National Aeronautics and Space Administration

The Heliophysics Big Year

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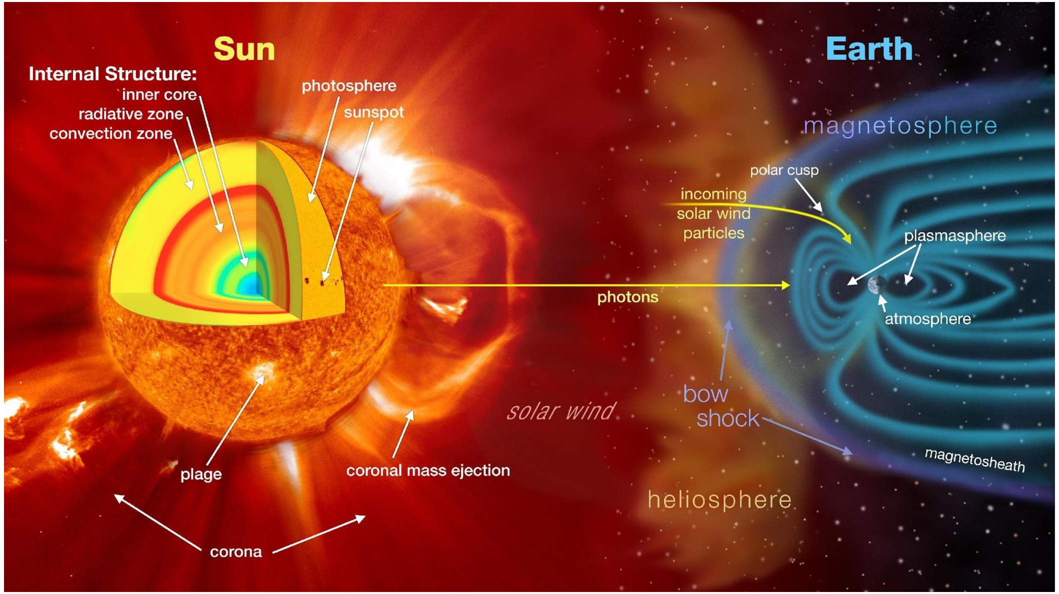
NASA Heliophysics Education Activation Team

December 2024: What is Heliophysics?

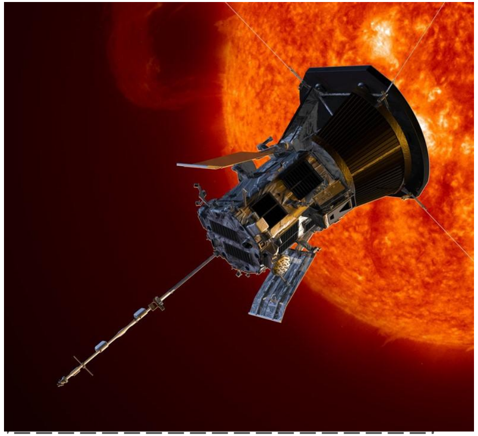
Heliophysics is the discipline in space science that deals with the matter and energy of our Sun and its effects on the solar system.

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



Heliophysics Big Year Timeline

Annular Eclipse	Total Eclipse	Solar Parker Probe Perihelion
October 14, 2023	April 8, 2024	December 24, 2024



Heliophysics Big Year Themes

2023

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

2024

- ☑ **January**- 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
- ☑ **October** – Solar Cycles
- ☑ **November-** Bonus Science
- **December-** Parker's Perihelion

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

December 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)

December 2024: The Parker Solar Probe

Launched:

August 12, 2018

Current Orbit:

