National Aeronautics and Space Administration

The Heliophysics Big Year

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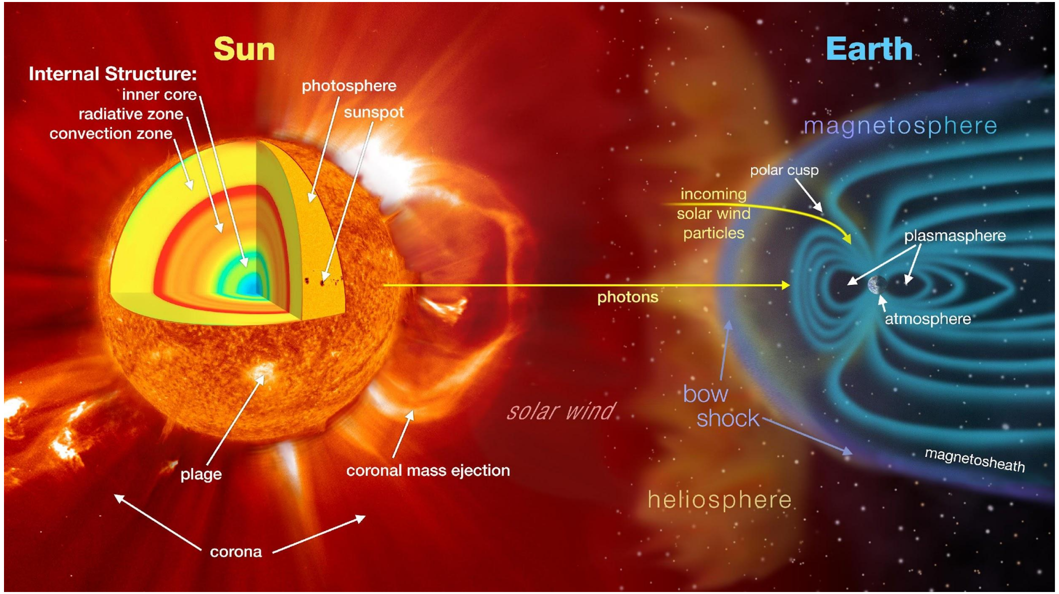
NASA Heliophysics Education Activation Team

November 2024: What is Heliophysics?

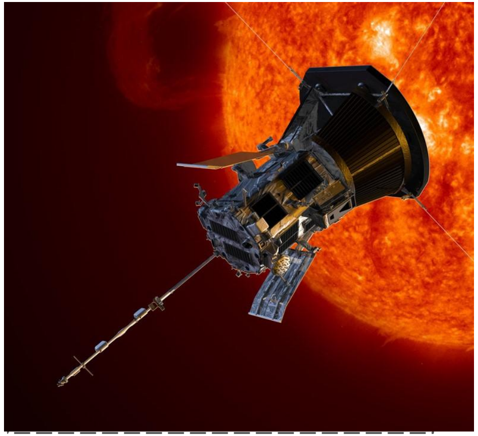
Heliophysics is the discipline in space science that deals with the matter and energy of our Sun and its effects on the solar system.

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/

November 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)

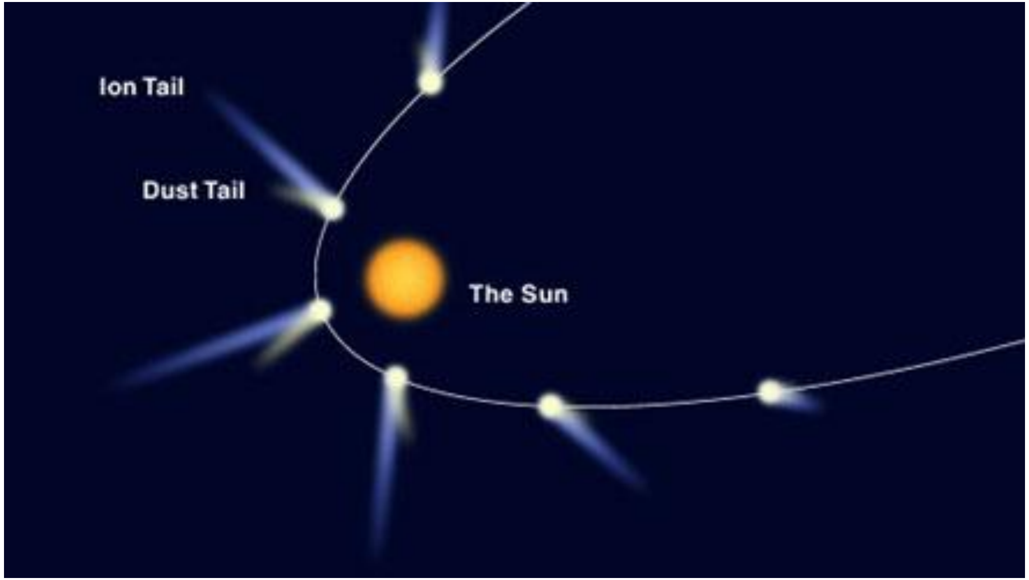
1. **How do Earth, the solar system, and the heliosphere respond to changes on the Sun?**
   2.1 Life on Earth has evolved with complex diversity because of our location near the Sun. It is just right! (PS3, PS4, LS1, LS2, ESS2)
   2.2 The Sun defines the space around it, which is different from interstellar 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)

November 2024: The Solar Wind-Origin

We have known about the solar wind since the 1950s.

