



The Heliophysics Big Year

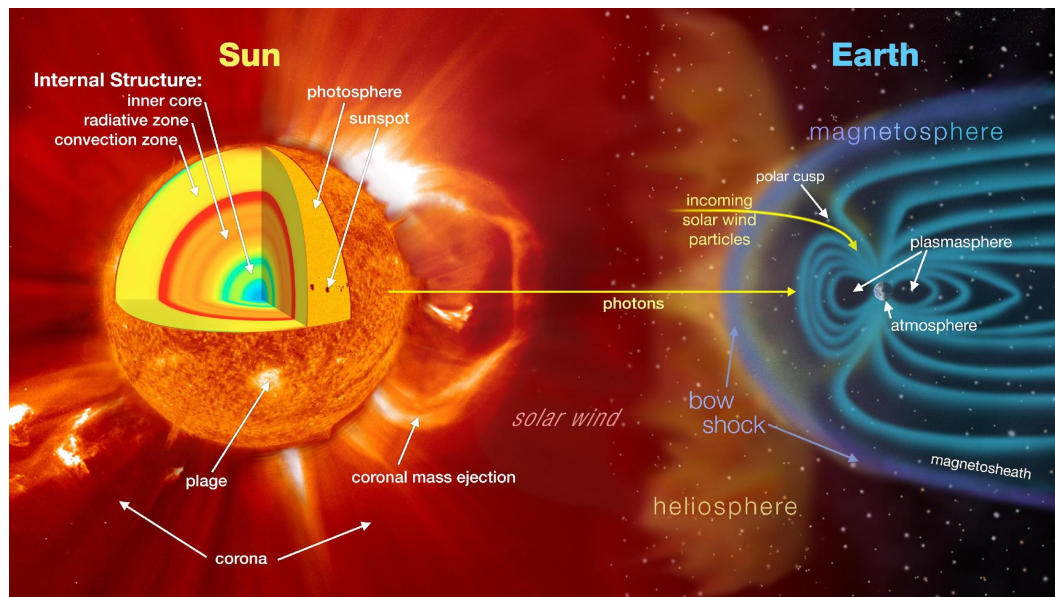
Dr. Sten Odenwald, Astronomer



May 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



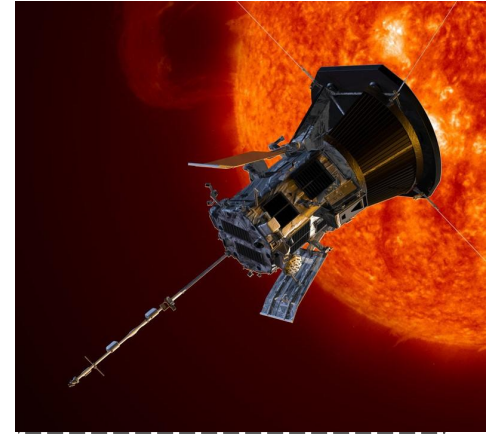
Total Eclipse

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/>

May 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)

May 2024 – Visual Art

The Sun has been depicted in art for thousands of years.

One of the most common beliefs is that the Sun is yellow, but it is actually white, as pictures from the ISS always show.



Credit: NASA

May 2024 – Visual Art

When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2).

What color is the sun in this photo?



Credit: Jim Grant/EarthSky Photos

<https://earthsky.org/earthsky-community-photos/entry/60281/>

May 2024 – Visual Art

Representations of the ancient Sun in art.



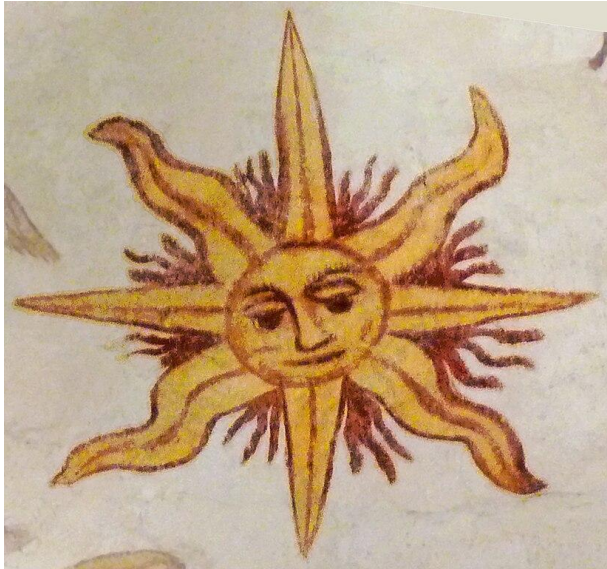
Tanum petroglyph
Underslos Museum, Sweden



