National Aeronautics and Space Administration

The Heliophysics Big Year

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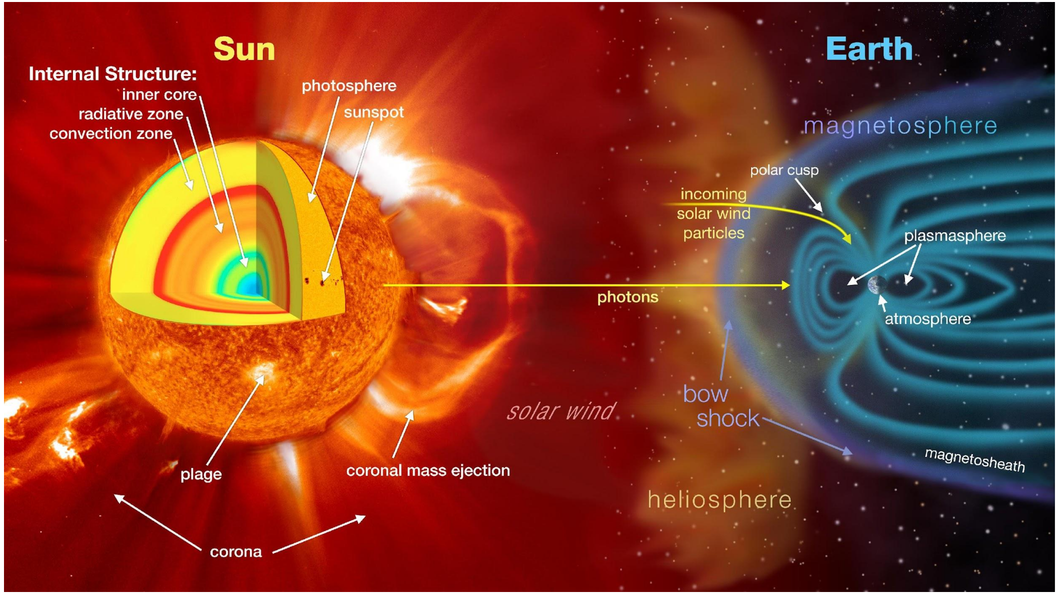
NASA Heliophysics Education Activation Team

November 2023: What is Heliophysics?

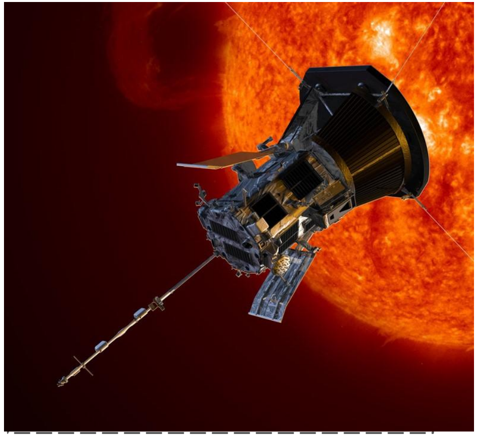
Heliophysics is the discipline in space science that deals with the matter and energy of our Sun and its effects on the solar system.

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



November 2023 : HBY Schedule

November 30 – NASA Heliophysics Mission Fleet

December 19: Citizen Science

January 16: The Sun Touches Everything

February 20: Fashion

March 19: Experiencing the Sun

April 8 – April 16: Total Solar Eclipse

May 21– December: Topics to follow

November 2023 : 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/

November 2023 : The Framework for Heliophysics Education

What are the impacts of the Sun on humanity?

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) <<< Tonight >>>

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)

How do the Earth, the solar system, and 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 our solar system.(PS1, PS2, PS3,PS4, ESS1)

What Causes the Sun to Vary?