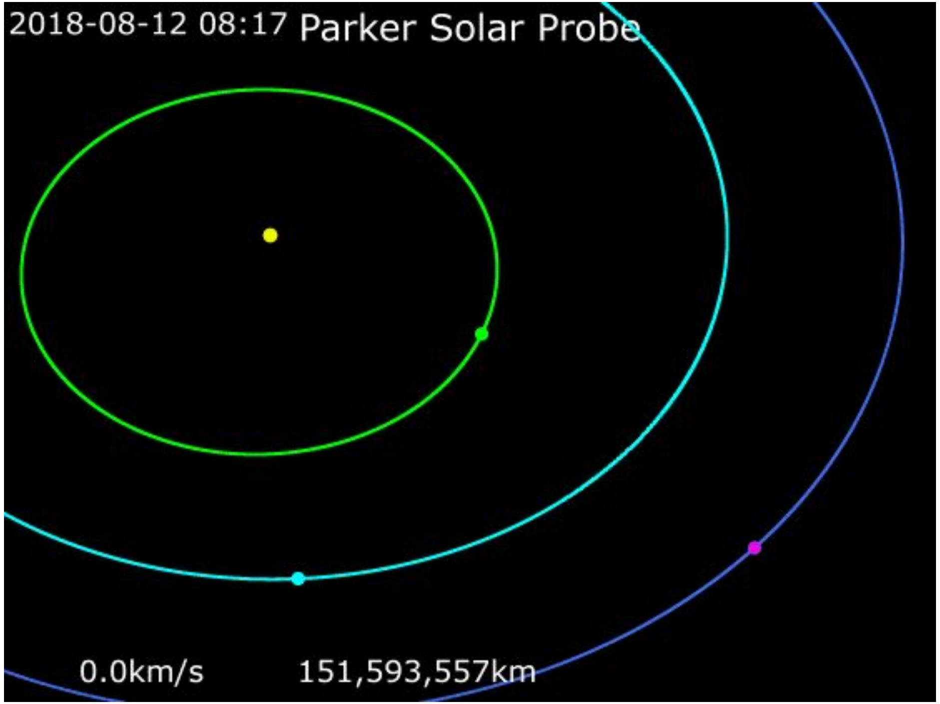
22

Perihelion:

7.3 million km

December 2024: Parker Solar Probe

The goal is to study the inner corona and investigate the origin of the solar wind and other phenomena.



Parker orbits: NASA/JPL/Horizons System

December 2024: Parker Solar Probe

Spacecraft Temp : 2,600 F

Speed: 640,000 km/h

400,000 mph

2009 Eclipse (Credit: Miloslav Druckmuller)

December 2024: Parker Solar Probe

Spacecraft Temp : 2,600 F

Speed: 640,000 km/h

400,000 mph

Travel time to Mars: **88 hours**

2009 Eclipse (Credit: Miloslav Druckmuller)

December 2024: Parker Solar Probe

Discoveries so far:

- ✔ First direct measurements and samples of solar atmosphere
- ✔ Detection of Alfven Surface where solar wind originates
- ✔ Detection of coronal streamers from surface that produce the wind
- ✔ Detection of boundary of the dust-free zone
- ✔ Discovery of magnetic ‘switchbacks’ of reversed polarity between supergranules
- ✔ SEPs are very common and not all related to CME shock compression

December 2024: Parker Solar Probe- Beginning

Problem: On June 23, 2023

the speed of the solar wind was measured by Parker as 350 km/s

The density was 300 protons/cc

The distance was 21.5 million kilometers.

How much mass was in the shell with a radius of R and a thickness of V x 1 second?

December 2024: Parker Solar Probe- Beginning

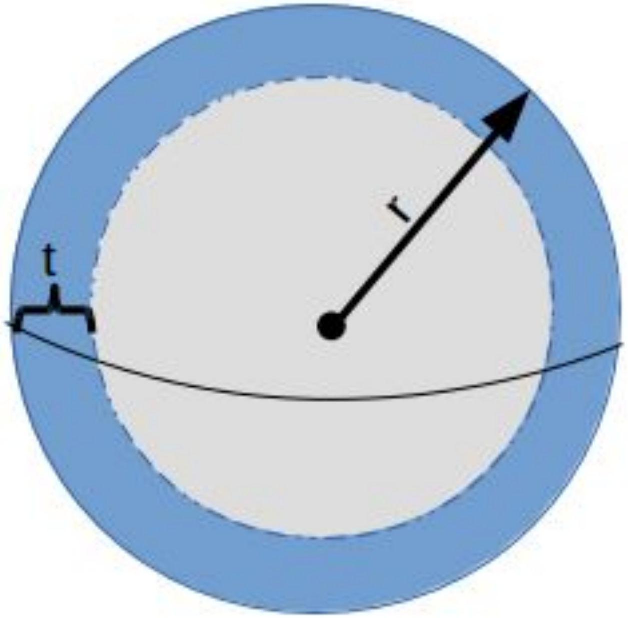
Surface area of shell:

$A = 4\ \pi\ (21.5 \text{ million x } 1000)^2 \quad = 5.8\text{x}10^{21}\ m^2$

Thickness: 350 km/s x 1 sec x 1000 m/km

t = 350,000 meters.

