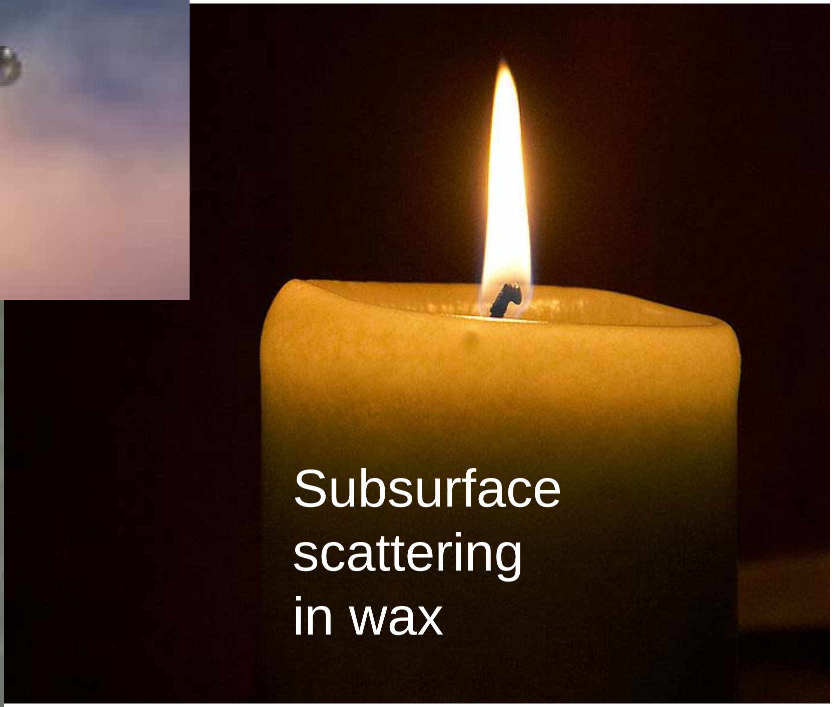
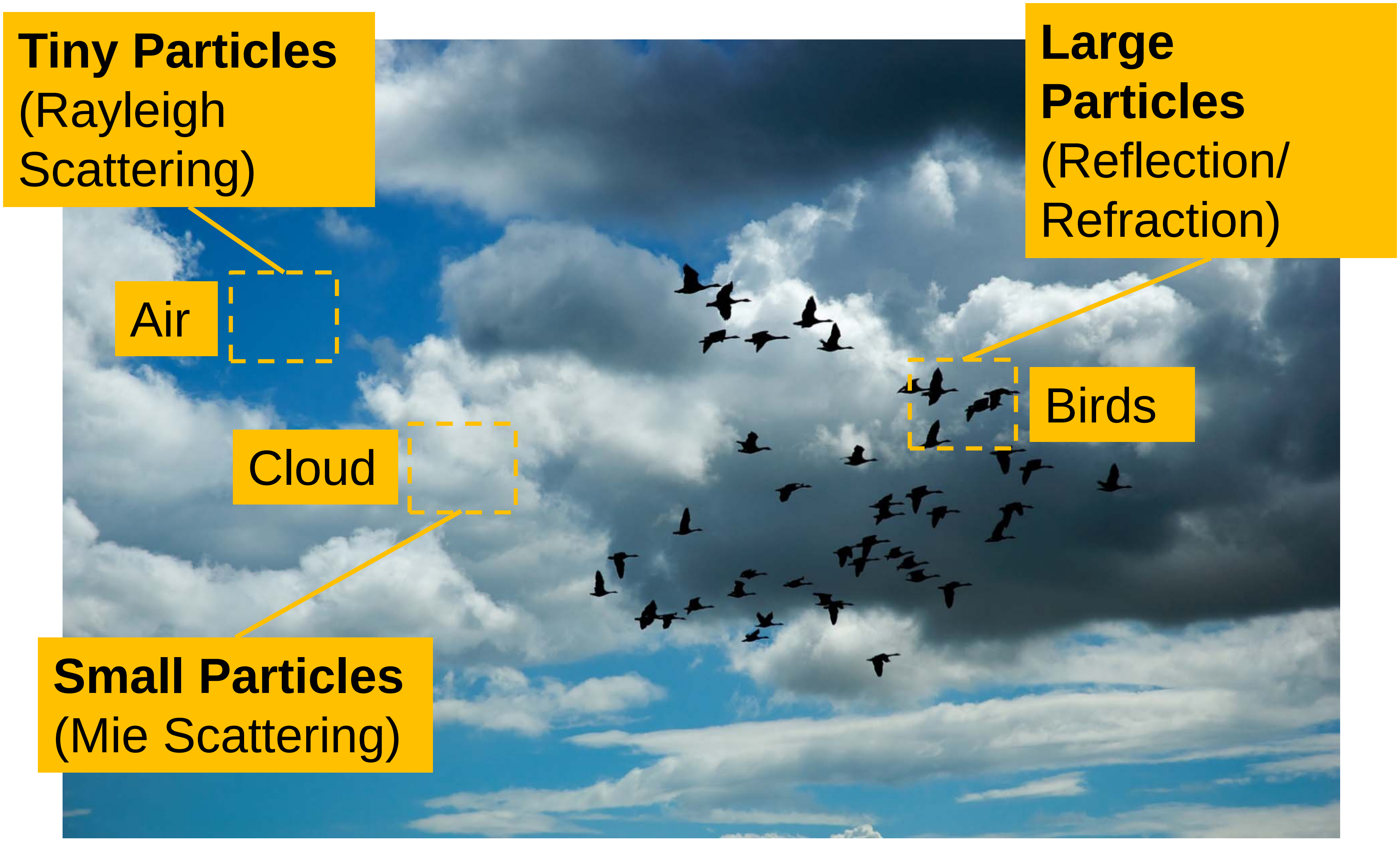
Scattering
Part 1