- Comet tails = wind socks
- Light pressure too weak
- Particle pressure needed
- Emitted from sun radially.



November 2024: The Solar Wind-Origin

Eugene Parker models ca 1957

Gas hydrodynamics described by

Navier-Stokes Equation

Continuity Equation

$$\nabla \cdot \vec{V} = 0$$

Momentum Equations

$$\underbrace{\rho \frac{D\vec{V}}{Dt}}_{\text{Total derivative}} = \underbrace{-\nabla p}_{\text{Pressure gradient}} + \underbrace{\rho \vec{g}}_{\text{Body force term}} + \underbrace{\mu \nabla^2 \vec{V}}_{\text{Diffusion term}}$$

Total derivative

=

$$\rho[\underbrace{\frac{\partial V}{\partial t}}_{\text{Change of velocity with time}} + \underbrace{(V.\nabla)V}_{\text{Convective term}}]$$

Change of velocity with time

Convective term

Pressure gradient

Fluid flows in the direction of largest change in pressure.

Body force term

External forces, that act on the fluid (gravitational force or electromegnetic).

Diffusion term

For a Newtonian fluid, viscosity operates as a diffusion of momentum.

November 2024: The Solar Wind-Origin

Eugene Parker models ca 1957

Gas hydrodynamics described by

Navier-Stokes Equation: F=ma

Let's look at simplest one!

Continuity Equation

$$\nabla \cdot \vec{V} = 0$$

Momentum Equations

$$\rho \frac{D\vec{V}}{Dt} = -\nabla p + \rho \vec{g} + \mu \nabla^2 \vec{V}$$

Total derivative

=

$$\rho[\frac{\partial V}{\partial t} + (V.\nabla)V]$$

Change of velocity with time

Convective term

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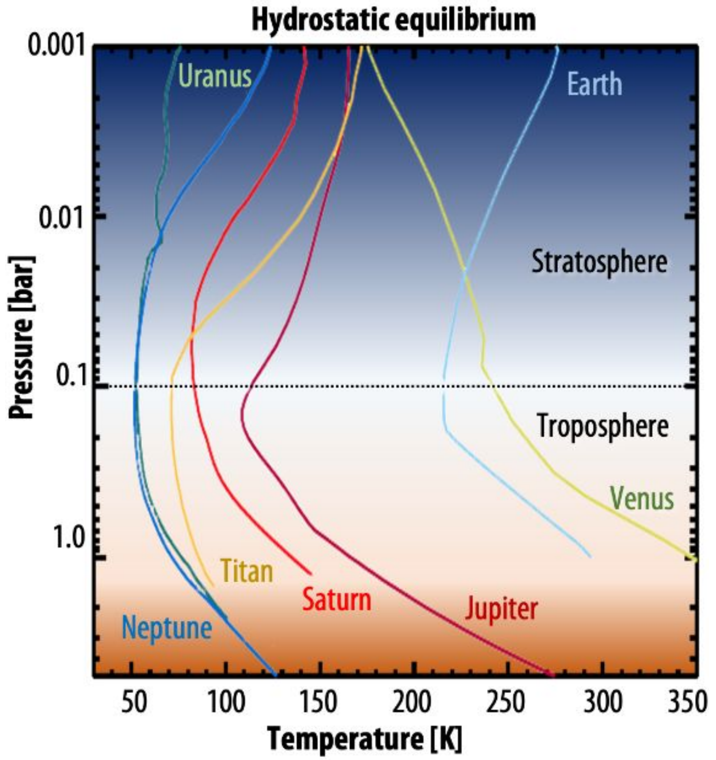
November 2024: The Solar Wind-Origin

Planetary atmosphere solution.