Akhenaten sun disk
Kestner Museum, Germany

May 2024 – Visual Art

The Medieval Sun



Wikipedia – ca 1610 BCE



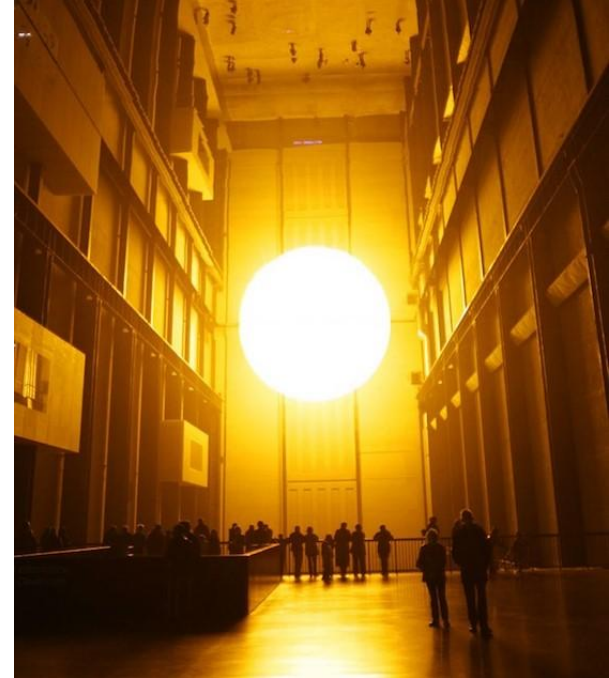
The Celestial Atlas of Andreas Cellarius ca 1660

May 2024 – Visual Art

Artist *Olafer Elaiisson's The Weather Project* was an installation unveiled at the Turbine Hall, in the Tate Modern in London - 2003

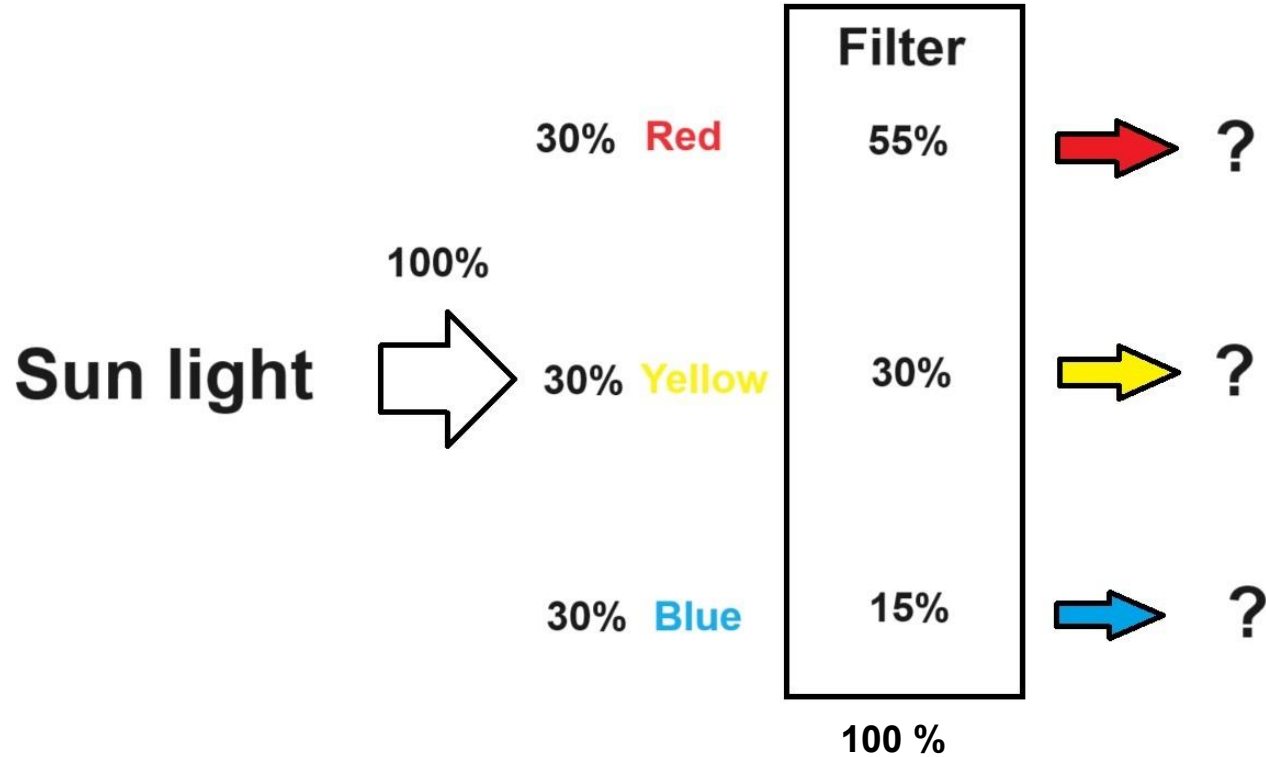
This installation employed a semi-circular screen, a ceiling of mirrors, and artificial mist to create the illusion of a sun.