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)

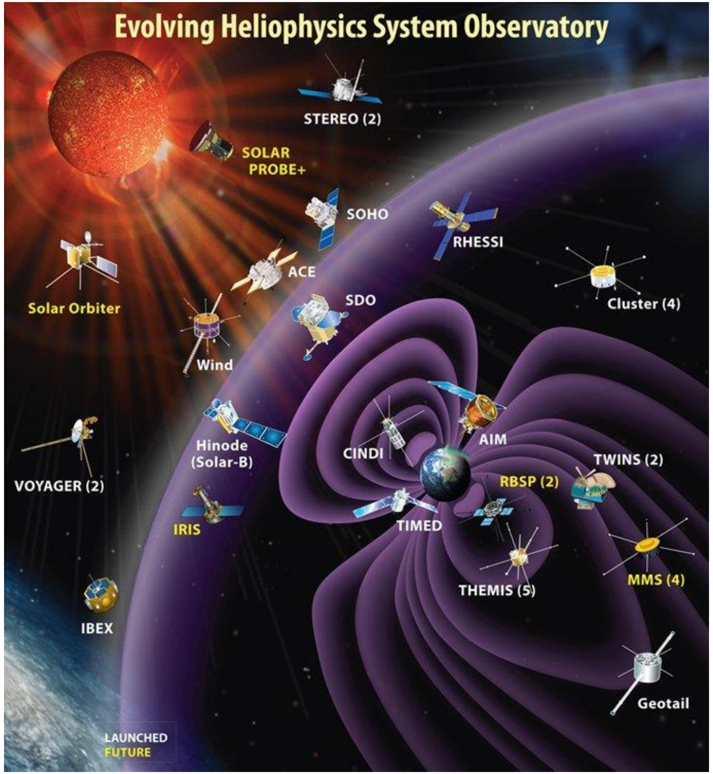
3.3 Our Sun, like all stars, has a life cycle. (PS1, LS1, ESS1)

November 2023: NASA's Mission Fleet

- There are 48 operating missions
- From the sun's corona to 120 AU.

These instruments and spacecraft measure the magnetic fields, the solar wind, particles and radiation storms.

Some missions carry imagers that study the solar surface, corona and interplanetary medium.



NASA HEAT

November 2023 : Mission Mathematics

The entire constellation of NASA missions collects terabytes of data every day from instruments across the entire solar system.

- ❑ The Sun is active and can impact technology on Earth via space weather. (PS1, PS2, PS4, ESS2, ESS3)
- ❑ Digital communication is used to communicate in space. (HS-PS4-2.)

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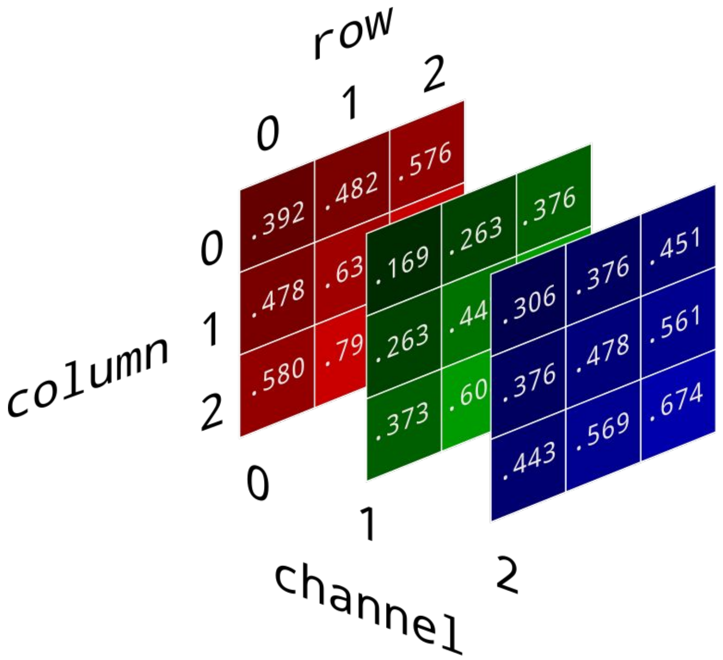
Instruments convert data into numbers that represent intensity values.