- Isothermal
- Gravity in one direction
- Hydrostatic equilibrium



Credit: NASA https://psg.gsfc.nasa.gov/helpatm.php

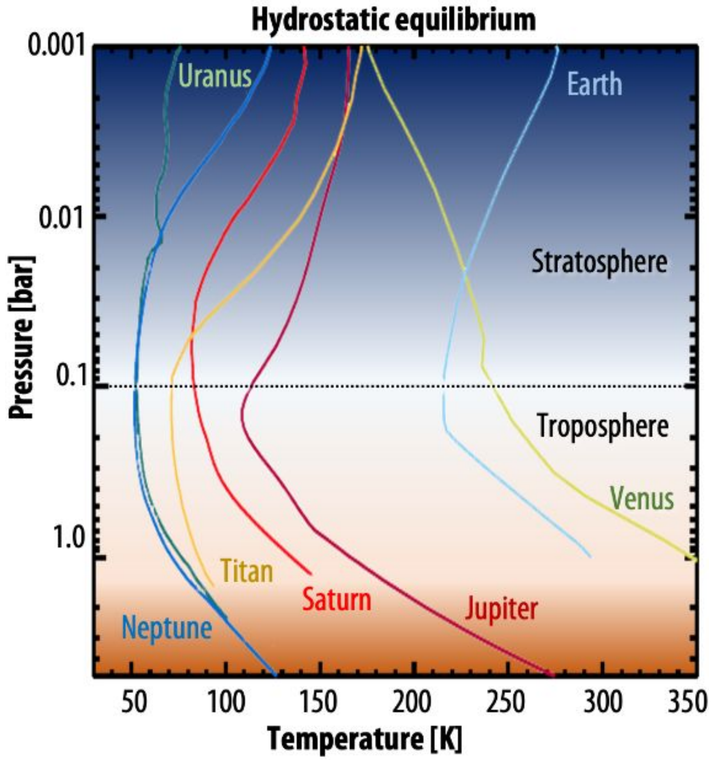
NASA HEAT

November 2024: The Solar Wind-Origin

Planetary atmosphere solution.

- Isothermal
- Gravity in one direction
- Hydrostatic equilibrium

Here's another solution!



