National Aeronautics and Space Administration

The Heliophysics Big Year

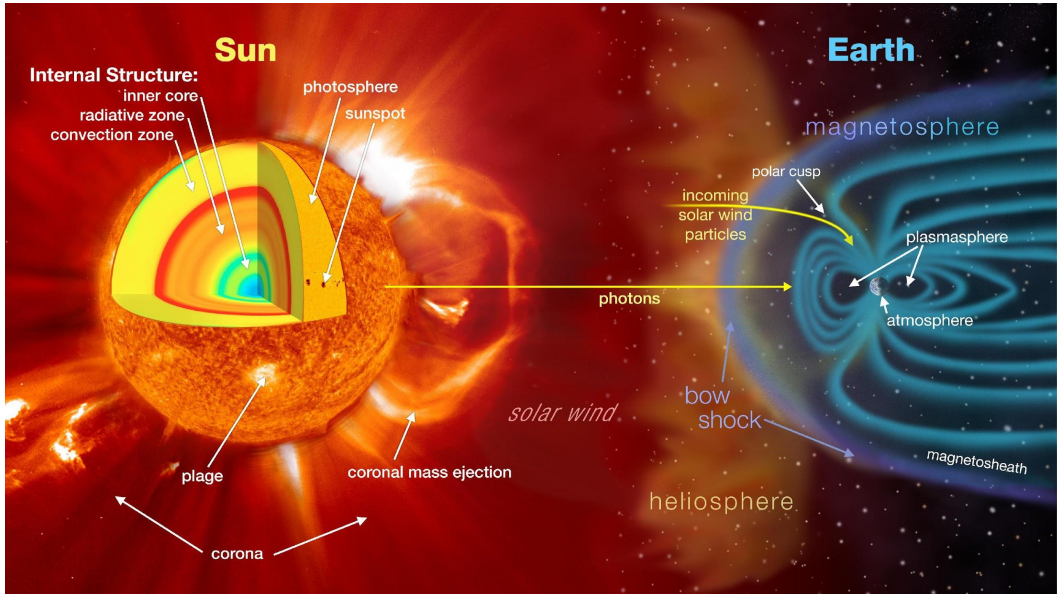
Dr. Sten Odenwald, Astronomer

NASA Heliophysics Education Activation Team

December 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 and how those changes pose a hazard to humans on Earth and in space



NASA HEAT

Heliophysics Big Year Timeline

Annular Eclipse

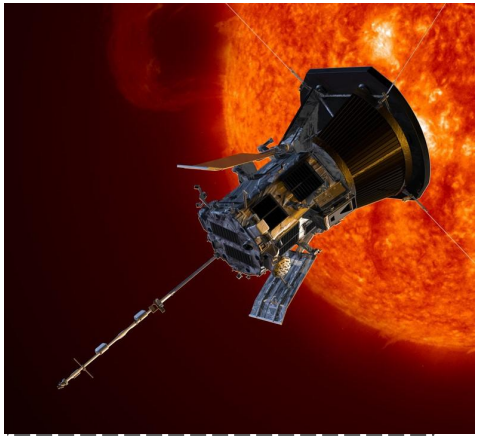
October 14, 2023

Total Eclipse

April 8, 2024

Solar Parker Probe Perihelion

December 24, 2024



NASA HEAT

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/

February 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)

February 2024 – Fashion, Color and Light

What is color?

Investigating visible light
and color filters
in fashion and
heliophysics

February 2024

The sun is a white star not a yellow one so where does color come from?

The Sun is the primary source of light in the solar system. (PS1, PS2, PS3,PS4, ESS1)

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)

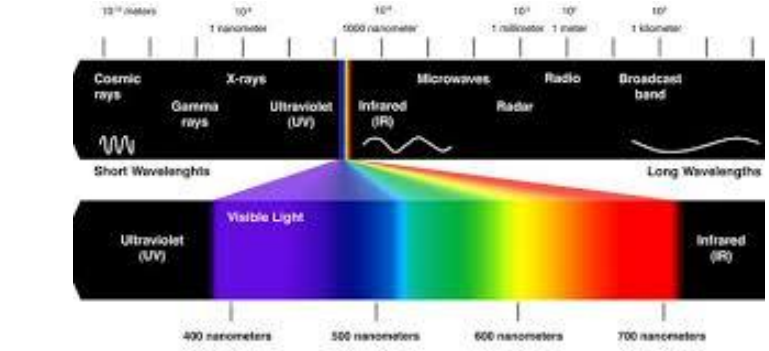
February 2024: Sunlight and the Visible Spectrum

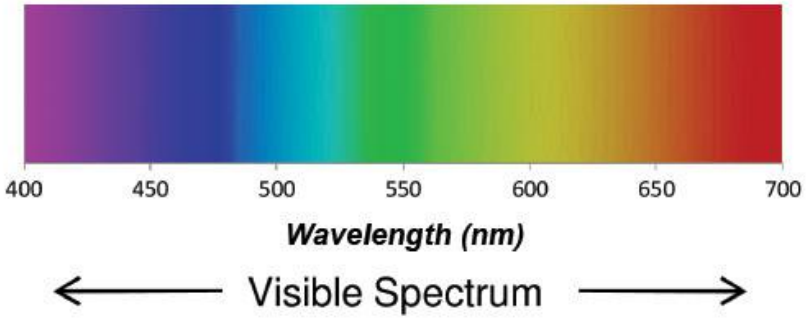
Light is produced by photons that carry energy.