National Science Foundation
WHERE DISCOVERIES BEGIN

Scattering

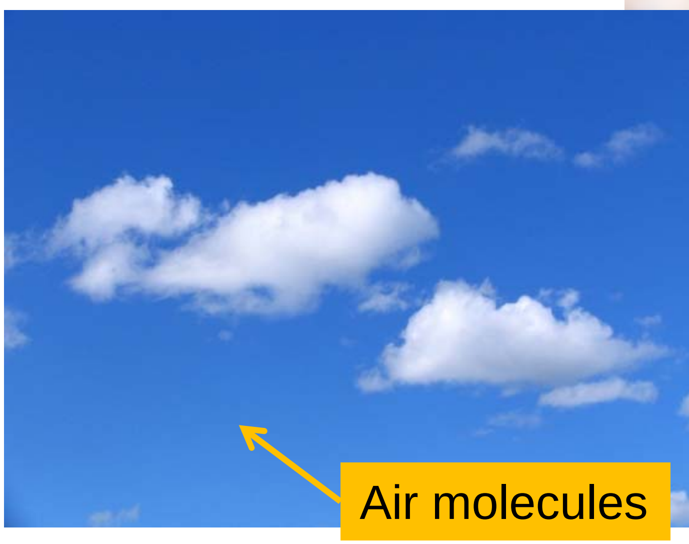


Particle Sizes & Scattering



Rayleigh Scattering

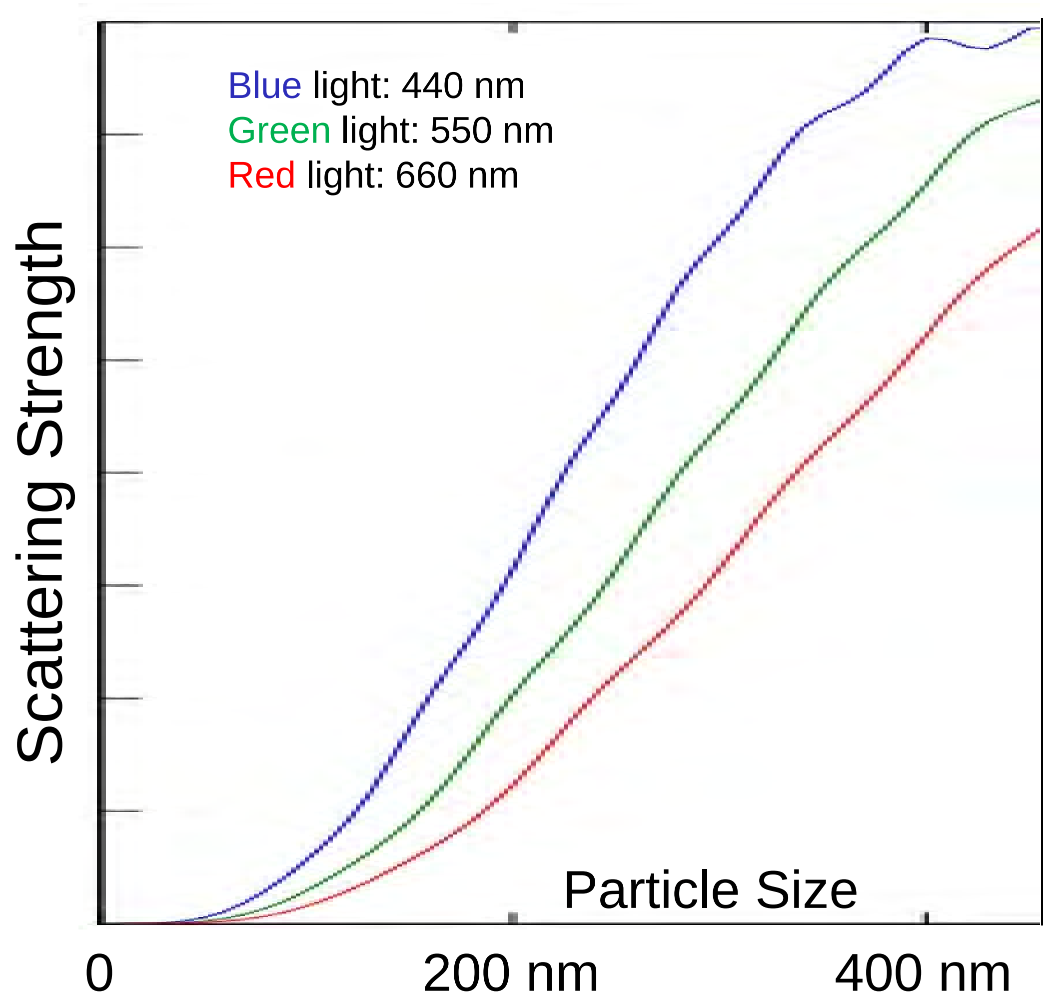
Tiny particles scatter blue light the most, red the least; white light is scattered with a hue shift to blue.