Credit: NASA https://psg.gsfc.nasa.gov/helpatm.php

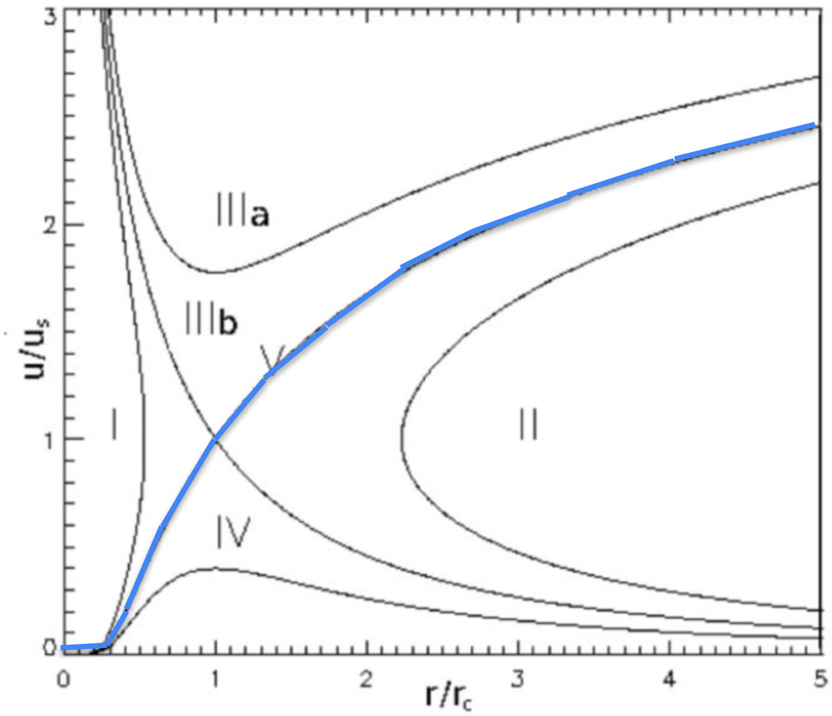
November 2024: The Solar Wind-Origin

Parker solar wind solutions

- Heated from base
- Mass inflow
- Temperature gradient

Five classes of solutions

Solar wind = **Solution V**



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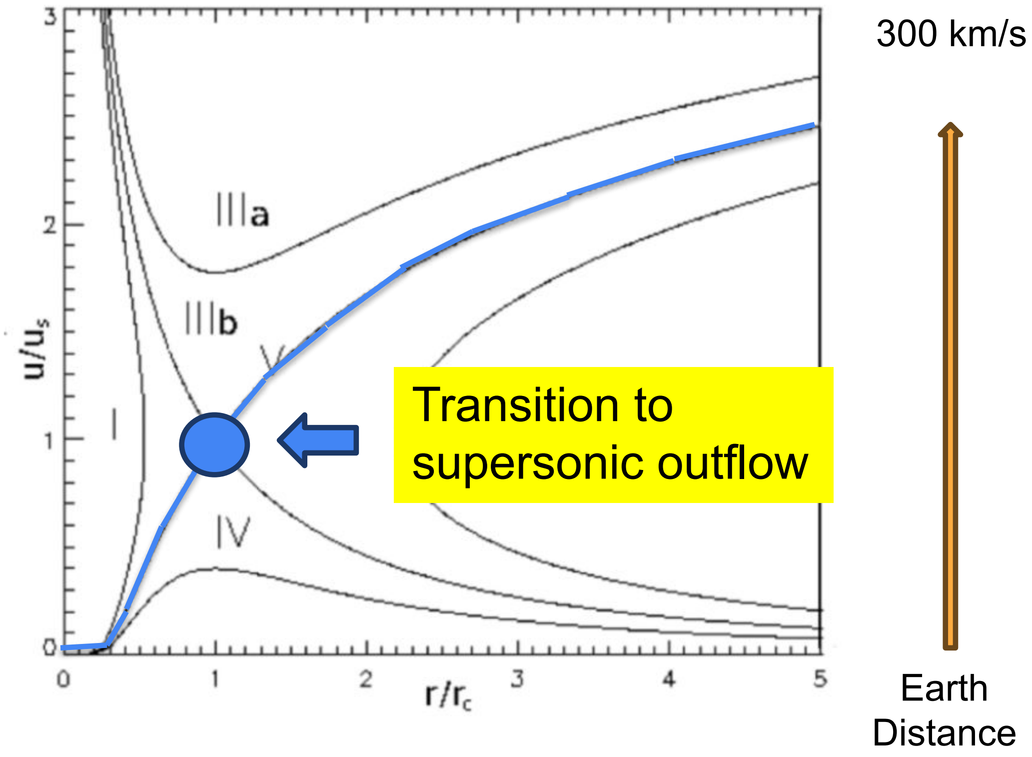
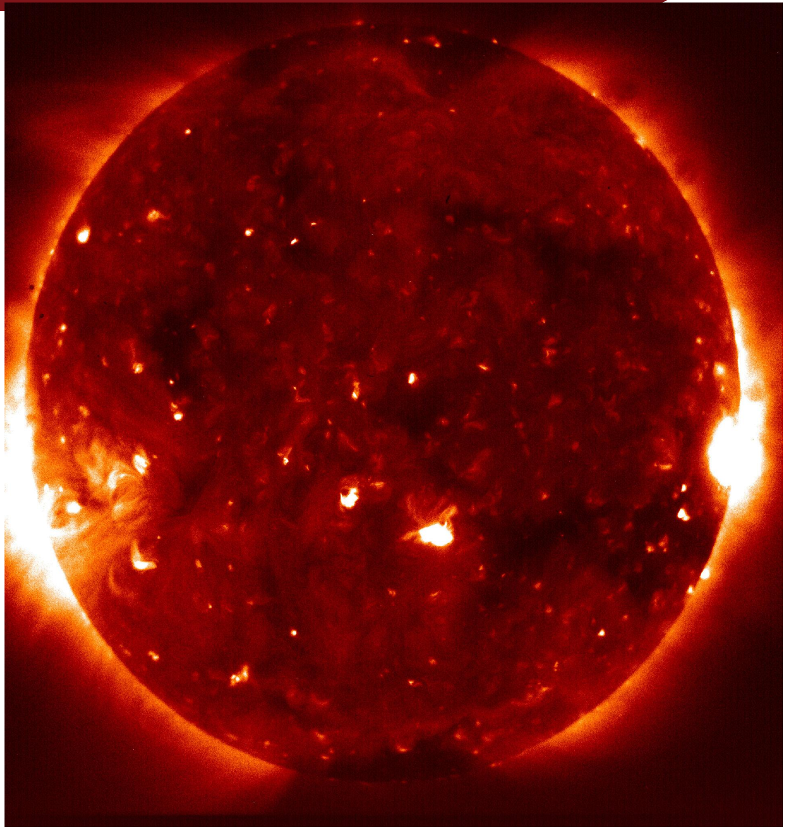


NASA HEAT

December 2024 – Where does it come from?

Hinode spacecraft 2006

Nanoflares



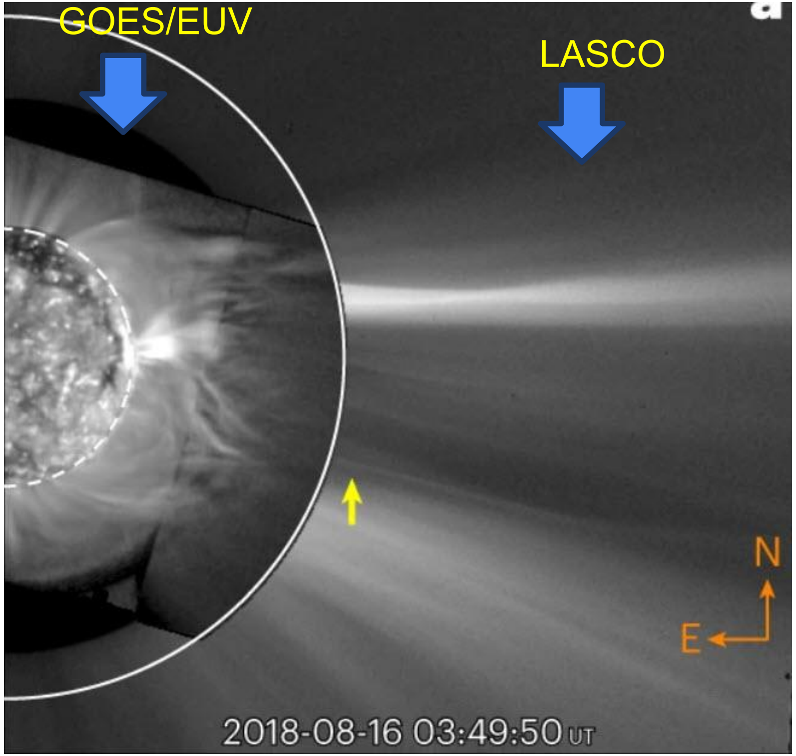
December 2024 – Where does it come from?