The amount of energy they carry depends on their wavelength.

We can sort these photons from their highest energy to their lowest energy by creating a ‘spectrum’ of wavelengths.

This spectrum, for wavelengths the human eye is sensitive to is called the Visible Spectrum.





NASA HEAT

February 2024: Origin of Color

Color does not exist in Nature.

Color is a purely internal coding of the wavelengths of visible light by the brain.

It is called a ‘qualia’ by brain researchers, and like consciousness, it is not known where the perception of color comes from.

February 2024: Origin of Color

The interaction of light with matter tends to favor some wavelengths over others.

Light from the sun passing through dust in the atmosphere causes shorter wavelengths to be deflected out of the light into other directions.

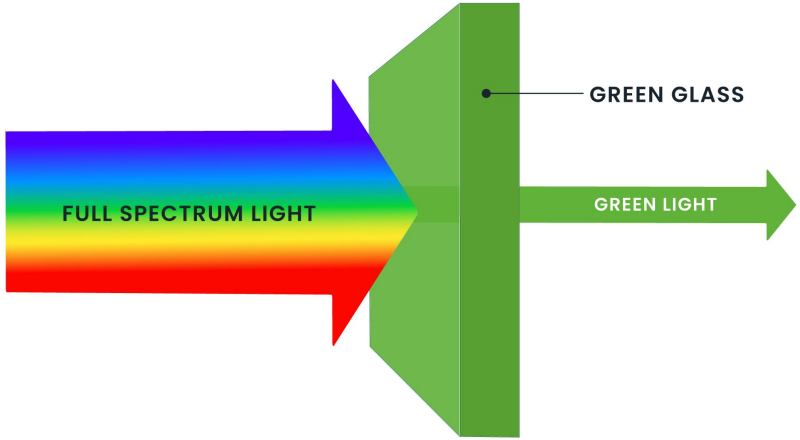
This leaves behind longer wavelength light, which we perceive as red. Meanwhile, the shorter wavelength light is scattered across the sky giving the sky a blue color

February 2024: Filtered Light

Like sunlight during a sunset, visible light interacting with matter can cause some of this light to be absorbed if the chemistry of the material is just right.

The matter will pass some wavelengths but not others.

We call this a ‘light filter’, or just a filter for short.

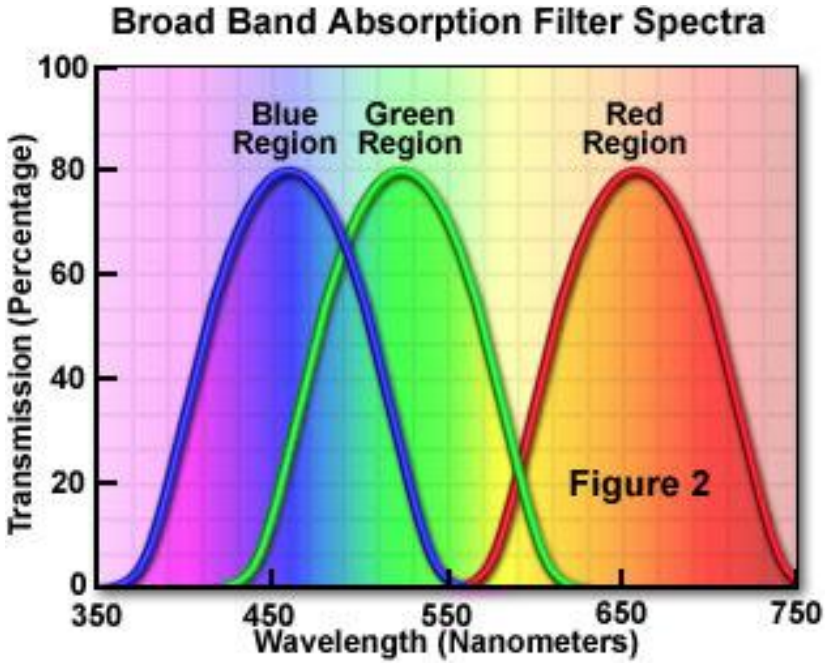


February 2024: How filters work

Filters can be designed to pass only specific wavelengths.

In photography, and in the human retina, light is filtered into its Red, Green and Blue components.