Particles smaller than wavelength of visible light.

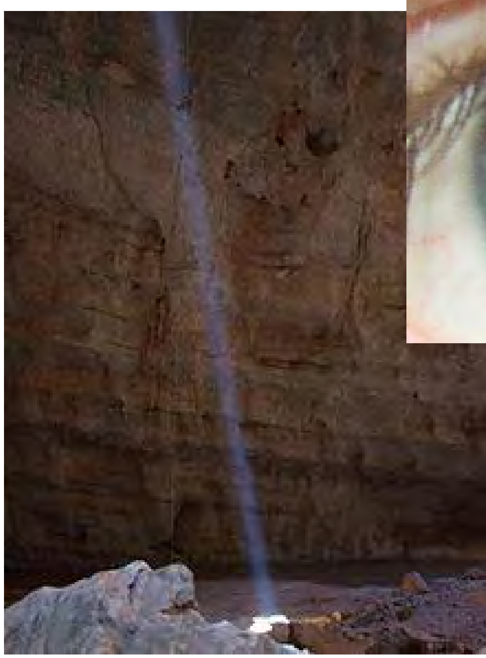
Rayleigh Scattering & Color

For tiny particles (under 400 nm) scattering is strongest for blue light and weakest for red light.

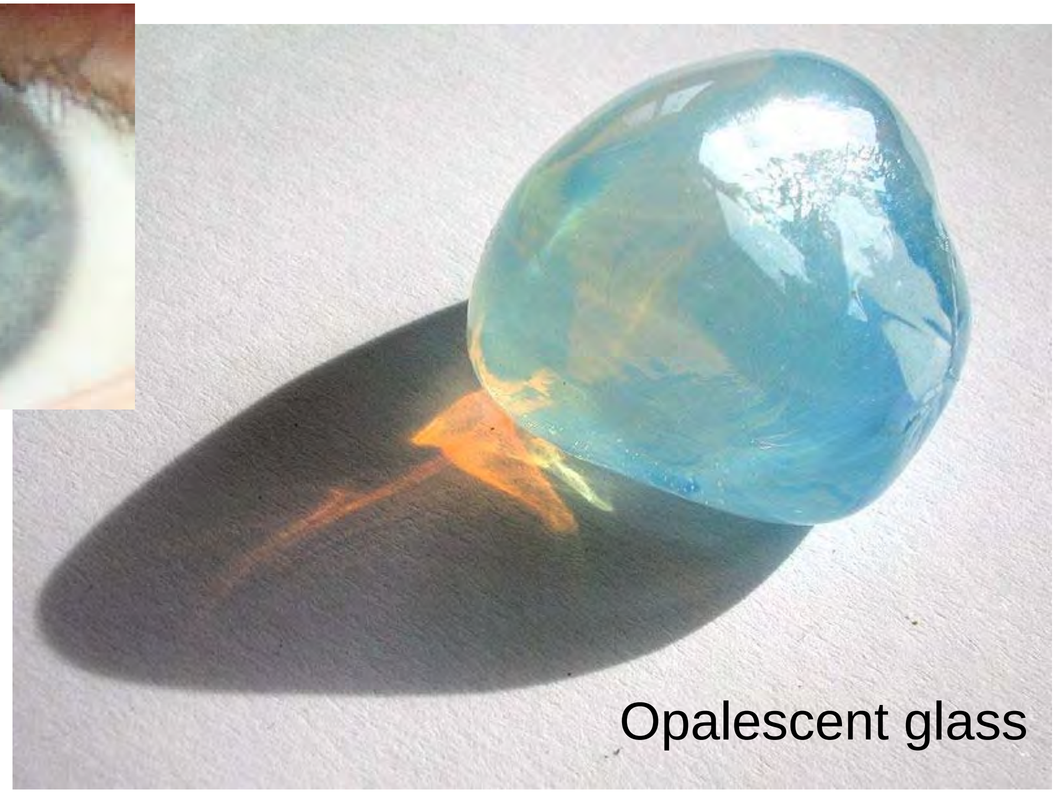


Tyndall Scattering

Tyndall scattering is very similar to Rayleigh scattering since both are the scattering of light (especially blue light) by very small particles.