Images: Each value has a specific X and Y coordinate defining a particular pixel.

There may be three or more intensity values for each pixel depending on the filters used.



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Each number is converted into a binary code, which is a series of on-off values called bits. There are 8 bits to each byte of data.

000 = 0	100 = 4
001 = 1	101 = 5
010 = 2	110 = 6
011 = 3	111 = 7 etc

$01101001 = 2^0 + 2^3 + 2^5 + 2^6 =$ 105 base 10

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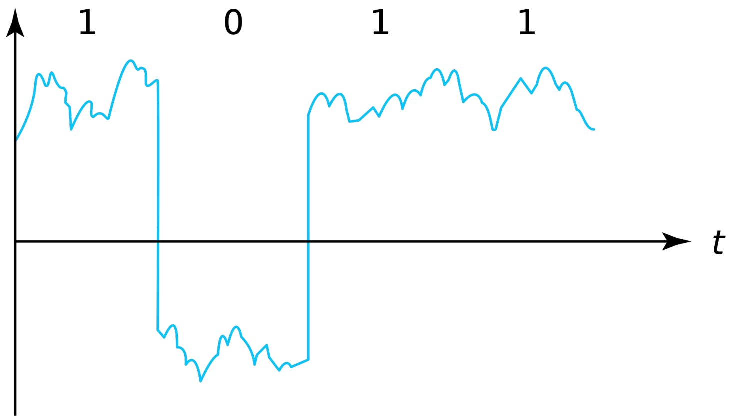
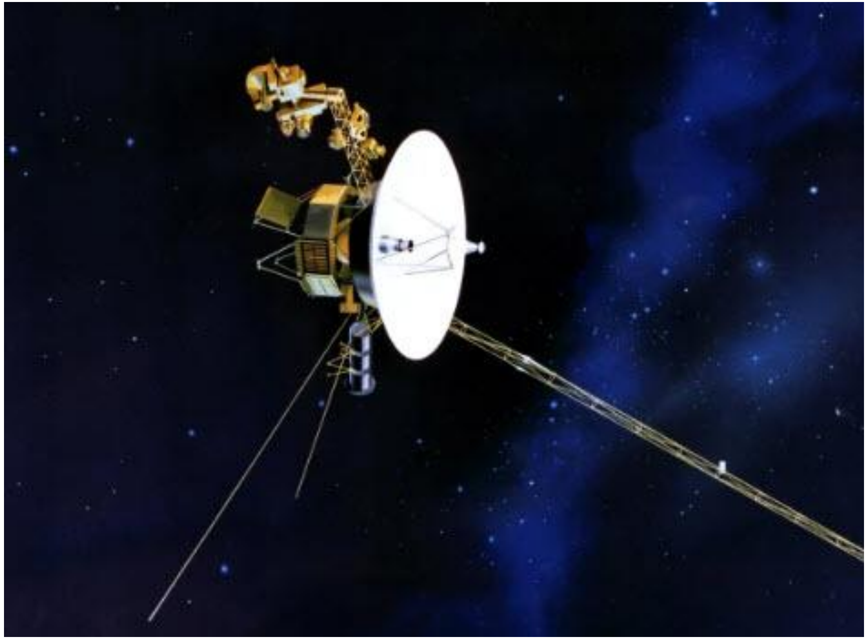
The strings of binary bits are transmitted by the spacecraft back to earth.

Transmitter ‘on’ = 1, Transmitter ‘off’ = 0.





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The ground stations receive the binary ‘on-off’ data, but after traveling millions of kilometers the signals are so weak that you need large dishes to collect the feeble energy.

Otherwise you can’t distinguish the ‘on’ state from the ‘off’ state in the transmitted signal.