Volume = Area x thickness = $2.0\text{x}10^{27}\ m^3$



December 2024: Parker Solar Probe- Beginning

Mass of the shell:

M = Volume x density

M = 2×10^{27} m^3 x 300 protons/cm^3 x (10^6 cm^3/m^3)

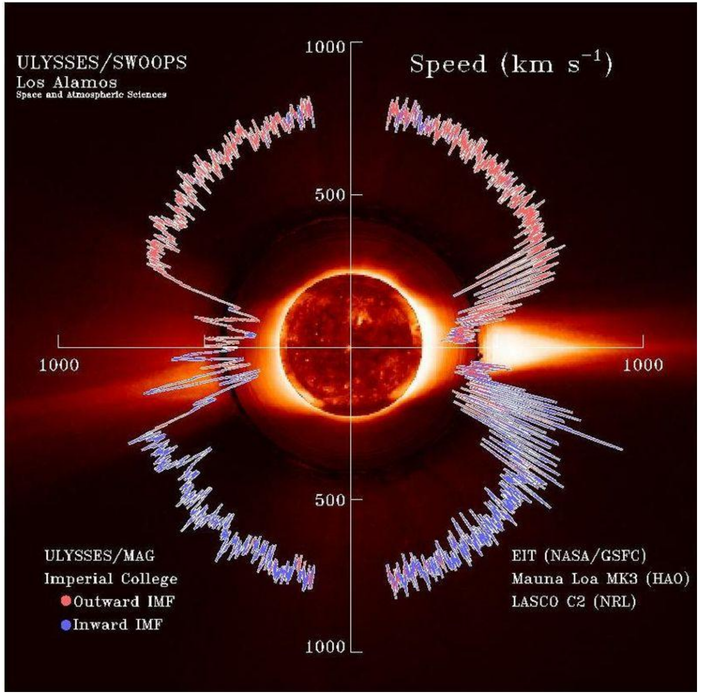
M = 6×10^{35} protons.

1 proton = 1.7×10^{-27} kg.

Mass = 6×10^{35} x 1.7×10^{-27}

Mass = 1 billion kg.

Sun looses 1 billion kg/sec of mass.



December 2024: Parker Solar Probe- Beginning

At a rate of one billion kg/sec, how much mass has the sun lost in 4 billion years?

M = 10^9 kg/s x 4×10^9 years x 365 days x 86,400 s/day

Mass = 1.3×10^{26} kg.

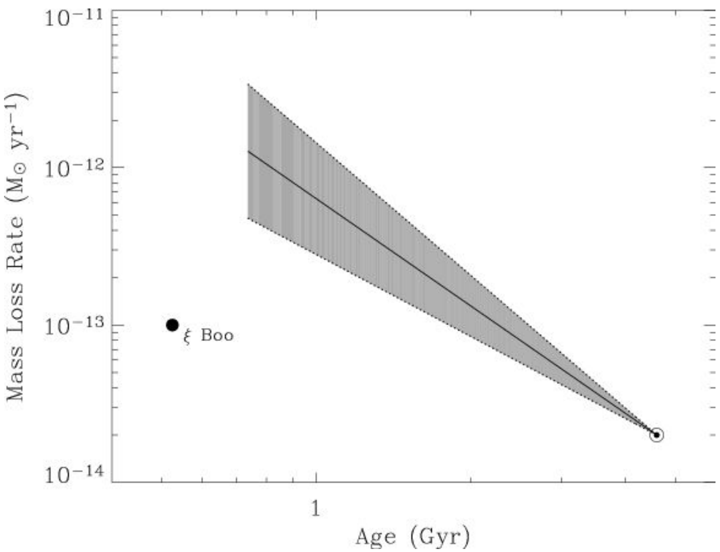
Mass of sun = 2×10^{30} kg

Percent of mass lost =

100% x $1.3 \times 10^{26} / 2 \times 10^{30}$ = **0.007%**

Our estimate from Parker: **1.6×10^{-14} Msun/year.**

Previous values: between 1 and 5 x 10^{-14} Msun/year.



Historical mass loss rates for the sun. (Credit: Wood, Redfield, Linsky and Muller)