Blue iris



Opalescent glass

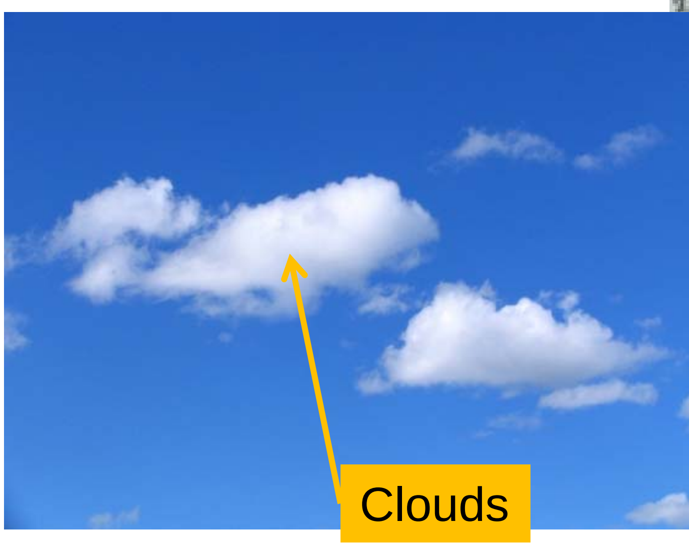
Tyndal Scattering in Dilute Mix

Pigment with fine particles may hue shift towards blue when diluted because of Tyndall scattering.

India ink in water

Mie Scattering

Scattering by small particles varies with size so the result averages out to white.

