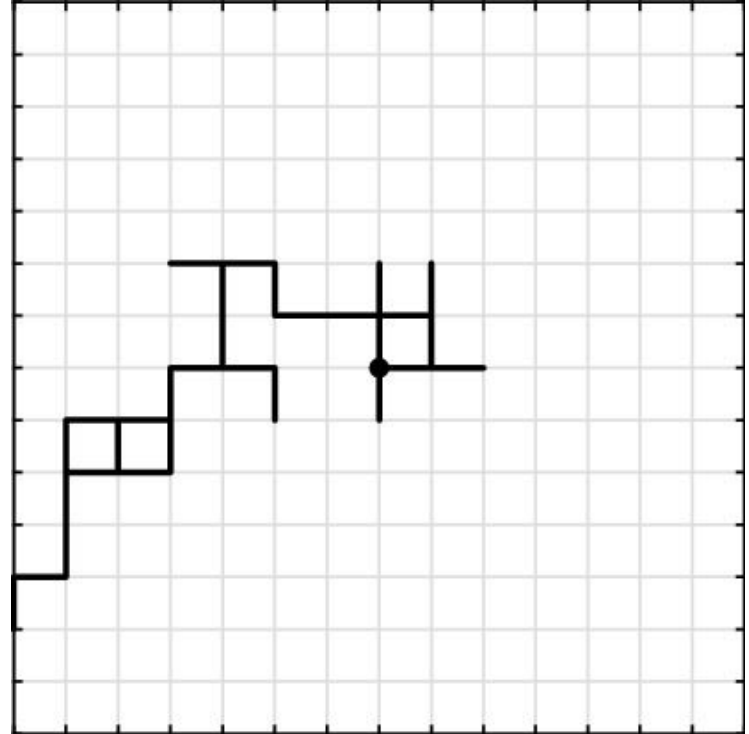
Toss a coin twice.

Toss 1: If heads, you will move along the X axis. If tails you will move along the Y-axis.

Toss 2: Tells you if you will take a step forwards (heads) or backwards (tails) or up(heads) or down(tails).

Mark your path after each step. Repeat this process about ten times and see where you wind up on the grid.

How far from the origin 'as the crow flies' did you get on the last step?



July 2024 – Intermediate – Random Walk

Use ChatGPT as a simulator.

Enter the query

“In 2-D, perform a Random Walk simulation and calculate the distance traveled after 16 steps if each step is 1.0 units.”

Repeat the query for 25 steps, 100 steps, 625 steps, 1000 steps, 5000 steps and 10,000 steps. Note the distance each time.



ChatGPT

Let's perform a 2D random walk simulation with 5000 steps, where each step is 1.0 unit, and calculate the distance traveled. The process involves:

1. **Initialization:** Start the point at the origin (0, 0).
2. **Random Walk Simulation:** For each of the 5000 steps, randomly choose a direction (up, down, left, or right) with equal probability and move the point one unit in that direction.
3. **Final Position:** Calculate the final coordinates of the point after all 5000 steps.
4. **Distance Calculation:** Calculate the Euclidean distance from the origin (0, 0) to the final position.

Let's run the simulation and calculate the distance traveled after 5000 steps in the 2D random walk.

After 5000 steps in the 2D random walk, the final position of the point is at coordinates (45, -47).

The distance traveled from the origin (0, 0) to the final position is approximately 65.07 units. [↩]

July 2024 – Intermediate – Random Walk

Create a model in which the distance traveled is given by the formula

$$\text{Distance} = \text{Step} \times \sqrt{N}$$

How do the simulations compare to the mathematical model?

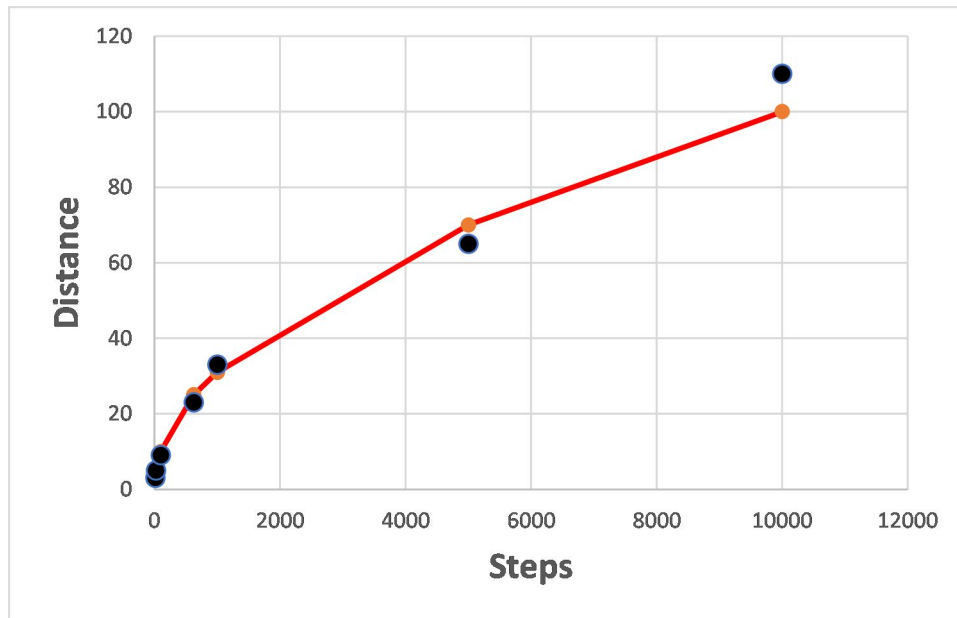
Steps	ChatGPT	Model
16	3	4
25	5	5
100	9	10
625	23	25
1000	33	31
5000	65	70
10000	110	100