The same principle applies to fashion and art using different pigments. By balancing the RGB properties of compounds, millions of different colors can be created

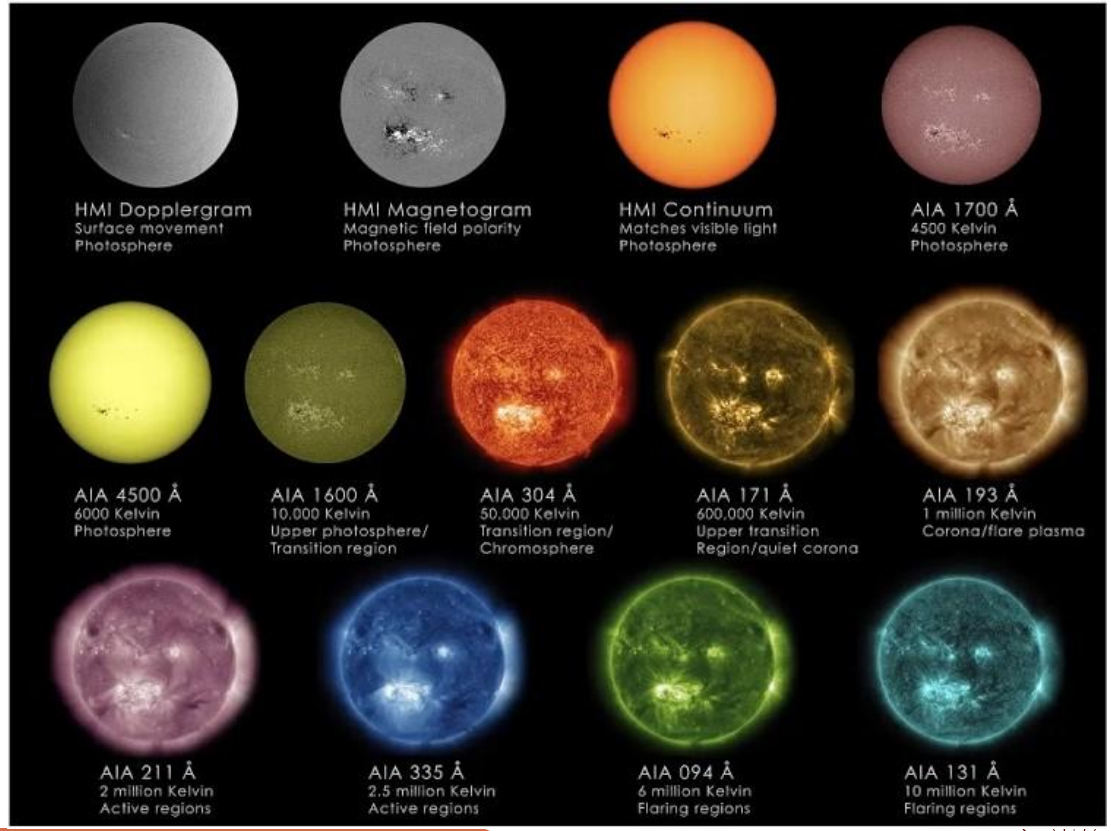


NASA HEAT

February 2024: Filters in Heliophysics

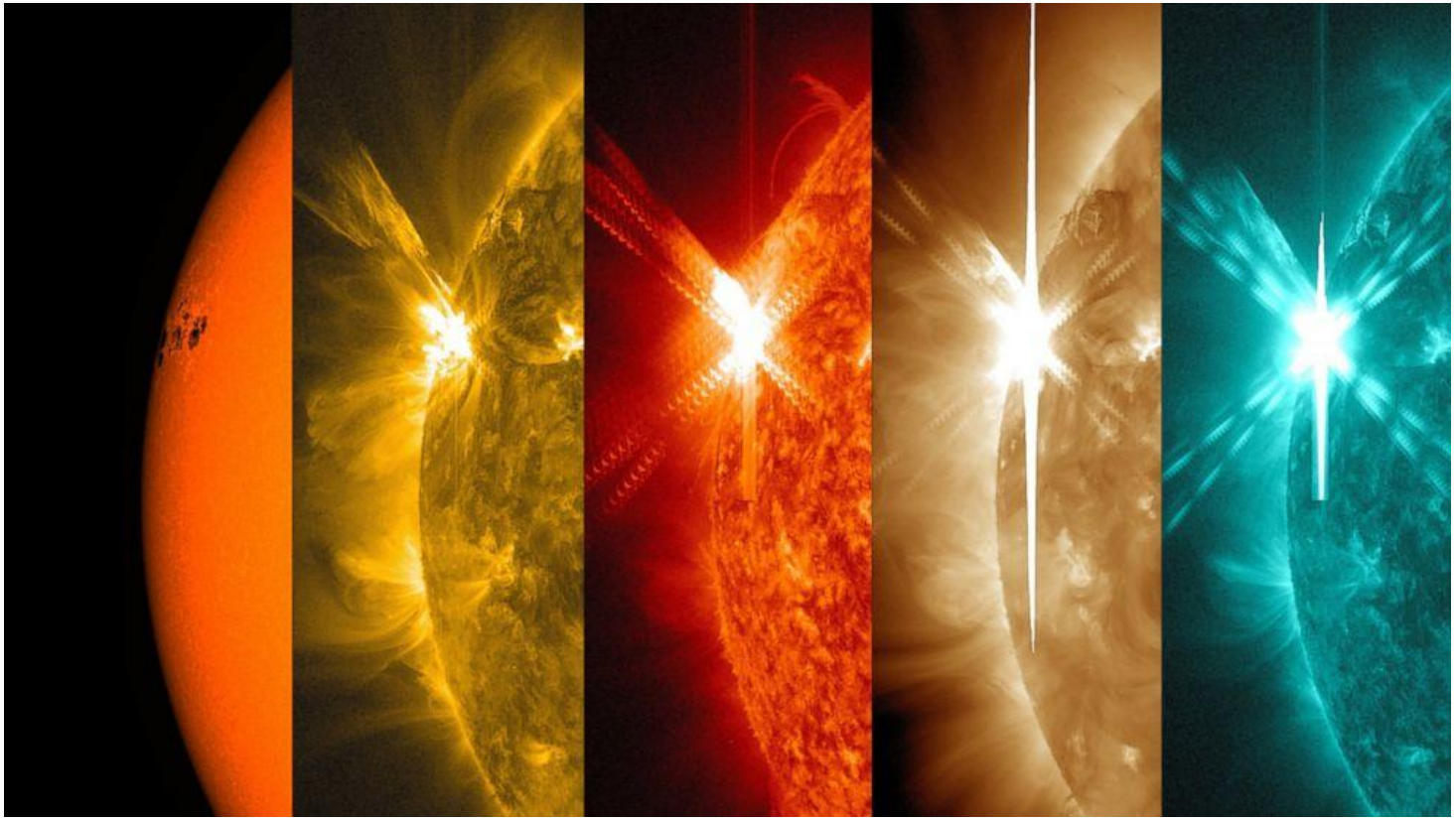
Different physical processes produce light in different specific colors.