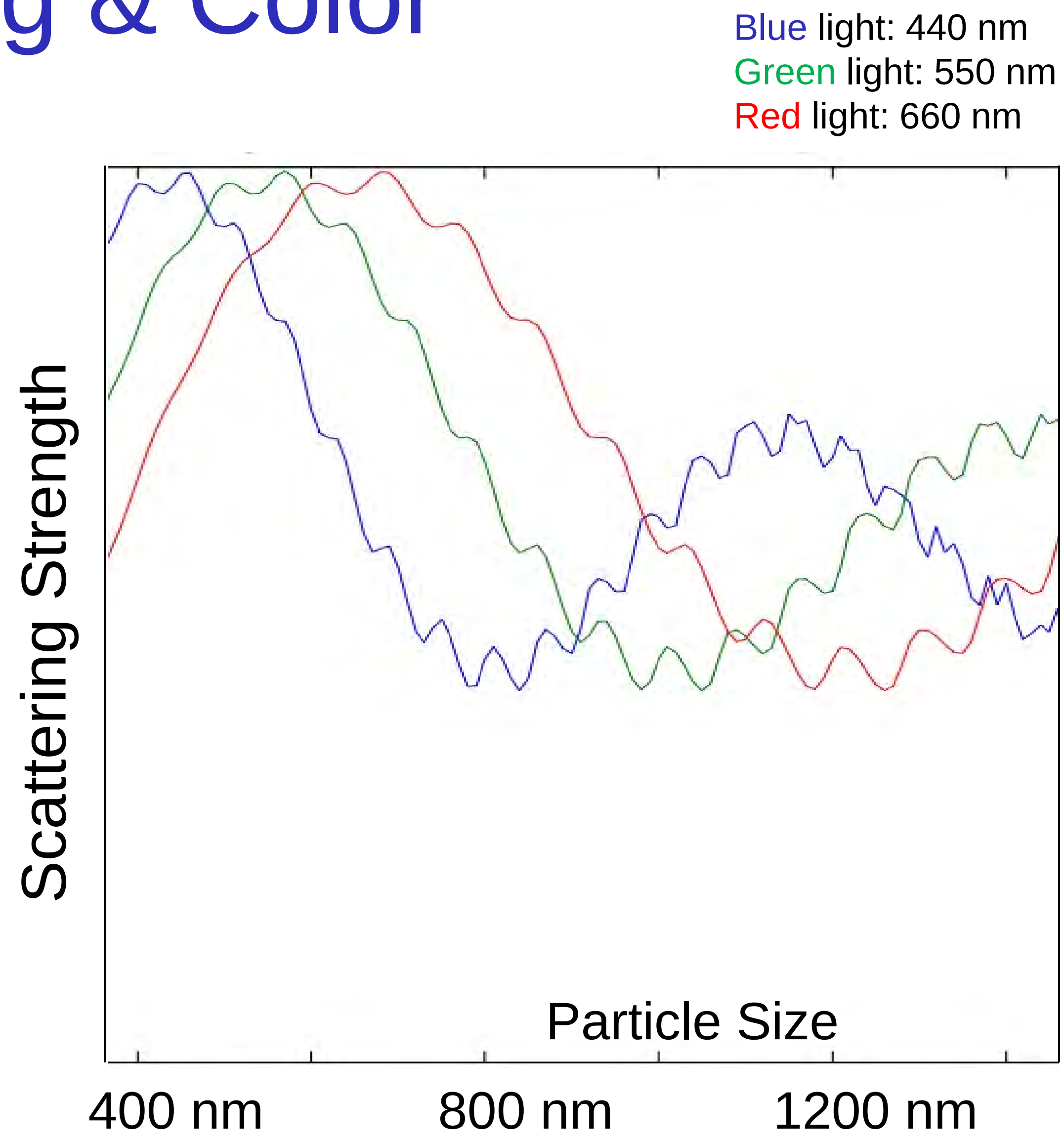


Particles comparable to wavelength of visible light.

Mie Scattering & Color

For small particles Mie scattering strength varies greatly with the particle size.

Since particles tend to be a mix of sizes, all hues are scattered equally resulting in white.



Mie Scattering & Color

Fog is white even if it is created with colored water.

Suspended Particles

Large particles reflect light off their surface or, if transparent, refract and transmit light.

Particles much larger than the wavelength of visible light.

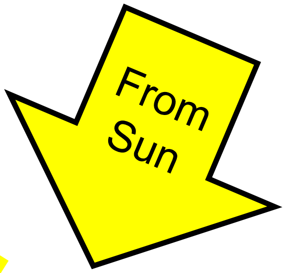
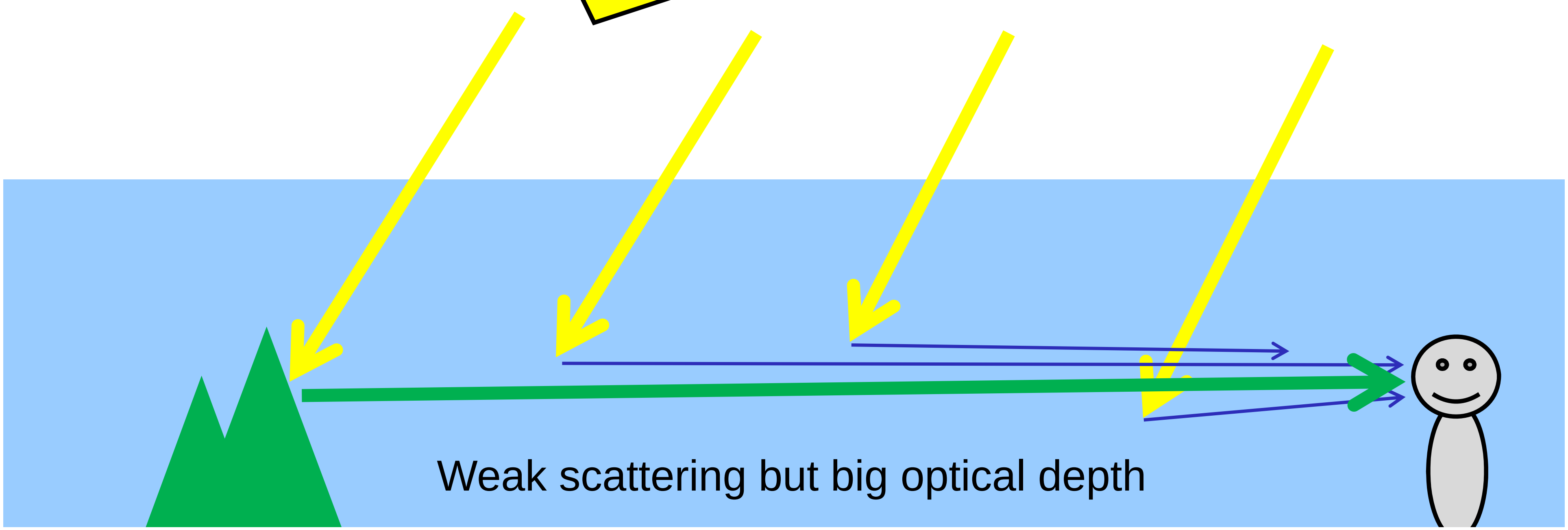
These cases are not truly scattering.

Atmospheric Perspective

Objects in the distance have a bluish, unsaturated color due to combination of Rayleigh, Tyndall, and Mie scattering.