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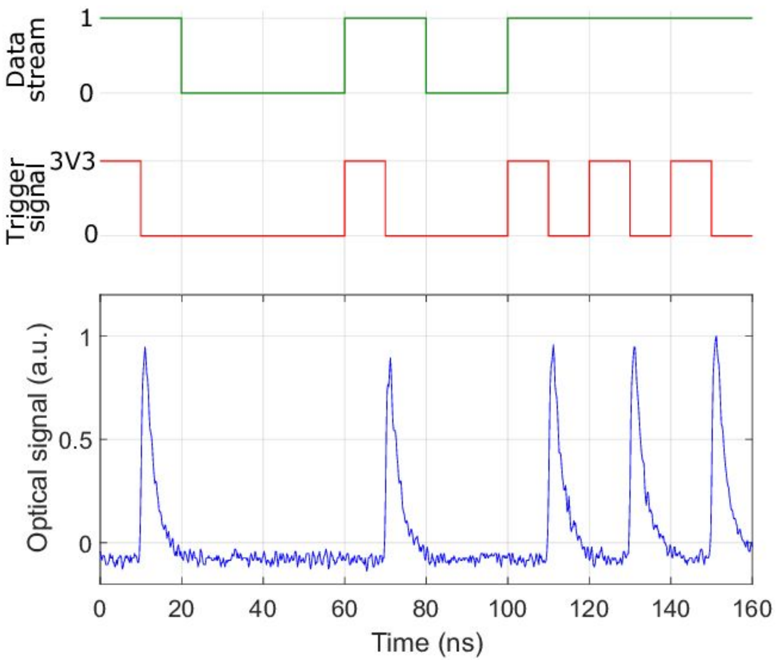
The received signal takes the form of pulses of radio energy that are

‘on’ = 1

‘off’ = 0

to represents the binary 1s and 0s of the numbers



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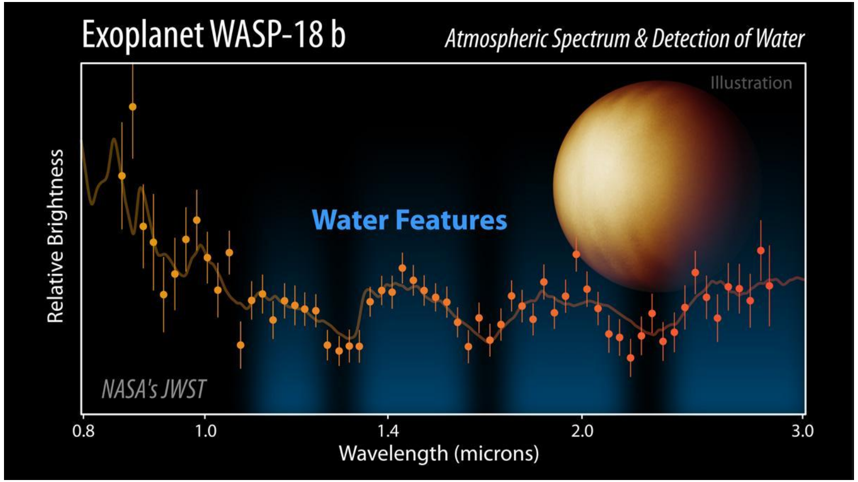
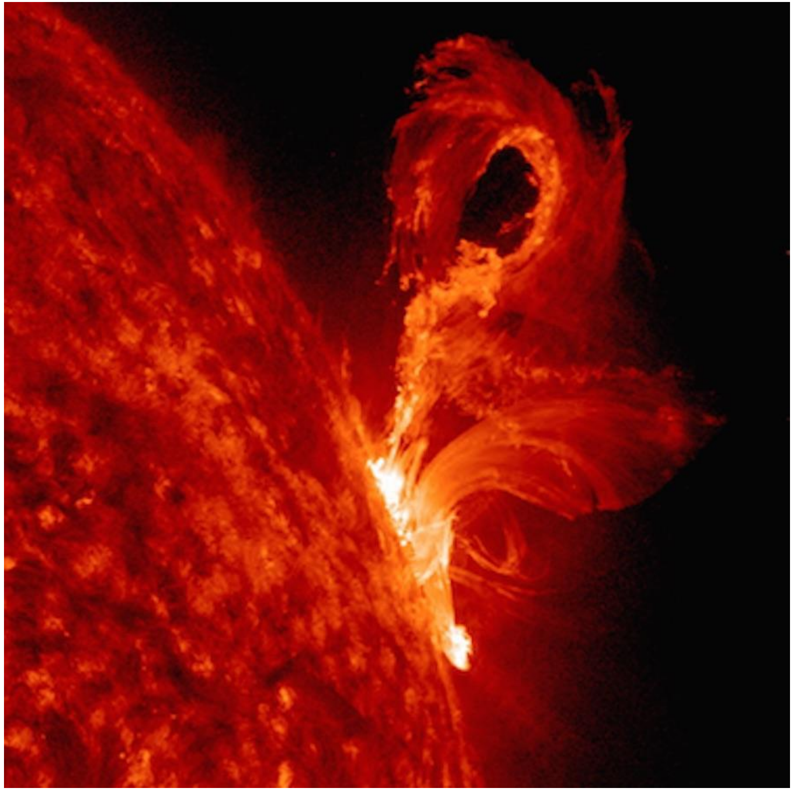
Then scientists translate the numbers back into digital images or other kinds of data such as spectra.