Direct observations of a complex coronal web driving highly structured slow solar wind.

GOES plus SOHO/LASCO

Yeimy Rivera et al 2022

https://doi.org/10.1038/s41550-022-01834-5

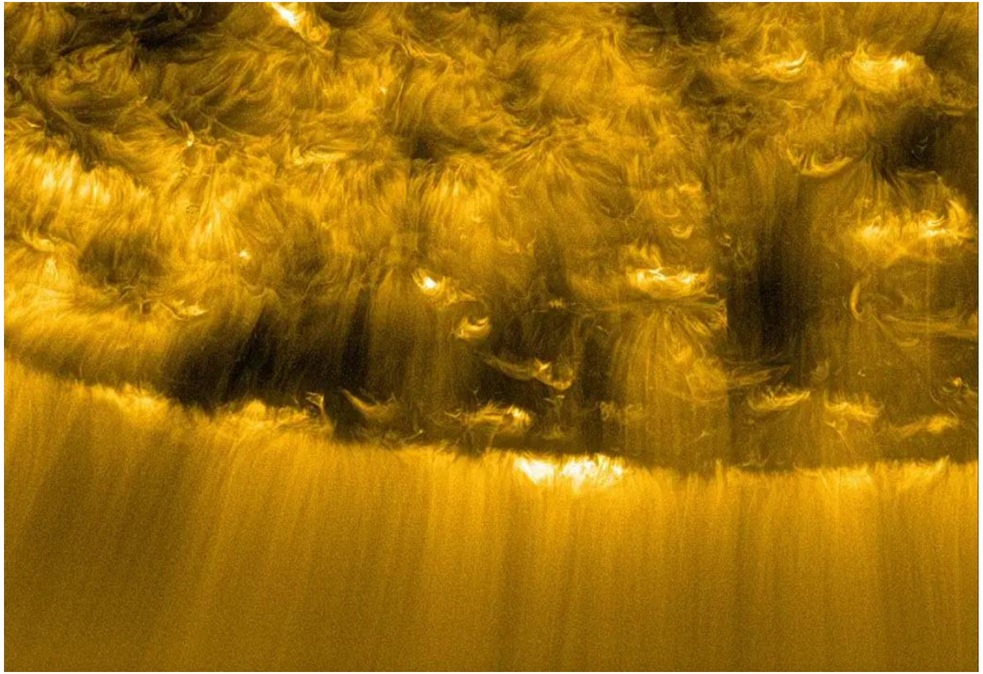


December 2024 – Where does it come from?

Numerous small picojets jets seen by Solar Orbiter spacecraft

Chitta et al. 2023

https://www.science.org/doi/10.1126/science.ade5801



Credit: ESA/https://www.mps.mpg.de/tiny-plasma-jets-power-the-solar-wind

December 2024 – Beginners – Picojets

If each picojet is a cylinder 200 km in radius.

How many picojets could cover the entire sun with a radius of 690,000 km?

Solar surface = $4\pi R^2$
$= 4\pi (690000)^2$
$= 6 \times 10^{12}$ km^2

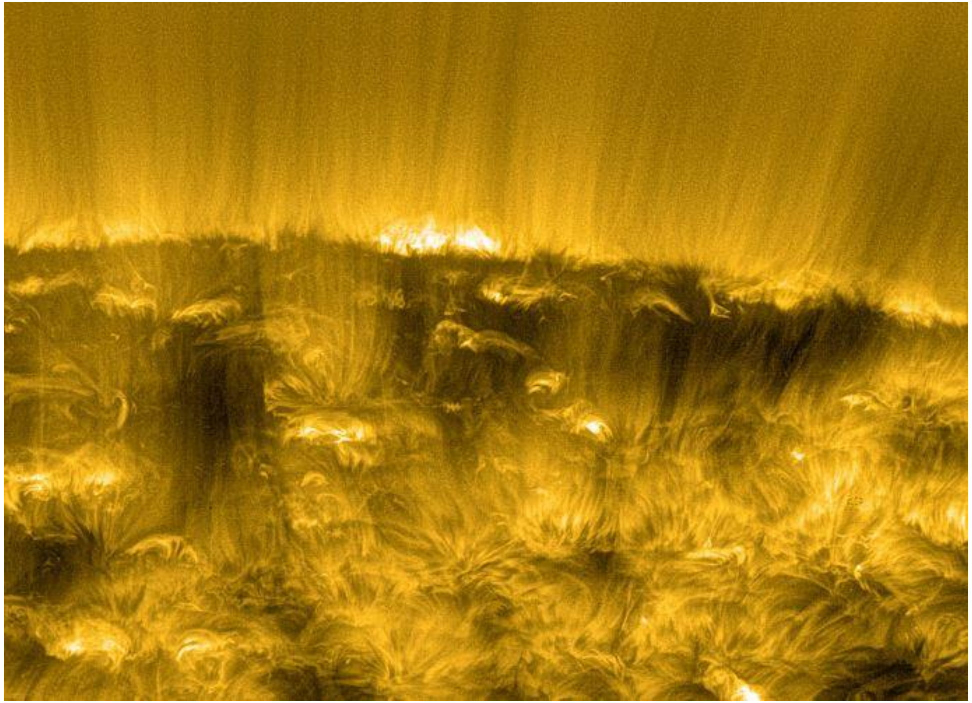
Jet area = πR^2
$= \pi(200)^2$
$= 1.3 \times 10^5$ km^2

So $N = 6 \times 10^{12} / 1.3 \times 10^5$
= **48 million**

December 2024 – Beginners - Picojets

The solar wind carries off 2 billion kg every second.