July 2024 – Intermediate – Random Walk

Create a model in which the distance traveled is given by the formula

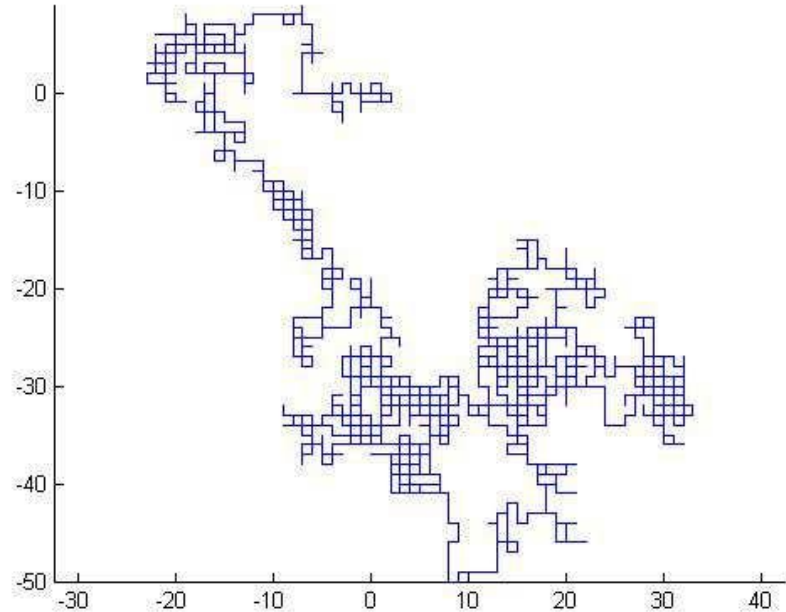
$$\text{Distance} = \text{Step} \times \sqrt{N}$$

How do the simulations compare to the mathematical model?



July 2024 – Intermediate – Random Walk

If you take a 0.7-meter step, how many steps will it take you to travel 1 mile from where you started?



July 2024 – Intermediate – Random Walk

If you take a 0.7-meter step, how many steps will it take you to travel 1 km from where you started?