NASA HEAT

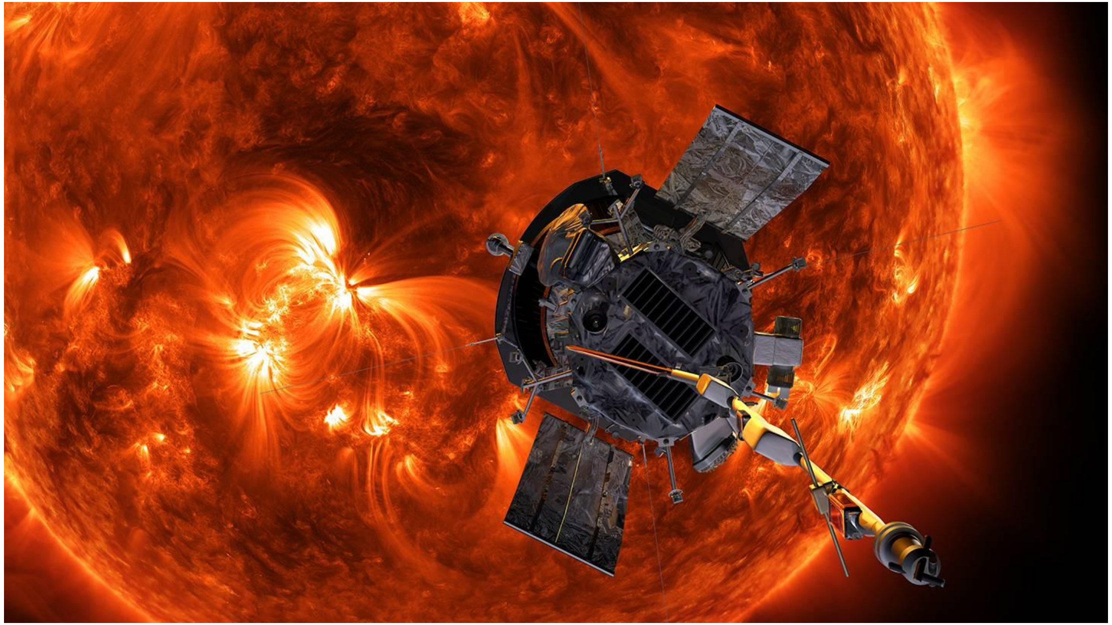
December 2024: Parker Solar Probe- Intermediate

How hot does the spacecraft get???

Simple model:

$L = 4\pi R^2 \sigma T^4$

$$T = \left[\frac{Lsun}{4\pi\sigma R^2}\right]^{\frac{1}{4}}$$



December 2024: Parker Solar Probe- Intermediate

- $$T = \left[\frac{Lsun}{4\pi\sigma R^2}\right]^{\frac{1}{4}}$$

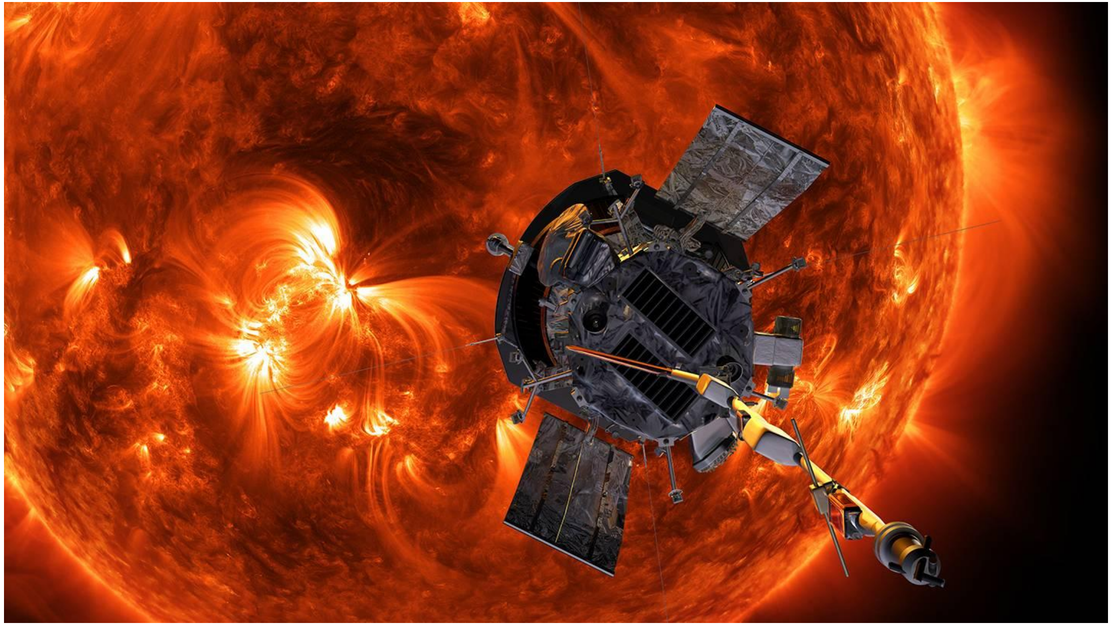
For R in millions of km and

Lsun = $4x10^{26}$ watts

σ= $5.7x10^{-8}$

Then:

$$T = \frac{4861}{R^{0.5}} \text{ kelvin}$$



December 2024: Parker Solar Probe- Intermediate

$$T = \frac{4861}{R^{0.5}} \text{ kelvin}$$

Solar surface R = 0.69 **T = 5850 k**

Actual = 5772 k.