How much matter is carried off by a single picojet?



December 2024 – Beginners - Picojets

The solar wind carries off 2 billion kg every second.

How much matter is carried off by a single picojet?

From our previous calculation, there are as many as 48 million picojets covering the solar surface.

Mass = 2 billion kg / 48 million

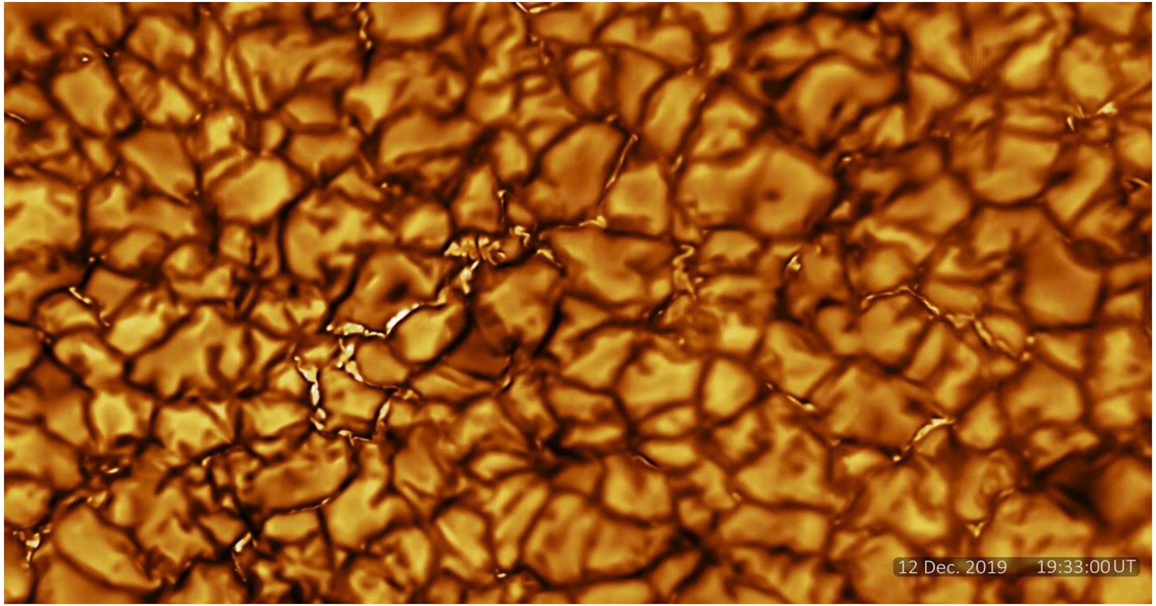
= **40 kg**

December 2024 – Intermediate - Networks

We know that the full sun is not completely covered by picoflares.

Instead there are networks of active regions matching the solar granulation scale.

Each granule is about 1,500 km across.



Inouye solar telescope:
https://www.youtube.com/watch?v=CCzl0quTDHw

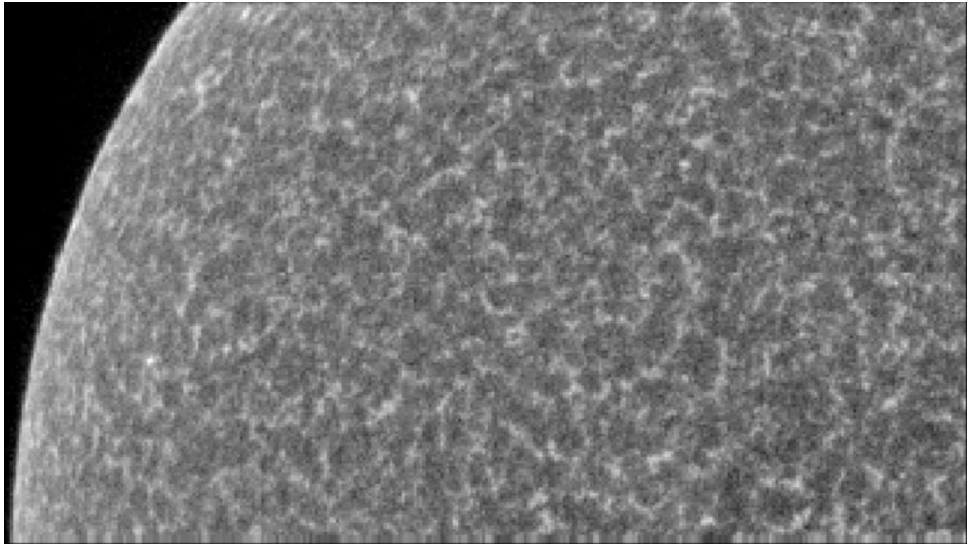
December 2024 – Intermediate - Networks

We know that the full sun is not completely covered by picoflares.