In Heliophysics we use this principle to diagnose why the sun works the way it does.



NASA HEAT

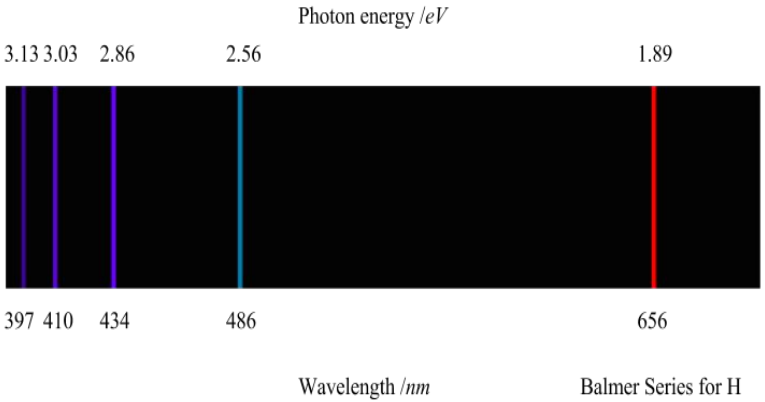
February 2024: Filters in Heliophysics



NASA HEAT

February 2024: Simple Transmission Filters

Beginners: You want to study the sun by using a filter that passes only the light from hydrogen at a wavelength near 656 nanometers (nm). Which filter should you use?



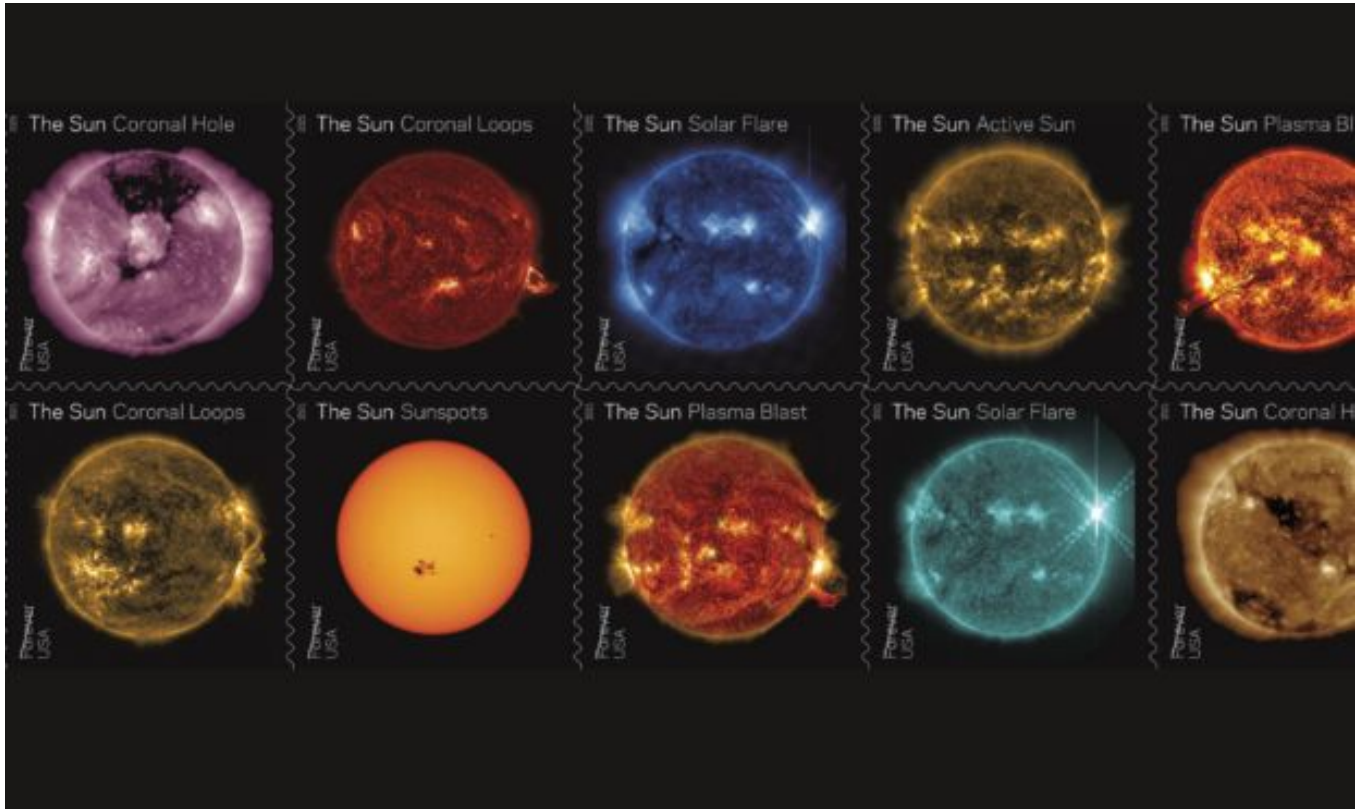
A) Passes wavelengths shorter than 700 nm.