Atmospheric Perspective

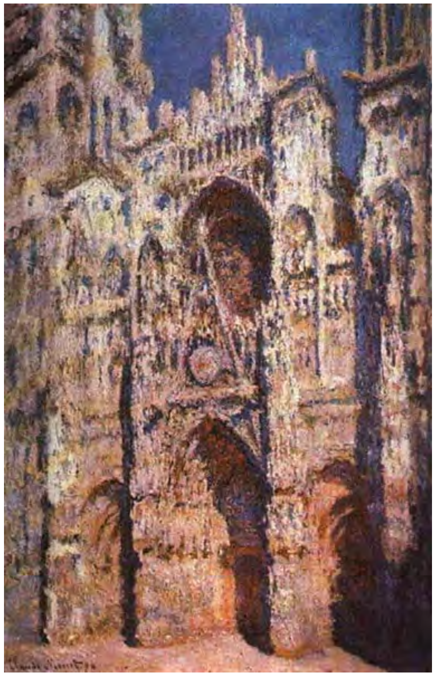
Far away mountains have a bluish tint due to blue light scattered in by Rayleigh scattering

The Sky is a Light Source

On Earth the sky is an important light source during the day. Mostly creates a bluish ambient light but with variations due to time of day and weather.

Rouen Cathedral Series, Claude Monet



“Perspective of Color”

Not only did Leonardo da Vinci make good use of what he called “Perspective of Color” but he also correctly predicted that scattering is why the sky is blue.

The Virgin of the Rocks, 1482

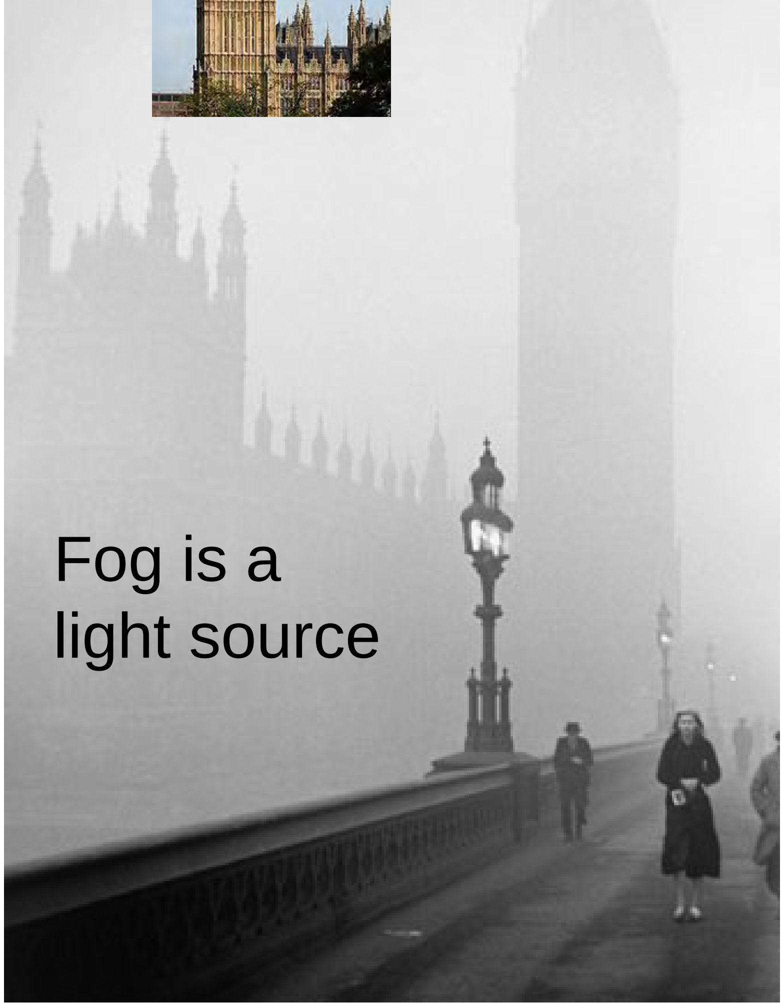
La Gioconda, 1503-06

The Virgin and Child with Saint Anne, 1510

Fog and Smog

Mie scattering can remove all contrast for distant objects, turning them into silhouettes.