Instead there are networks of active regions matching the solar granulation scale.

Each granule is about 1,500 km across.

This produces the chromospheric network of active regions.



SUMER Data/ D. Hassler

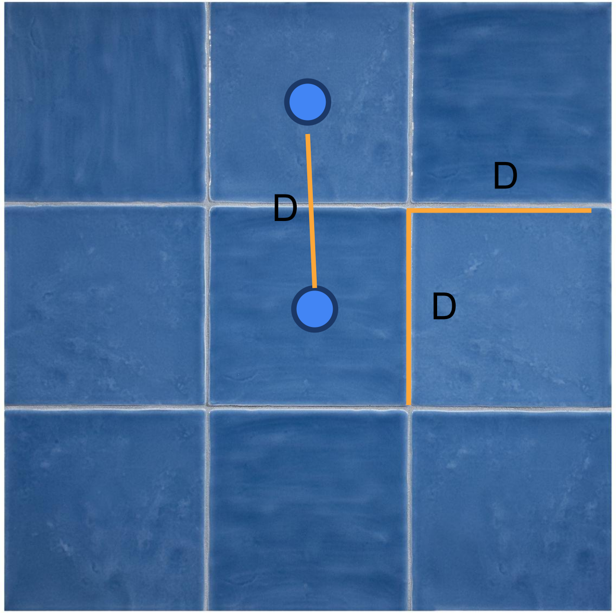
https://www.researchgate.net/figure/An-example-of-the-chromospheric-network-pattern-showing-the-intensity-of-the-Si-I_fig2_226879894

December 2024 – Intermediate - Networks

If the average distance between picojets is 1500 km in the chromospheric network, how many jets are present in the chromosphere?

From properties of a square

D = √Area



December 2024 – Intermediate - Networks

If the average distance between picojets is 1500 km in the chromospheric network, how many jets are present in the chromosphere?

From properties of a square

$D = \sqrt{Area}$

Area of sun = 6×10^{12} km^2

Area of network cell = $(1500)^2$
= $2.2\mathrm{x}10^6$ km^2

Number of jets = $6\mathrm{x}10^{12} / 2.2\mathrm{x}10^6$
= **2.7 million**

December 2024 – Intermediate - Networks

If the average distance between picojets is 1500 km in the chromospheric network, how many jets are present in the chromosphere?

From properties of a square

$D = \sqrt{\text{Area}}$

To create a solar wind with 2 billion kg/sec, how much mass has to flow in each jet?

Area of sun = 6×10^{12} km^2

Area of network cell = $(1500)^2$

= 2.2×10^6 km^2

Number of jets = $6 \times 10^{12} / 2.2 \times 10^6$

= **2.7 million**

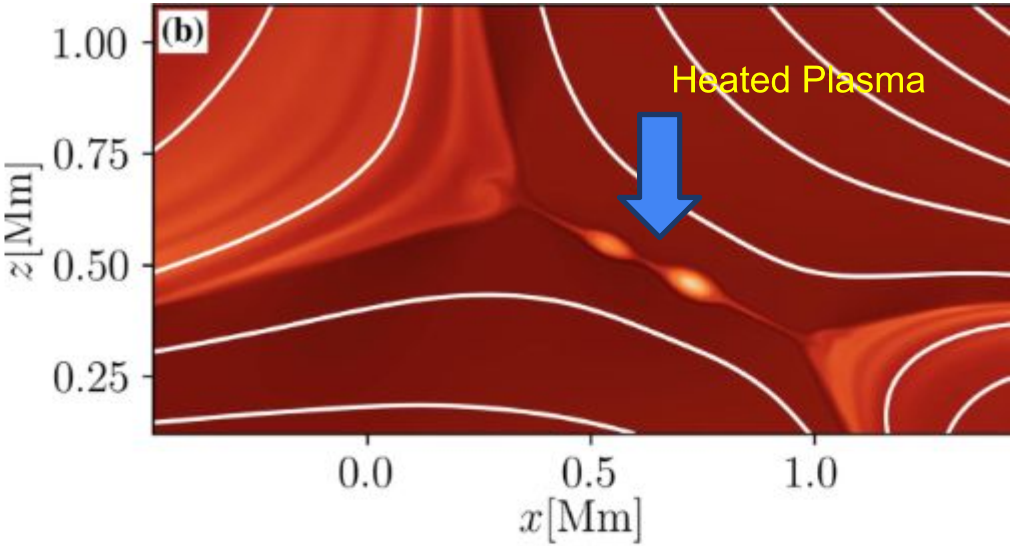
2 billion kg/sec / 2.7 million jets

= 740 kg/sec.