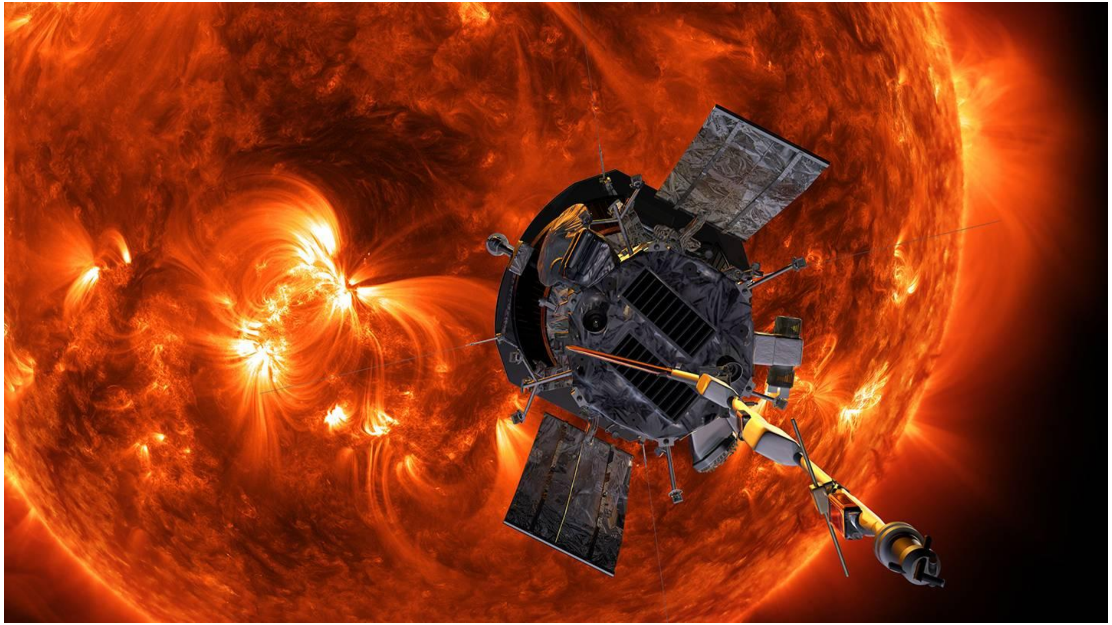
At Parker Spacecraft R = 7.3 +0.7 = 8.0 from the center of the sun during Orbit 21 in September

T = 1700 k

Melting point of

Aluminum= 933 k

Titanium = 1941 k



December 2024: Parker Solar Probe- Advanced

Problem: What would be the predicted density of the solar corona at the perihelion of 7.3 million km from the solar surface (8.0 from the center) during Orbit 21 in September?

Data from previous perihelia with:

distance in millions of km from center

density in particles/cc

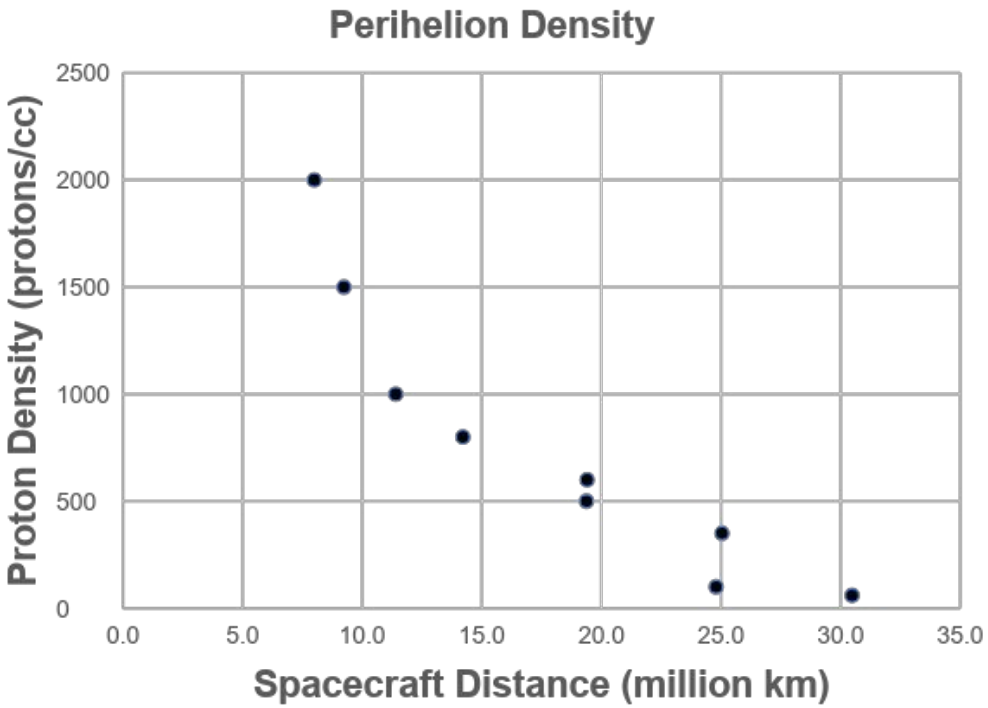
Perihelion #	Distance	Density
11	9.3	2000
14	9.2	1500
6	14	1000
7	14	800
4	19	500
1	25	350
10	30.5	60