Notice clock face



Underwater Perspective

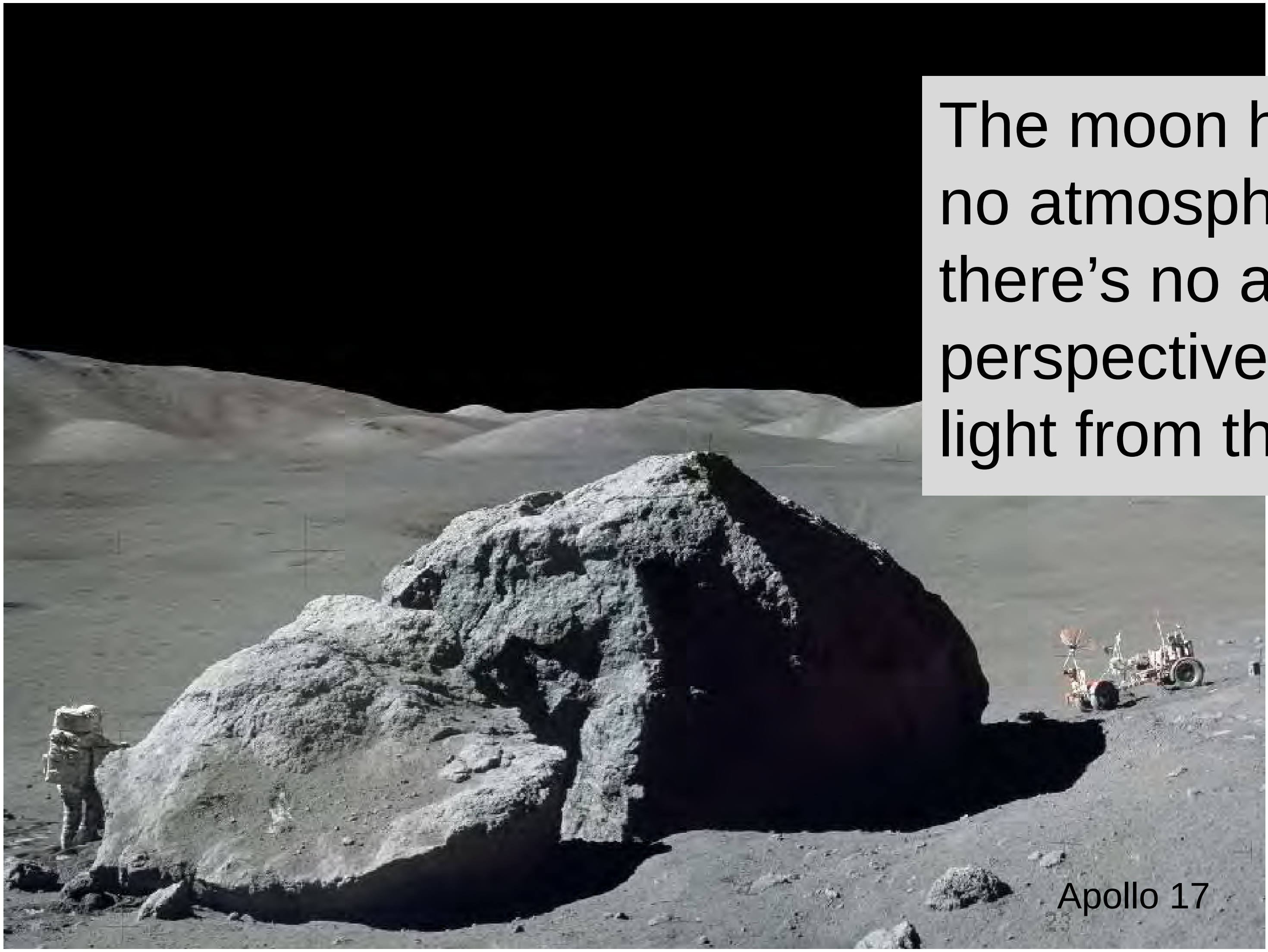
Water is transparent but absorbs red light about x100 more than blue light.

In clear water, distant objects are bluish but *saturated*.

Significant reflection by suspended particles in murky water.

Particles are easily mixed in water due to buoyancy.

Space “Perspective”



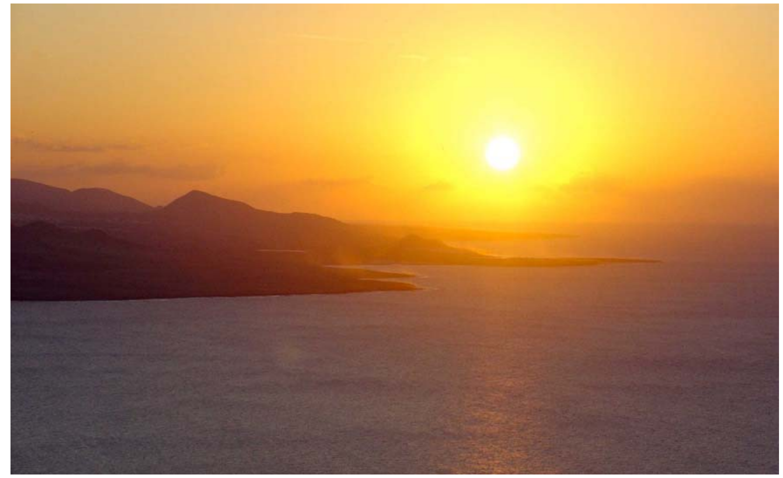
The moon has virtually no atmosphere so there’s no atmospheric perspective or ambient light from the sky.