200 mono-frequency lights created the image of an indoor sunset seen through the mist seeping into the room.

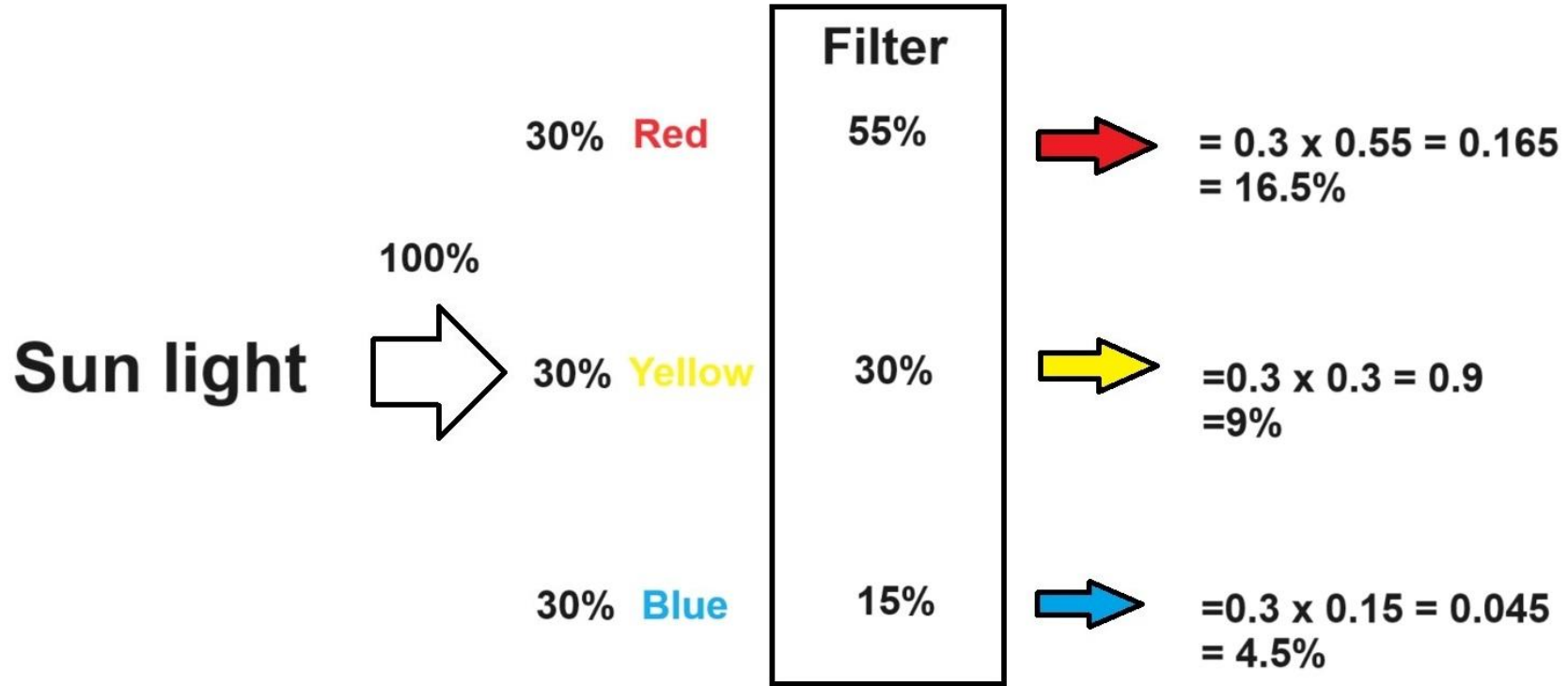


Wikipedia – Michael Reeve