B) Passes wavelengths longer than 450 nm

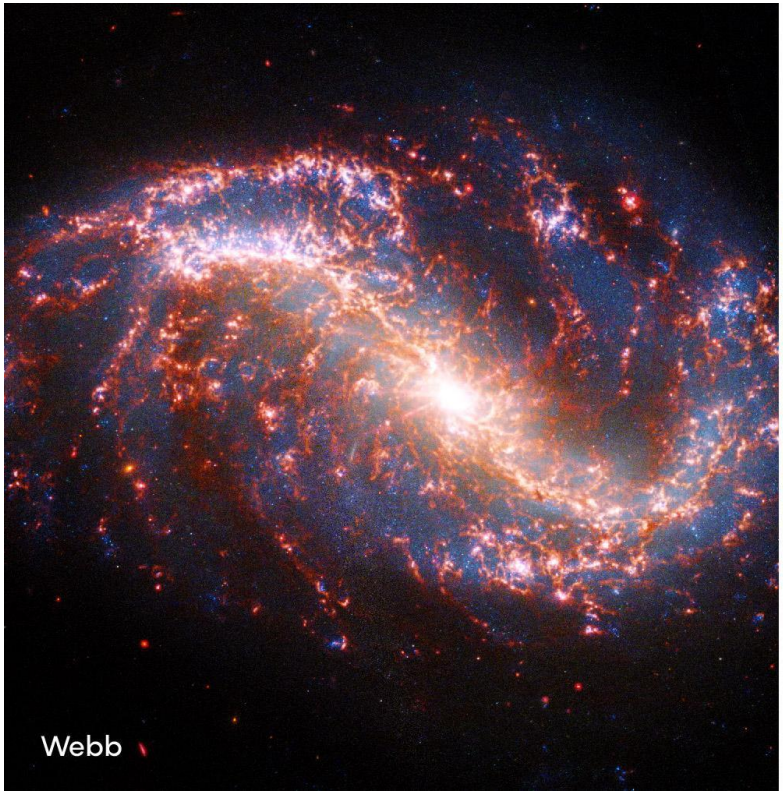
C) Passes wavelengths from 500 to 700 nm

D) Passes wavelengths from 650 to 660 nm.

February 2024 – Simple Transmission Filters



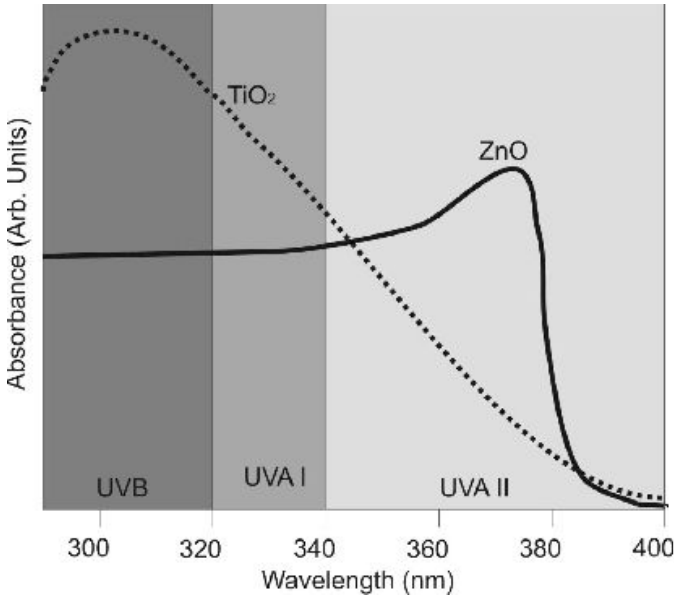
February 2024 – Simple Transmission Filters



NASA HEAT

February 2024 – Intermediate: UV Filters and Sunblock

Zinc oxide and bandpass filters



NASA HEAT

February 2024 – Intermediate: UV Filters and Sunblock

Applying a sunblock lotion.