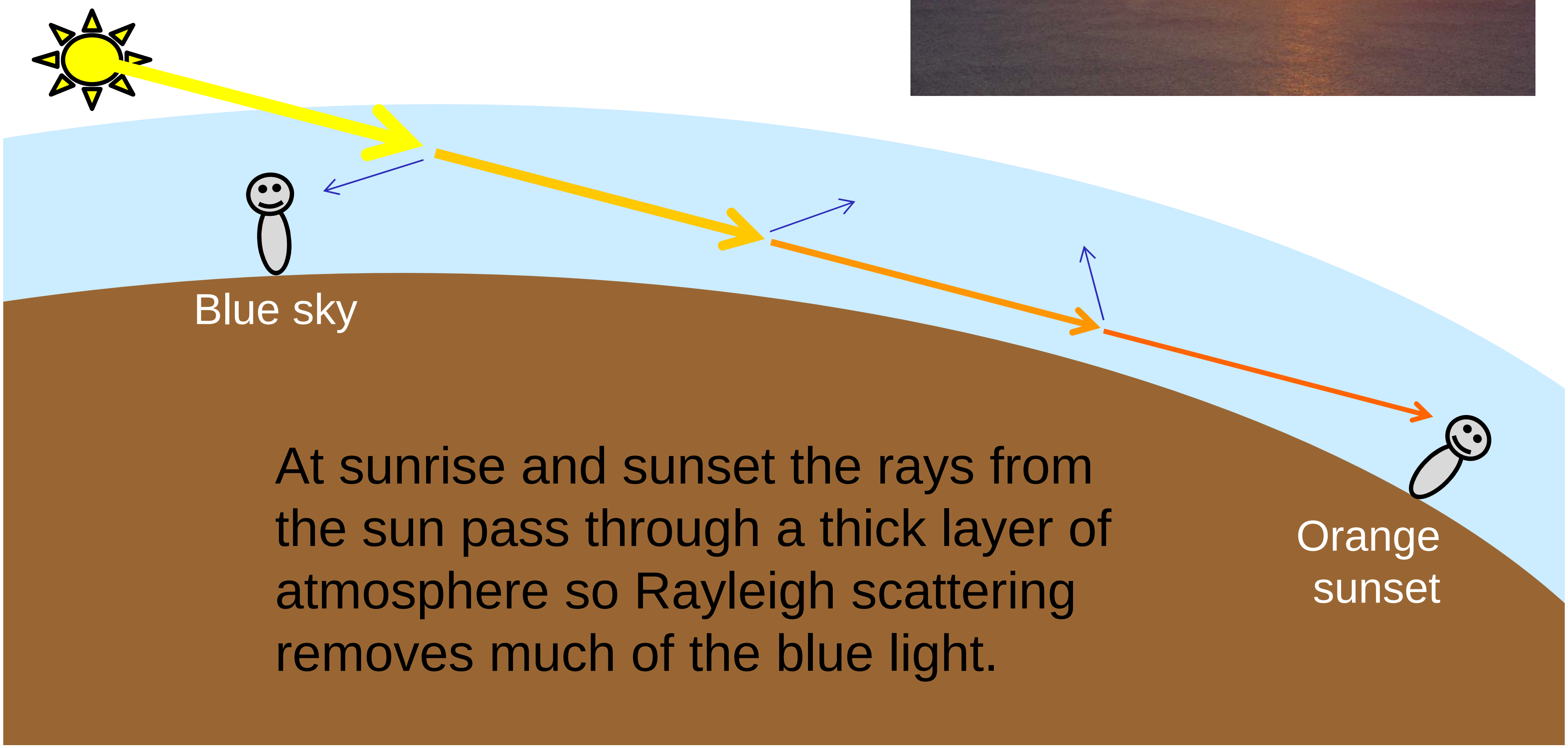
Scattering Out & Scattering In

To this viewer, the fog has scattered out some of the light so the sun isn't as bright

To this viewer, the fog has scattered in some light so the fog is visible.

Sunrise & Sunset





At sunrise and sunset the rays from the sun pass through a thick layer of atmosphere so Rayleigh scattering removes much of the blue light.

Opalescence

Aerogel is ultralight, hard foam made from SuperGlue.

Summary

- Extremely small particles scatter mostly blue light (Rayleigh / Tyndall scattering).
- Small particles scatter all wavelengths so the scattered light is white (Mie scattering).
- Objects in the distance have a bluish, unsaturated color due to Rayleigh, Tyndall, and Mie scattering (Atmospheric perspective).
- The daytime sky is an important light source.
- Rayleigh scattering of blue light causes the blue sky during the day and the reddish skies are sunrise and sunset.