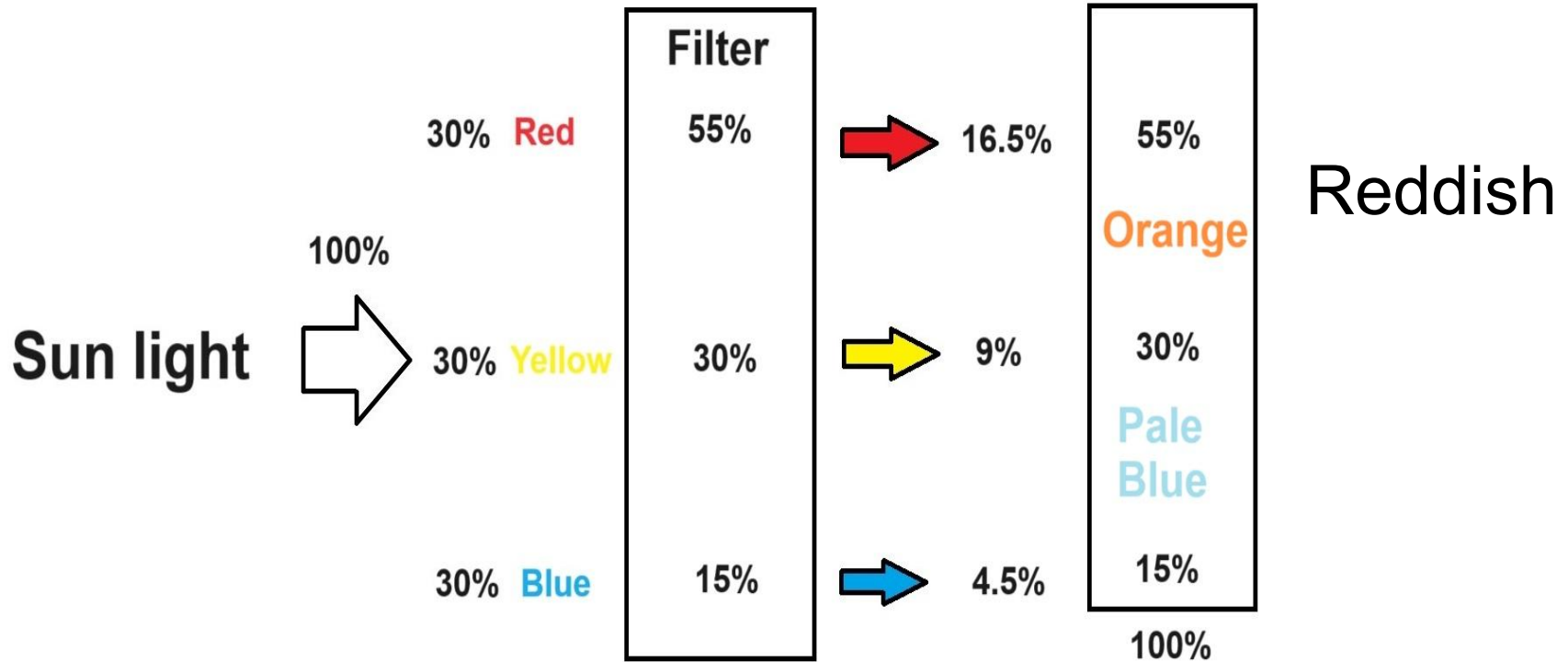
May 2024 – Beginning – Light Filters and Color



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May 2024 – Beginning – Light Filters and Color