Orbit data : https://psp-gateway.jhuapl.edu/
SWEAP density only available to April 13, 2024.

Distance from surface = Distance – 0.7

December 2024: Parker Solar Probe- Advanced

Graph it.



December 2024: Parker Solar Probe- Advanced

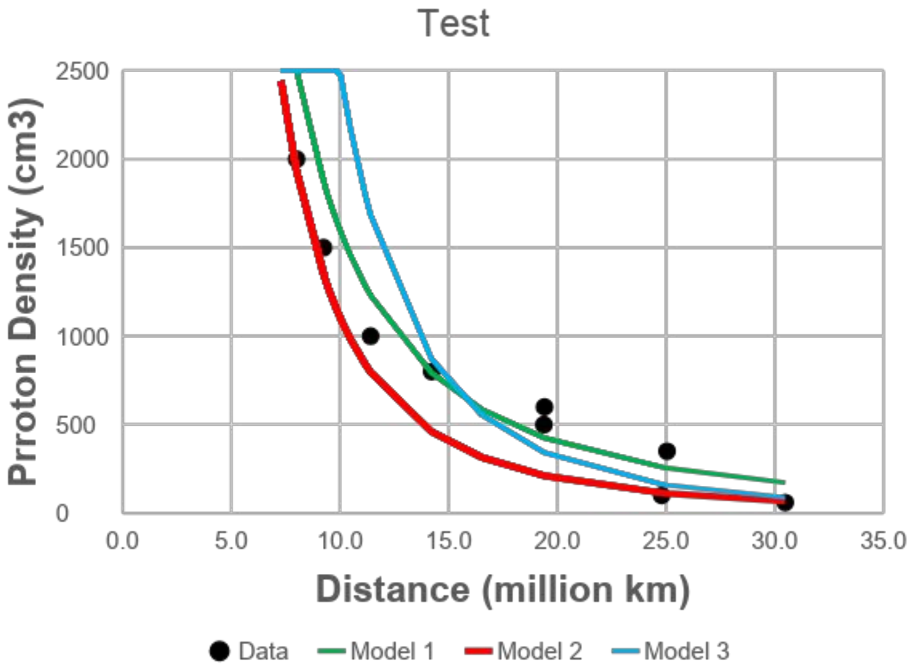
Model with a power law. $D(x) = Ax^{-n}$