NASA HEAT

November 2023 : Data Transfer - Introductory

Problem: xx

Old Way: 300-baud modem (300 bits per second)

Typical image 1024x1024 pixels, 16-bit color

1024x1024 Pixels x 16 bits/pixel = 16 megabits/picture.

Transfer at 300 bits/sec: 16 million/300 = 3333 sec = **56 minutes**.

New Way: Cell Phone: 4G = 50 megabits/sec

Transfer time: 16 million/50 million = **0.3 seconds.**

November 2023 : Data Transfer - Exploratory

Problem: xx

Solar Dynamics Observatory transfers 130 megabits/sec at a continuous rate, 24/7/365.

In 1 days this equals 86,400 seconds/day x 130 megabits/second =

11.2 million million bits/day = 11.2/8 = **1.4 terabytes per day**.

This is used to transmit to Earth about 70,000 images every day,

or one image every second.

November 2023 : Data Storage - Exploratory

Average smartphone stores about 256 gigabytes

In one day, SDO accumulates 1.4 terabytes = 1400 gigabytes

That equals 1400 gigabytes

--------------------- = 5 ½ smartphones every day.

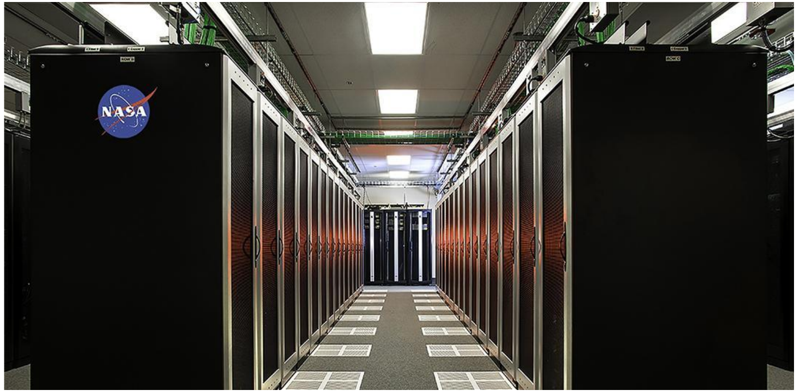
256 gigabytes

November 2023 : Data Storage - Exploratory

1.4 terabytes/day x 365 days/year =

511 terabytes/year or 0.5 petabytes for ONE MISSION

where 1000 terabytes = 1 petabyte.



As of 2023, there is over 213 petabytes of unique data stored in the NASA, NAS archival storage system.

213 petabytes = 213,000 terabytes

NASA needs 215 more petabytes of storage by the year 2025. That's a LOT of smartphones!