$$D = 0.7 \times \sqrt{N}$$

$$N = (D/0.7)^2$$

$$\text{Time} = 1\text{sec/step}$$

$$N = (1000/0.7)^2$$

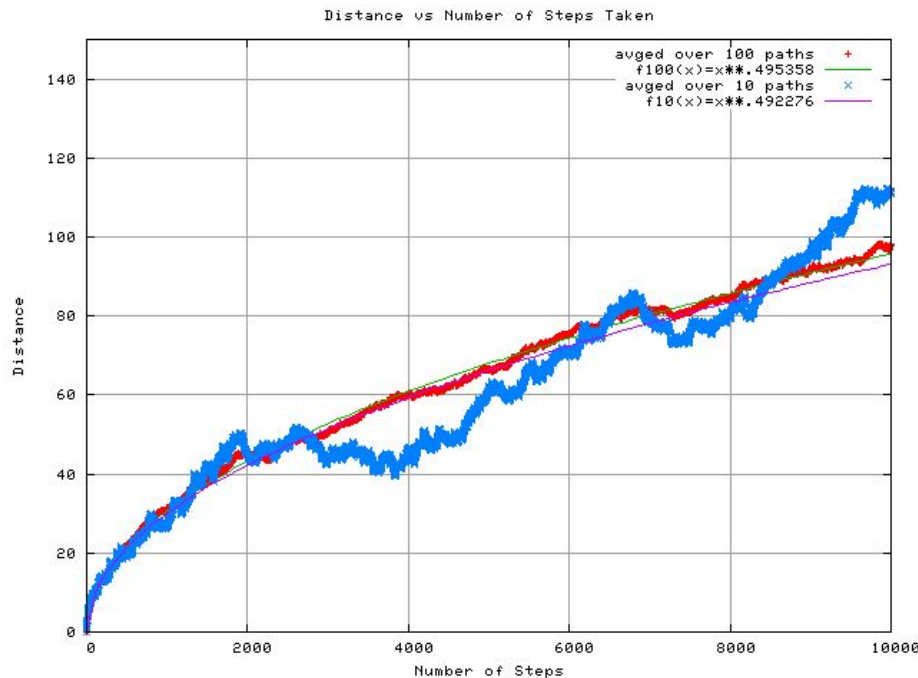
$$T = N \times 1 \text{ sec/step}$$

$$N = (1428)^2$$

$$T = 2 \text{ million seconds}$$

N = 2 million.

T = 23 days.



July 2024 – Advanced – Sunlight Escape

Core of the sun

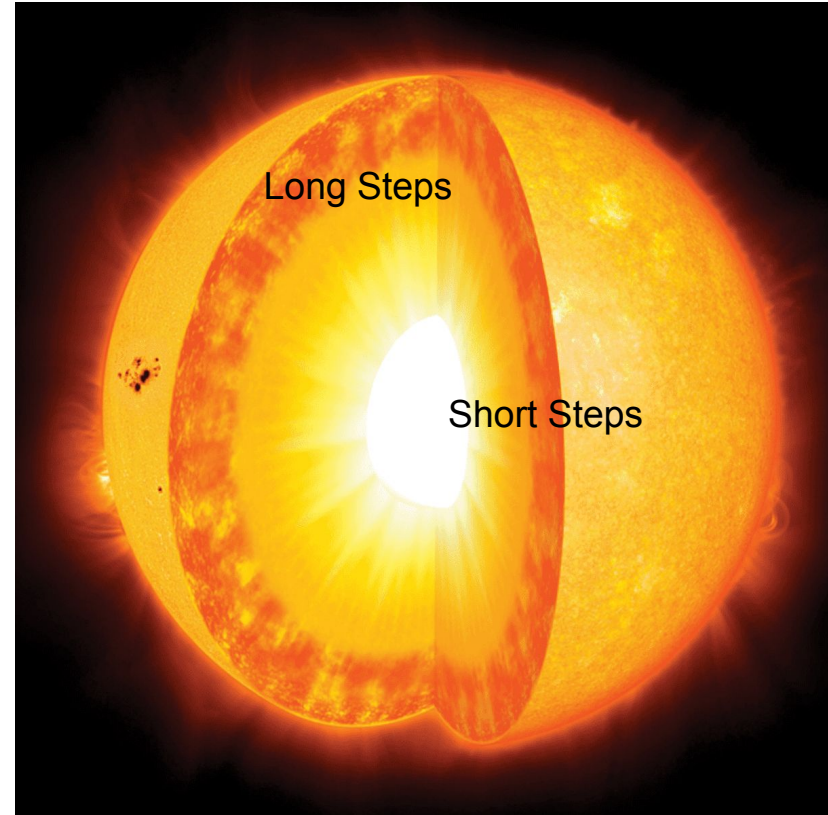
Radius: 140,000 km

Step size: 0.1 mm

Exterior

Radius: 690,000 km

Step Size: 3 mm



July 2024 – Advanced – Sunlight Escape

Core of the sun

Distance: 140,000 km

Step size: 0.1 mm

$$\text{Step size} = 0.1 \text{ mm} / 1000 \text{ mm/m} = 1.0 \times 10^{-4} \text{ m}$$

$$\text{Steps} = (140000000 \text{ m} / 1.0 \times 10^{-4})^2$$

$$\text{Steps} = 2.0 \times 10^{24} \text{ steps}$$

$$\text{Time/step} = 1.0 \times 10^{-4} \text{ m} / (3 \times 10^8 \text{ m/s}) = 3.3 \times 10^{-13} \text{ sec/step}$$

Travel Time = 21,000 years

Exterior

Distance: 690,000 km –
140,000 km = 550,000 km

Step Size: 3 mm

$$\text{Step size} = 3 \text{ mm} / 1000 \text{ mm/m} = 3.0 \times 10^{-3} \text{ m}$$

$$\text{Steps} = (550000000 \text{ m} / 3.0 \times 10^{-3})^2$$

$$\text{Steps} = 3.4 \times 10^{22} \text{ steps}$$

$$\text{Time/step} = 3.0 \times 10^{-3} \text{ m} / (3 \times 10^8 \text{ m/s}) = 1.0 \times 10^{-11} \text{ sec/step}$$

Travel Time = 11,000 years

Total exit time = 32,000 years...give or take!

August 2024 – Back to School

All about the life cycles of stars and their remnants:

White Dwarfs

Neutron Stars

Black Holes