Trial and error

Model 1 : A=160000 n = 2.0

Model 2: A = 350000 n=2.5

Model 3: A = 2500000 n = 3.0



December 2024: Parker Solar Probe- Advanced

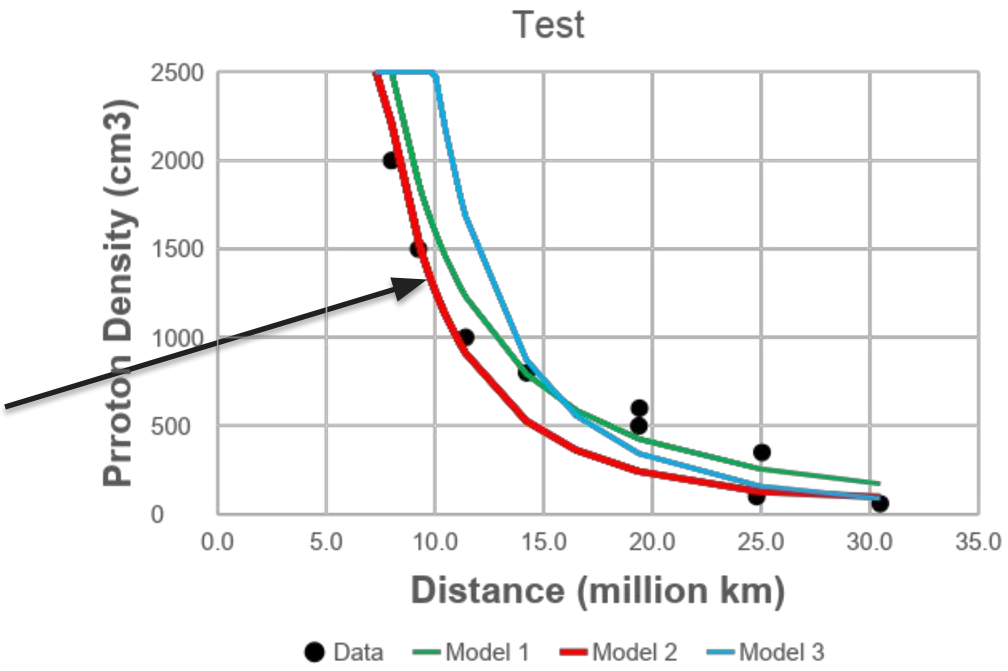
Trial 2: Select $D(x)=Ax^{-2.5}$

Adjust A to get a better match to closed-in points where we will make the prediction

A1= 30000 Best for x > 15

A2= 400000 works best for x<10

A3 = 500000



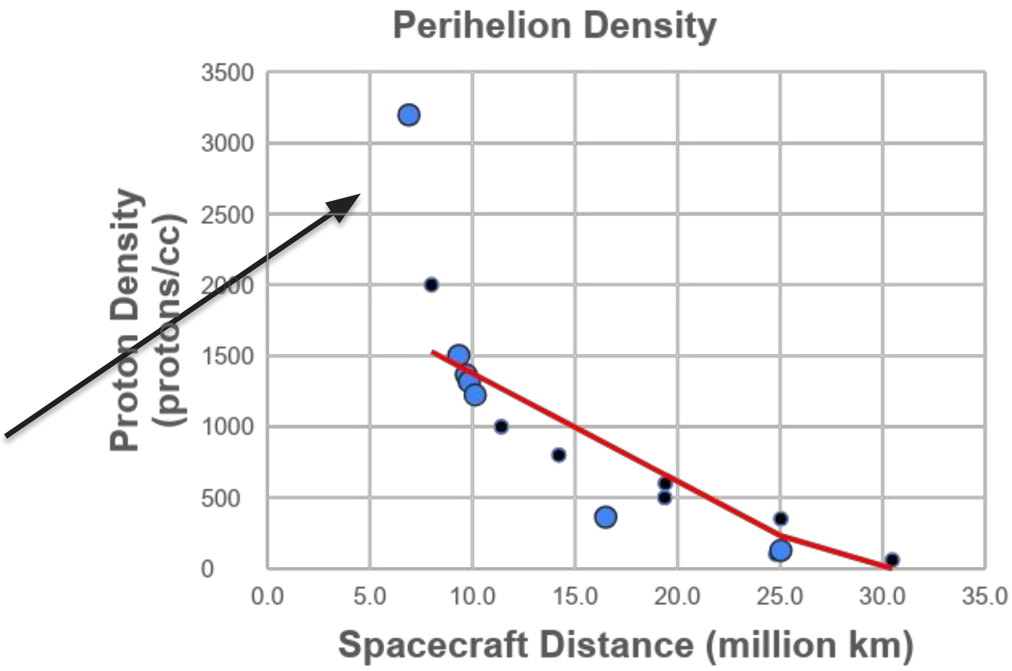
December 2024: Parker Solar Probe- Advanced

On December 24, 2024 Orbit 22, Parker perihelion is at 6.2 million km from surface or 6.9 million km from center.

Predicted density at X = 6.9 million km

$D(x) = 400000\ (6.9)^{-2.5}$ **our best model**

$D(x) = 3200$ protons/cc



https://psp-gateway.jhuapl.edu/website/Tools/SummaryImagePlotter

December 2024: Parker Solar Probe- ChatGPT

Let ChatGPT calculate the models!

ChatGPT Query. Find a power-law of the form Y= Ax^-2.5 that fits the six data points (9.3,2000), (14,900) and (30 ,60), (9.2,1500), (19, 500), (25, 350). Find the best value for A that passes close to the three points. Show your work.