November 2023 : Data Transfer - Advanced

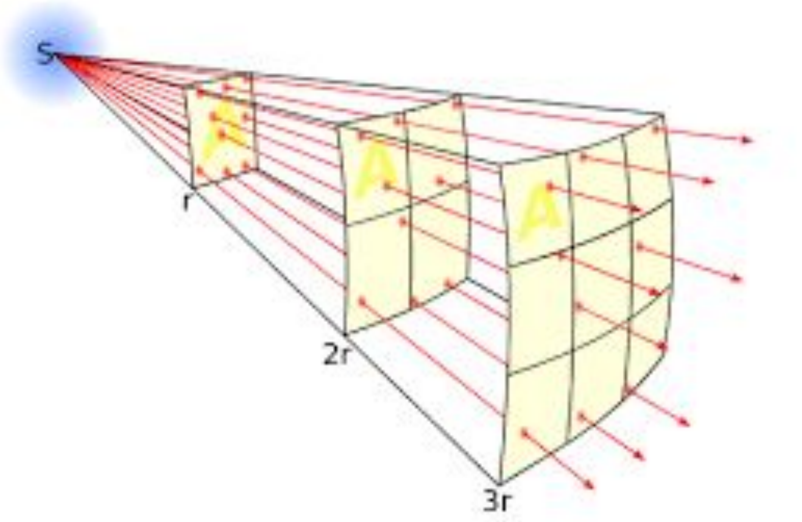
Problem:

The Inverse-square law

Spacecraft with a 100-watt transmitter

Intensity = Power/Area

= 100 W/1 m^2 = **100 w/m^2.**



November 2023 : Data Transfer - Advanced

The Inverse-square law

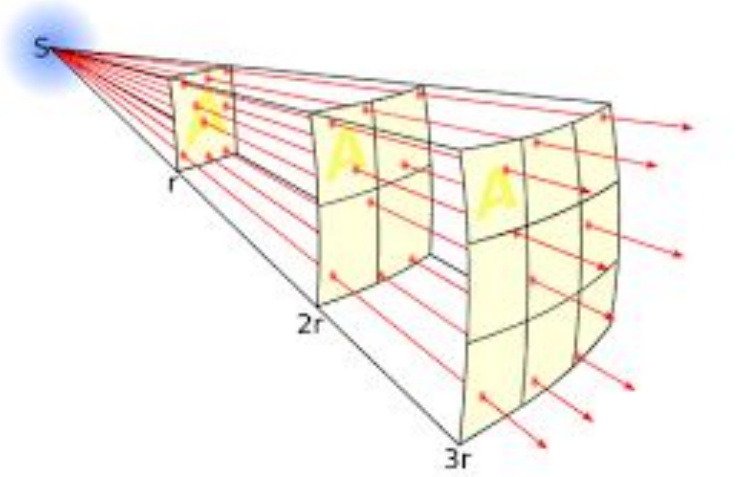
A 100-watt bulb is placed 10 meters away.

A 1-watt flashlight is placed 1 meter way.