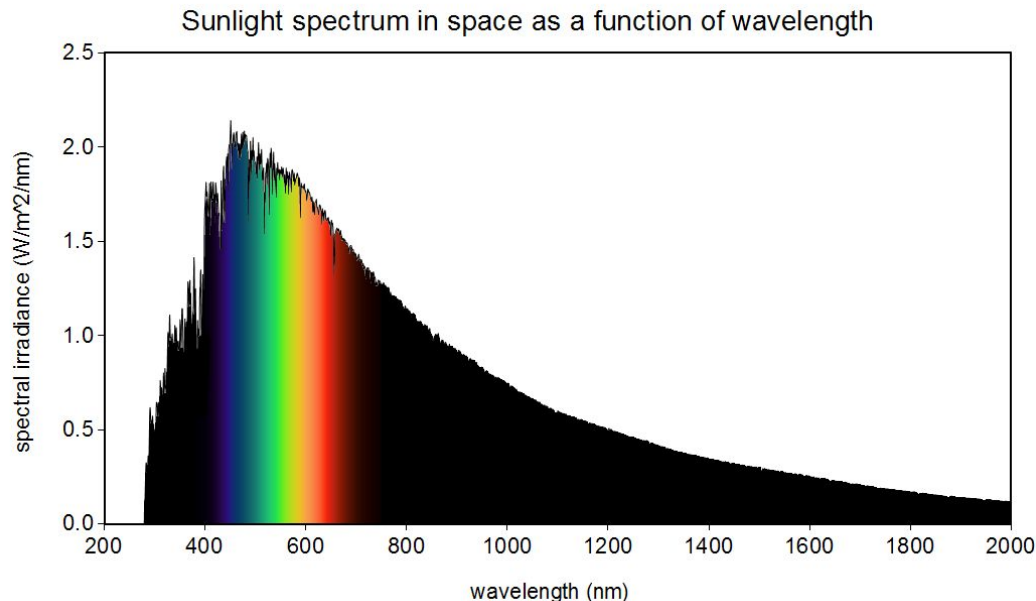


May 2024 – Intermediate – Dust Size and Light Color

What we see as 'white light' is actually created by our brain. Light does not come in colors but does come in wavelengths.

Light at different wavelength will be scattered by dust, and this gives the atmosphere and volcanic ash plumes their characteristic color.

Let's see how this works!



Christopher S. Baird, data source: American Society for Testing and Materials Terrestrial Reference.

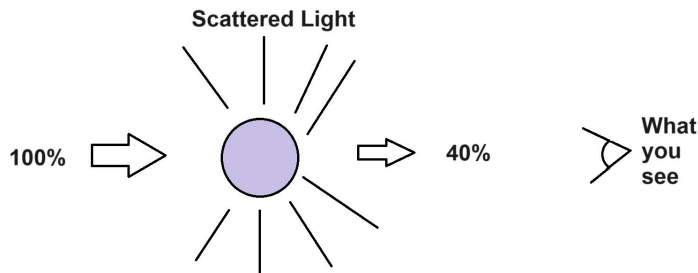
May 2024 – Intermediate – Dust Size and Light Color

Typical dust particles in the atmosphere have sizes of about 0.1 microns or less.

Dust particles from volcanic eruptions have sizes of about 1.5 microns.

	450 nm	550 nm	650 nm
Atmosphere	60%	40%	10%
Volcano	10%	40%	60%

The table shows about how much light is **scattered** by these dust particles at red, yellow and blue wavelengths assuming 100% of the light enters the dust at each wavelength.



Example: At 450 nm, 60% of the incoming light is removed due to dust grain scattering so only 40% remains at this wavelength.

May 2024 – Intermediate – Dust Size and Light Color

From this table, predict what you will see as the color of:

A) A sunset with ordinary atmospheric dust

B) The full moon looking through a dust layer from a volcanic eruption.

	450 nm	550 nm	650 nm
Atmosphere	60%	40%	10%
Volcano	16%	50%	70%
Sunlight	100%	85%	75%

Sunlight does not have the same intensity at all wavelengths. The 'Sunlight' row gives the maximum amount of intensity at the three wavelength bands.

May 2024 – Intermediate – Dust Size and Light Color

A sunset with ordinary atmospheric dust

	450 nm	550 nm	650 nm
Atmosphere	60%	40%	10%
Volcano	16%	50%	70%
Sunlight	100%	85%	75%

How much light is scattered?

Blue (450 nm) = $100\% \times 60\% = 60\%$

Yellow (550 nm) = $85\% \times 40\% = 34\%$

Red (650 nm) = $75\% \times 10\% = 7.5\%$

How much light is transmitted?

Blue = $100\% - 60\% = 40\%$

Yellow = $100\% - 34\% = 66\%$

Red = $100\% - 7.5\% = 92.5\%$



Sunsets
are red

May 2024 – Intermediate – Dust Size and Light Color

The full moon looking through a dust layer from a volcanic eruption

	450 nm	550 nm	650 nm
Atmosphere	60%	40%	10%
Volcano	16%	50%	70%
Sunlight	100%	85%	75%

How much light is scattered?

Blue (450 nm) = $100\% \times 16\% = 16\%$

Yellow (550 nm) = $85\% \times 50\% = 42\%$

Red (650 nm) = $75\% \times 70\% = 52\%$

How much light is transmitted?