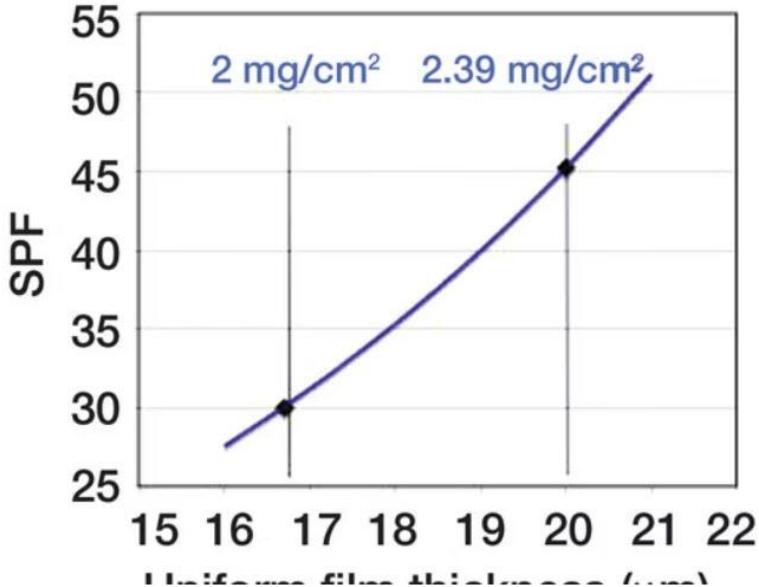
A sunbather applies a sunblock to her entire exposed body surface.

How much should she use to get an SPF of 45 so that she can be in the sun for the entire day?

Surface area = 1.8 meters^2

Bathing suit coverage = 30%

Cream density = 2.4 gm/cm^3



Credit Paul McCormick:
http://tinyurl.com/3aj9v7mb

NASA HEAT

February 2024 – Intermediate: UV Filters and Sunblock

Skin coverage: 1.8 m^2 x 0.7 = **1.3 m^2**

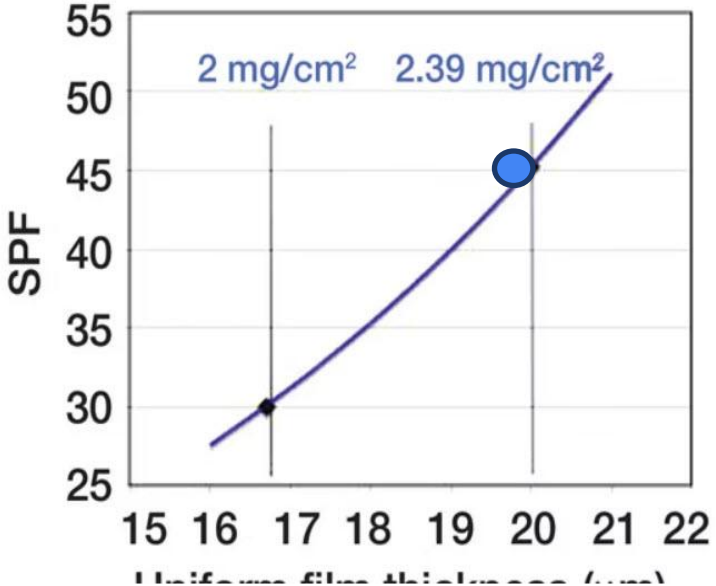
Graph says we need a **20 micron** layer to get to SPF = 45.

Volume of liquid = Area x thickness

=1.3m^2 x 20 x 10^{-6} meters = 2.6x10^{-5} m^3

In terms of cubic centimeters:

2.6x10^{-5} m^3 x (100 cm/m)^3 = **26 cm^3**.



Credit Paul McCormick:
http://tinyurl.com/3aj9v7mb

NASA HEAT

February 2024 – Intermediate: UV Filters and Sunblock

We need to apply 26 cm^3 of sunblock. The density is 2.4 gm/cm^3 so we need

26/2.4 = **11 grams of sunblock**.

Lower quality screens have lower density and require more cream to get the same SPF.