I = power/area where Area = $4\pi R^2$

Light bulb: I = 100 watts/$4\pi(10m)^2$ = **0.08 watt/m^2**

Flashlight: I = 1 watt/$4\pi(1m)^2$ = **0.08 watt/m^2**

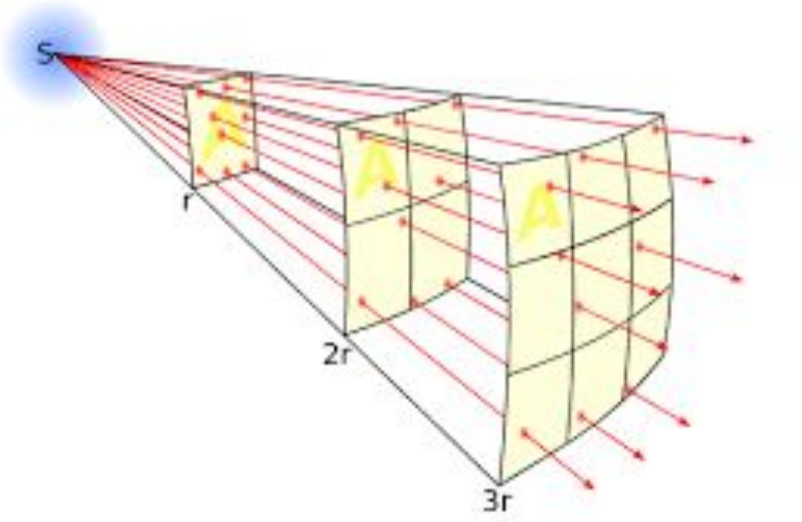


November 2023 : Picture Transfer - Advanced

Voyager 1 has a 23-watt transmitter

Distance = 120 AU ; 1AU = 1.5×10^{11} meters

Voyager distance = 120 x 1.5×10^{11} = **1.8×10^{13} m**.



Intensity = power/area

What area should we use?

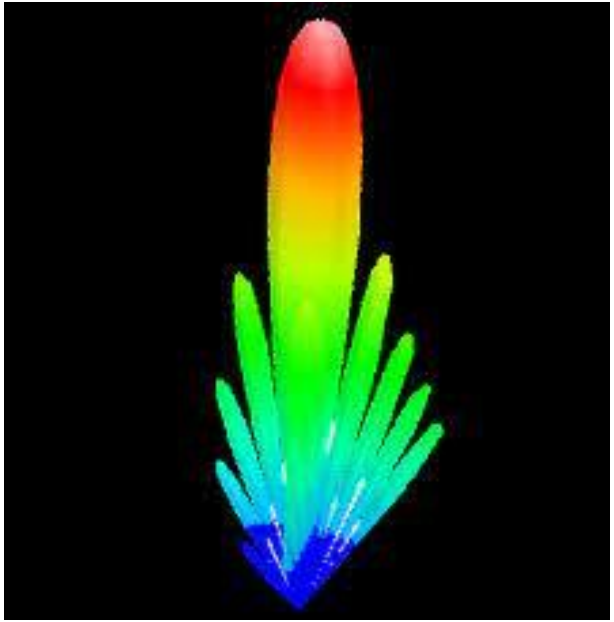
November 2023 : Picture Transfer - Advanced

R= **1.8×10^{13} m**.

What area should we use?

Surface area of a sphere with radius R:

$S = 4 \pi R^2 = 4(3.14)(1.8 \times 10^{13} m)^2 =$ **4.0×10^{27} m^2**



But the 34.7-m Voyager dish focusses the transmitted 23-watts of power into a beam with an angle of 0.5-degrees or an area of 0.25 square degrees.

The full sky has 41,253 square degrees, so the beam fraction at 120 AU is $A = 0.25/41253 = 6 \times 10^{-6}$.