Blue = $100\% - 16\% = 84\%$

Yellow = $100\% - 42\% = 58\%$

Red = $100\% - 52\% = 48\%$



The moon is blue

May 2024 – Advanced – Rayleigh's Law

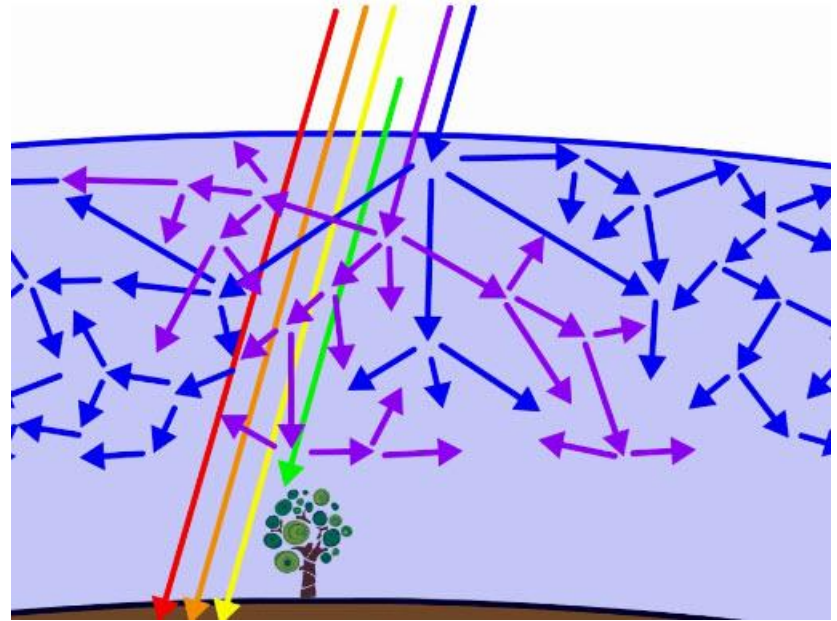
The way that dust scatters light is not random but follows a mathematical relationship called **Rayleigh's Law**.

$$I = I_0 \frac{A}{\text{Wavelength}^4}$$

May 2024 – Advanced – Rayleigh's Law

Use Rayleigh's Law to explain why sunsets are red (650 nm) and the sky is blue (450 nm)

$$I = I_0 \frac{A}{\text{Wavelength}^4}$$



NOAA Global Monitoring Lab

May 2024 – Advanced – Rayleigh's Law

Use Rayleigh's Law to explain why sunsets are red (650 nm) and the sky is blue (450 nm)

$$I = I_0 \frac{A}{\text{Wavelength}^4}$$

$$I(\text{blue}) = I_0 \times \frac{A}{(450\text{nm})^4} = 2.4 \times 10^{-11} I_0 A$$

$$I(\text{red}) = I_0 \times \frac{A}{(650\text{nm})^4} = 5.6 \times 10^{-12} I_0 A$$

$$\frac{I(\text{blue})}{I(\text{red})} = \frac{2.4 \times 10^{-11} I_0 A}{5.6 \times 10^{-12} I_0 A} = 4.3$$

So, 4.3x more blue light is scattered than red light

May 2024 – Advanced – Rayleigh's Law-ChatGPT

ChatGPT Query. Using Rayleigh's Law, calculate how much more blue light (450 nm) is scattered than red light (650nm). Show the calculation.

Given the wavelengths of blue light and red light:

- Blue light:** 450 nm (or $450\text{ nm}=450\times10^{-9}\text{ m}$)
- Red light:** 650 nm (or $650\text{ nm}=650\times10^{-9}\text{ m}$)

The calculations based on Rayleigh's Law show:



- Scattering of blue light (450 nm):** 2.44×10^{25} (inversely proportional to the fourth power of the wavelength).
- Scattering of red light (650 nm):** 5.60×10^{24} (inversely proportional to the fourth power of the wavelength).

To find out how much more blue light is scattered than red light, we calculate the ratio:

Scattering ratio=Scattering-blue / Scattering-red

$$\text{Scattering ratio} = 2.44\times10^{25} / 5.60\times10^{24} \approx \mathbf{4.35}$$

Therefore, blue light at 450 nm is approximately **4.35** times more scattered than red light at 650 nm.

This result confirms the significant difference in scattering between these two wavelengths of light.

Next Time!

The Sun also shows up in music and dance – two areas that will be celebrated this month. Carly Simon’s song, “You’re so vain” mentioned the total eclipse of the sun in Nova Scotia.

So, how do songs about the Sun compare to the sunspot cycle?

Are there more of them when there are more sunspots?

June explores how to test data for correlations using statistics.