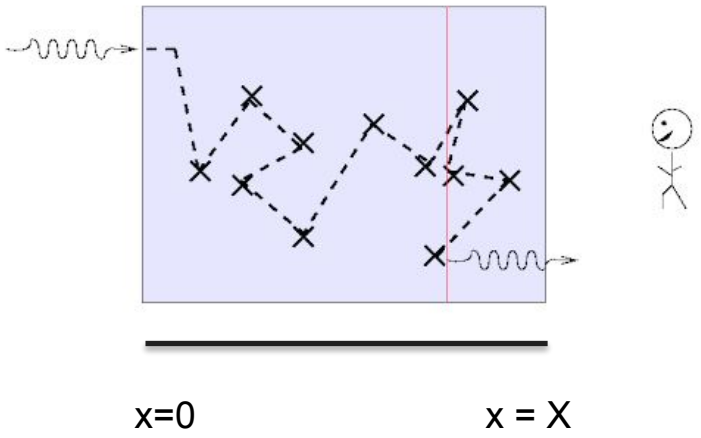
February 2024 – Advanced – Light transport through matter

Opacity and color.

Light is attenuated when it passes through matter according to Beer's Law, which can be stated mathematically as

$$I(X) = I_o e^{-kX}$$

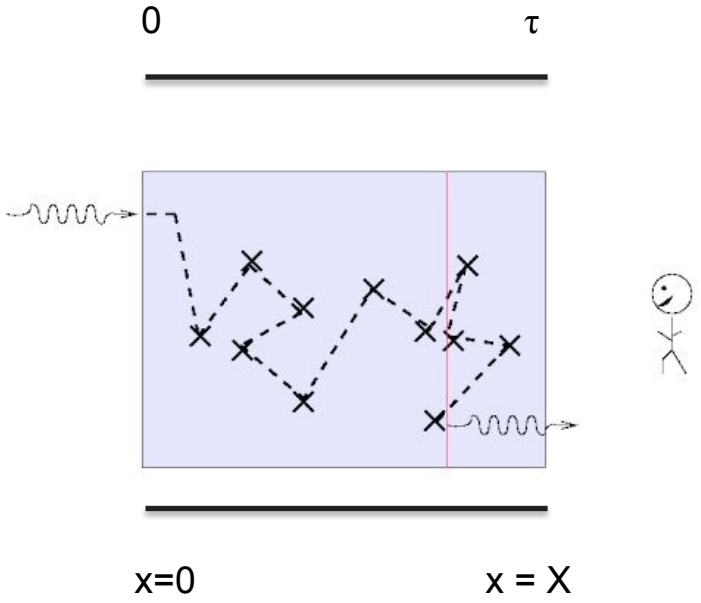
where k is the absorption coefficient, which depends on the wavelength of the light and the composition of matter



February 2024 – Advanced – Light transport through matter

This can also be expressed in terms of the optical depth of the material given by the Greek letter tau (τ).

$$I(X) = I_o e^{-\tau}$$



February 2024 - Advanced – Light transport through matter

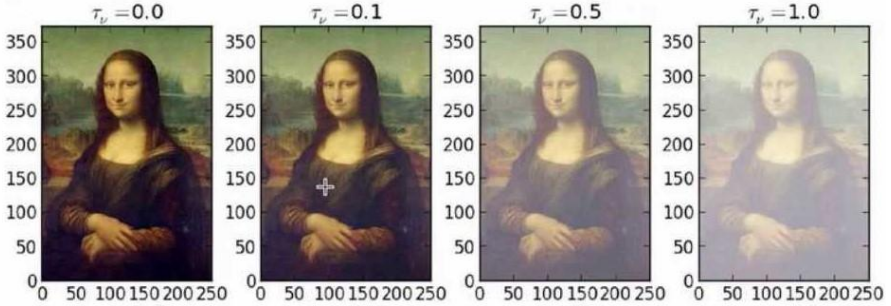
Absorption of radiation depends on the wavelength of the radiation.

Suppose that you have a material which has the following property:

$K = 0.35\ cm^{-1}$ at a wavelength of 300 nm

$K = 0.05\ cm^{-1}$ at a wavelength of 800 nm

What percentage of the light at these two wavelengths will remain after passing through 1.5 centimeters of a filtering material?