So $S = 6 \times 10^{-6} \times 4.0 \times 10^{27} m^2 =$ **2.4×10^{22} m^2.**

November 2023 : Picture Transfer - Advanced

P = 23 watts and S = **$2.4x10^{22}$ m^2**

Intensity of the signal at Earth is then

I = power/area = 23 watts/$2.4x10^{22}$ m^2

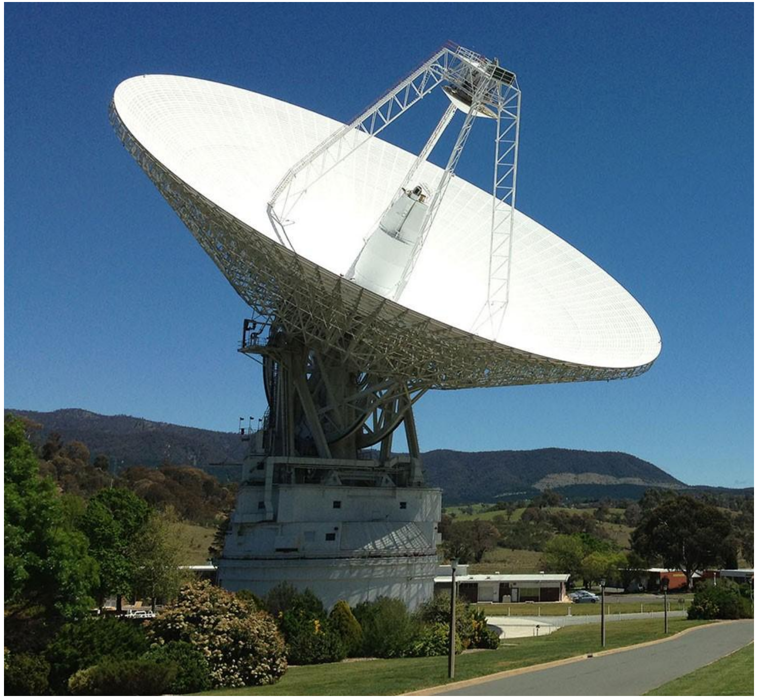
= $9.5x10^{-22}$ watts/m^2.

How do we detect a signal this weak? Use a BIG DISH!

R = 35m, Area = π $(35)^2$ = 3846 m^2.

So P at antenna = $9.5x10^{-22}$ x 3846

= **$3.7x10^{-18}$ watts.**



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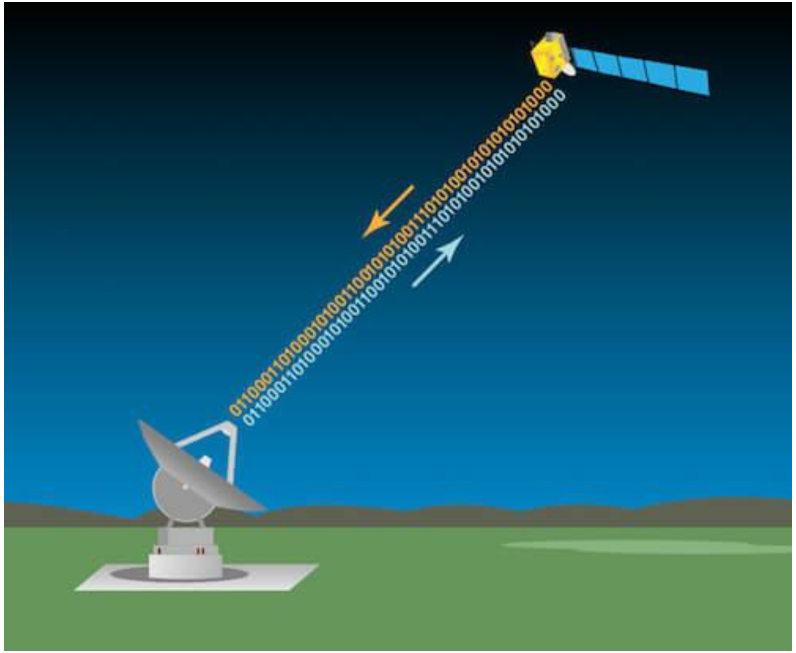
Voyager 1 is at 120 AU. Its rate is **160 bits/sec** now.

Back in 1994, when Voyager was closer to Earth, we still received data at **7,400 bits/sec**. In 2050 it will be slowed to 40 bits/sec.

Voyager images contain 800 lines, 800 dots (pixels) per line, and 8 bits per pixel. Most pixels are black so data can be compressed by 60%.



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Encounter	(DSN with 1979–1981 capability)	
	Inverse Square	Expected Rate (bps)
Jupiter	1/1	115,200 (ref.)
Saturn	1/4	~29,000
Uranus	1/13	~9,000
Neptune	1/36	~3,200
120 AU	1/14,400	160
1500 AU	1/2,250,000	1

December 2023

Next Time: HBY and Citizen Science

December 19, 7PM EST; 4PM PST

Citizen science has enabled many heliophysics discoveries, including new types of auroras.

How high up in the sky are auroras?