December 2024 – Advanced - Energy

Magnetic reconnection converts stored magnetic energy into kinetic and thermal energy.

Opposite polarity lines come together and re-connect into a simpler shape. Plasma is heated to thousands of degrees in between.



Credit: Eric Priest
https://www.sciencedirect.com/science/article/pii/S0273117722002149

December 2024 – Advanced - Energy

Available magnetic energy in a volume

De= $B^2/8\pi$ ergs/cm^3

Energy = Volume x De

If jets are cylinders 200 km in radius and 10,000 km tall, and the magnetic field has a strength of 100 gauss, what is the total available energy?

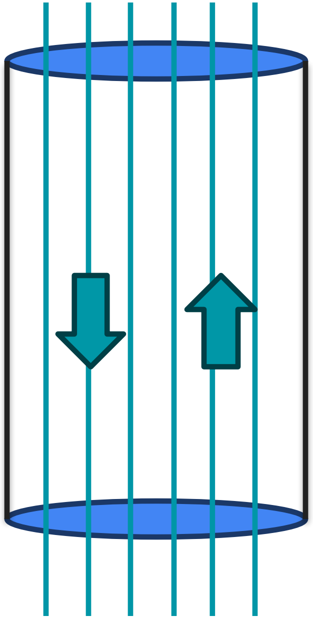
December 2024 – Advanced - Energy

Available magnetic energy in a volume

De= $B^2/8\pi$ ergs/cm^3

Energy = Volume x De

If jets are cylinders R=200 km in radius and H=10,000 km tall, and the magnetic field has a strength of about B= 10 gauss, what is the total available energy in ergs?



December 2024 – Advanced - Energy

$De = 100^2/8\pi$

$= 40 \text{ ergs/cm}^3$

$\text{Volume} = \pi\,(200)^2\ 10000$

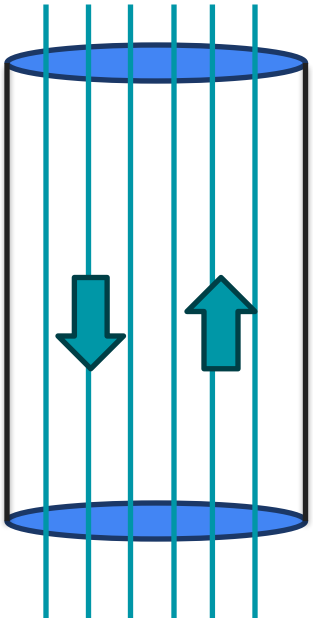
$= 1.25\text{x}10^9 \text{ km}^3$

100,000 cm = 1 km

$\text{Volume} = 1.25\text{x}10^{24} \text{ cm}^3$

$E = (40) \text{ x } (1.25\text{x}10^{24})$

$= 5\text{x}10^{25}$ ergs per flare



December 2024 – Advanced - Energy

De= $100^2/8\pi$

= 40 $ergs/cm^3$

Volume = π $(200)^2$ 10000

= 1.25×10^9 km^3

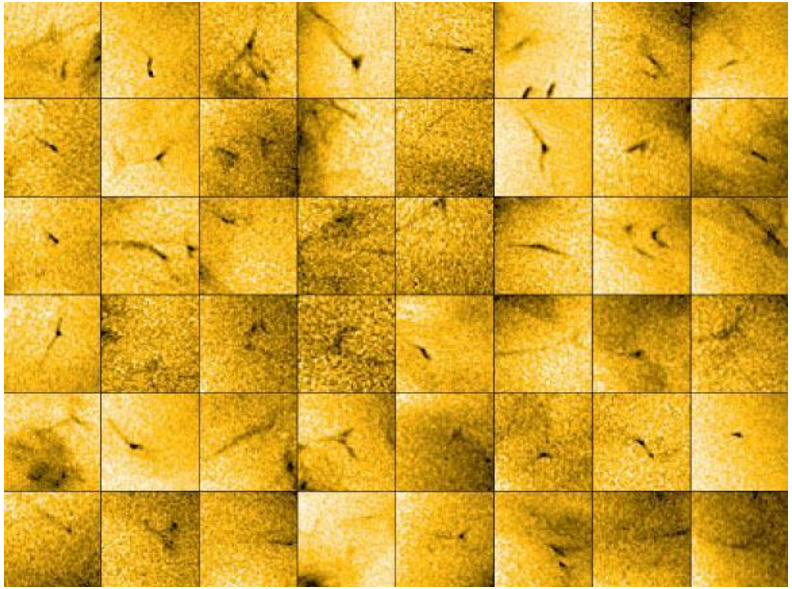
100,000 cm = 1 km

Volume = 1.25×10^{24} cm^3

E = (40) x (1.25×10^{24})

= 5×10^{25} ergs per flare

= 1200 megatons TNT each minute



ESA / NASA / Solar Orbiter / EUI Team / Lakshmi Chitta, Max Planck Institute for Solar System Research / CC BY-SA 3.0 IGO.

December 2024 – Intermediate

Next Time!

The Parker Solar Probe

Slides and Recordings

Slides: https://rb.gy/qsgmbr

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