$2000 = A(9.3)^{-2.5}$
$900 = A(14)^{-2.5}$
$60=A(30)^{-2.5}$
$1500 =A(9.2)^{-2.5}$
$500 = A (19)^{-2.5}$
$350 = A(25)^{-2.5}$

Average value for A = 1,527,211

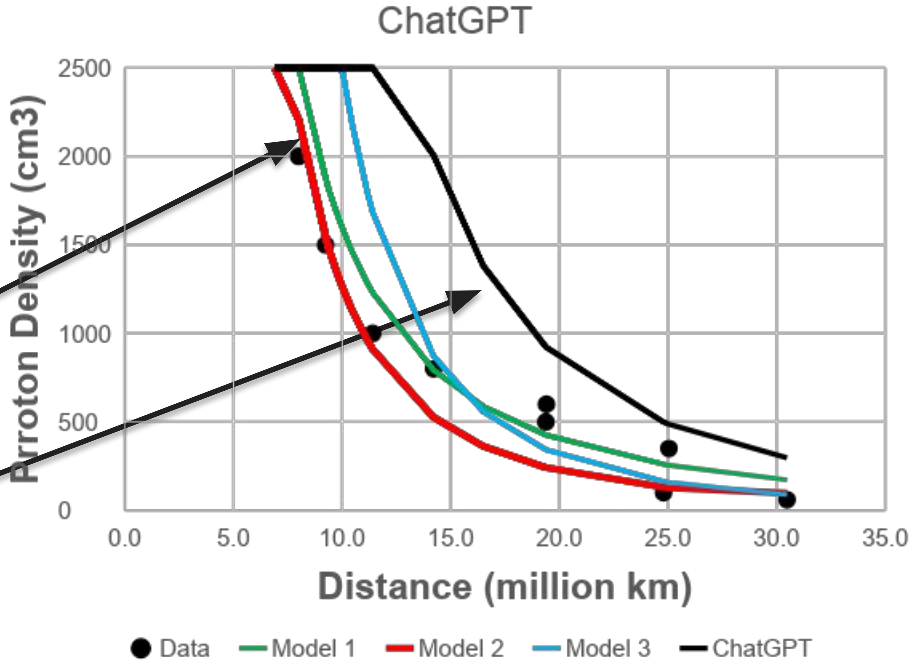
December 2024: Parker Solar Probe- ChatGPT

Let ChatGPT calculate the models!

It provides the worst fit of all trials because it does a straight average of all six values for A.

Best = 400000

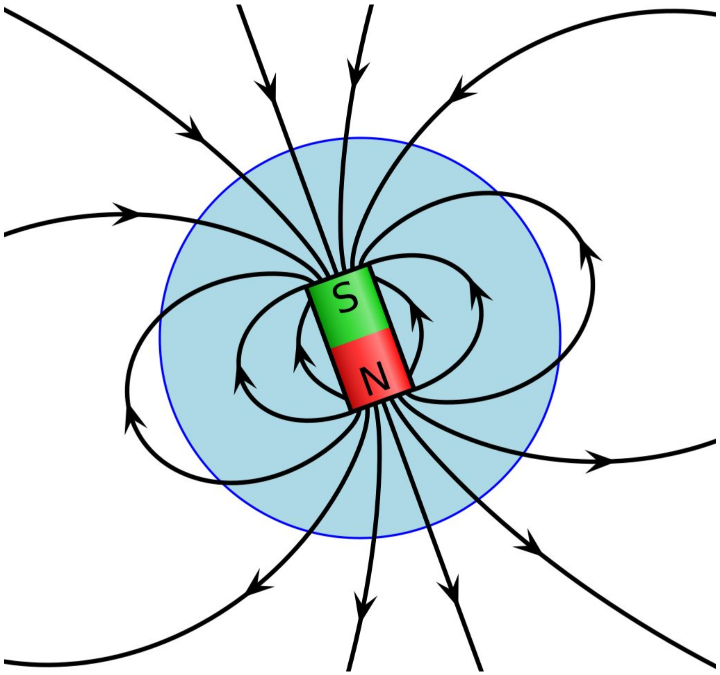
ChatGPT= 1,527,211



January– New Webinar Series Starts

Is Earth about to reverse its polarity?

Facts and Misconceptions



Wikipedia

Slides and Recordings

Slides: https://rb.gy/qsgmbr

Previous webinar recordings
https://www.youtube.com/watch?v=Iwf8Y_fOOIs&list=PL5mpEj48YwXntxhPvZBgJn0ZG5MRm4UIS