February 2024 - Advanced – Light transport through matter

$K = 0.35\ cm^{-1}$ at a wavelength of 300 nm

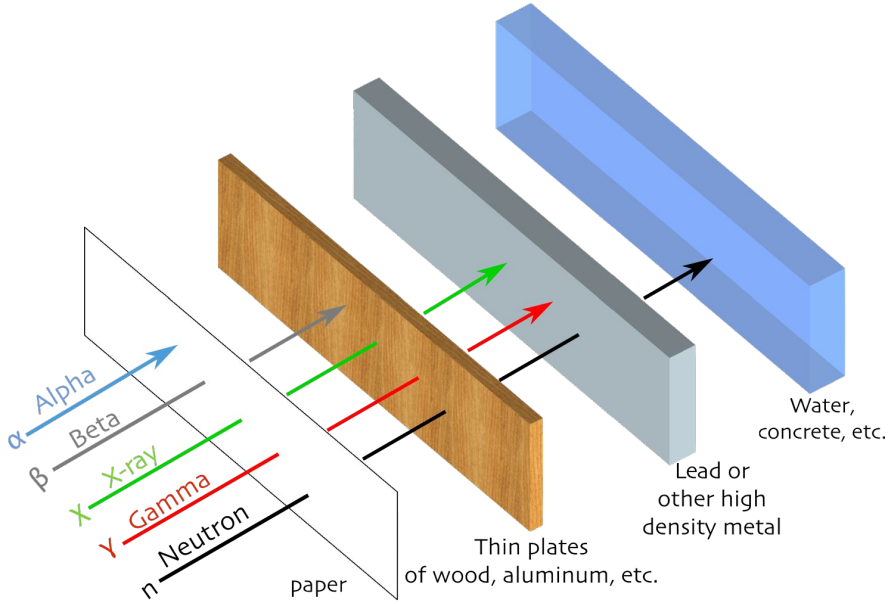
X = 1.5 centimeters

$$I(X) = I_o\, e^{-(0.35)(1.5)}$$

$I(1.5) = Io\ e^{-0.53}$ (i.e. $\tau = 0.53$)

$I(1.5) = I(0) \times 0.59$

So 100% x I(1.5)/Io = 59%



February 2024 - Advanced – Light transport through matter

K = 0.35 cm^{-1} at a wavelength of 300 nm

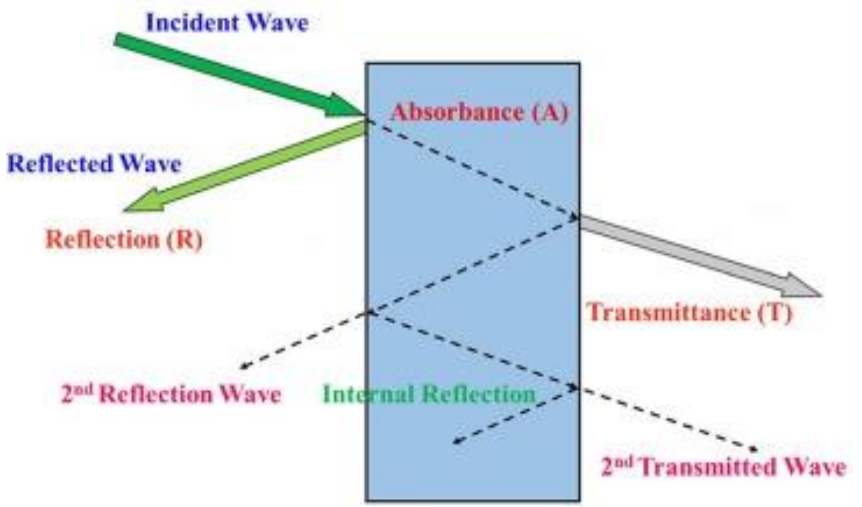
X = 1.5 centimeters

$$\mathbf{I(X) = I_o\, e^{-(0.05)(1.5)}}$$

$I(1.5) = Io\ e^{-0.075}$ (i.e. $\tau = 0.075$)

$I(1.5) = I(0) \times 0.93$

So 100% x I(1.5)/Io = 93%

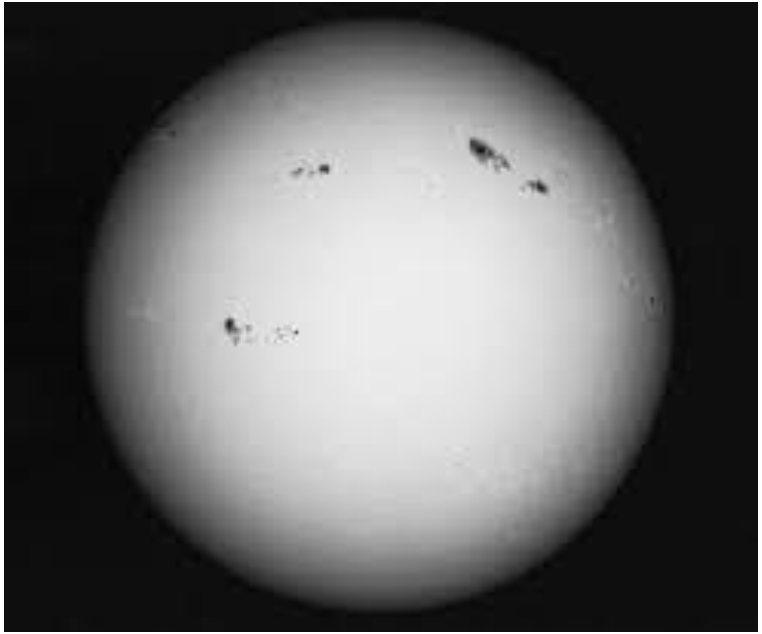


NASA HEAT

February 2024 - Advanced – Light transport through matter

So for the light at 300 nm, it will be attenuated to 59% of its initial brightness. The optical depth of the material is $\tau = 0.53$

For light at 800 nm, it will be attenuated to 93% of its initial intensity. The optical depth is only $\tau = 0.075$



February 2023: Experiencing the Sun

Next Time!

The Sun may be 93 million miles away, but we can still experience it from home, whether its watching eclipses, auroras, or observing its daily influence on our lives.