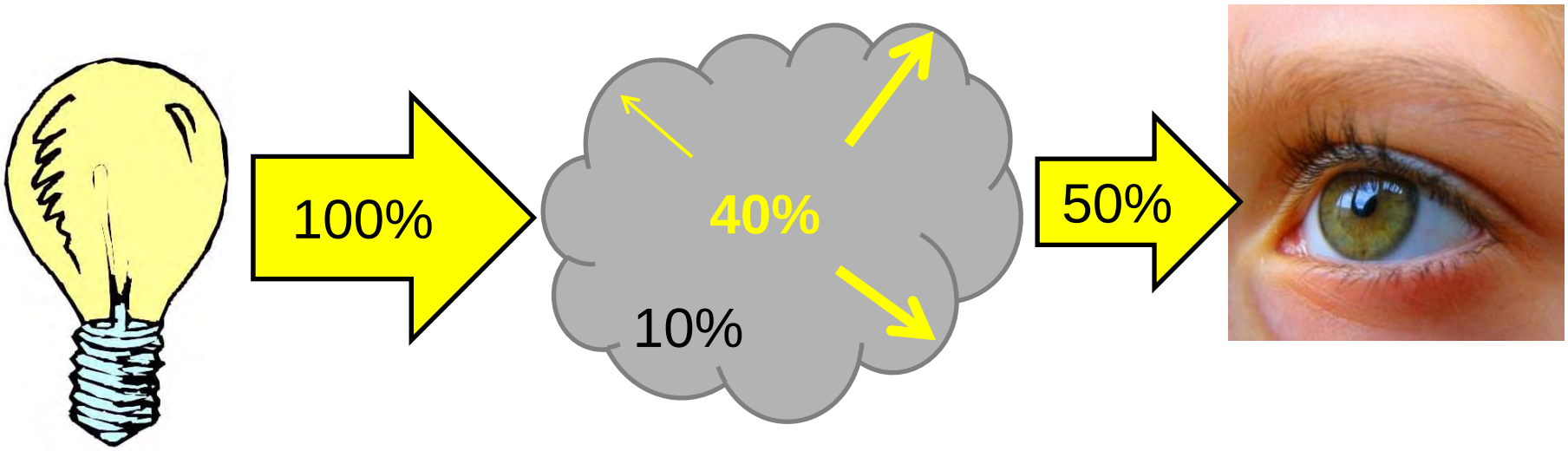
Scattering
Part 2

Scattering vs. Absorption

Scattering is a *deflection* of the light.
Absorption is an *elimination* of light.



For example, if 40% of the light is scattered and 10% is absorbed then 50% directly reaches viewer.

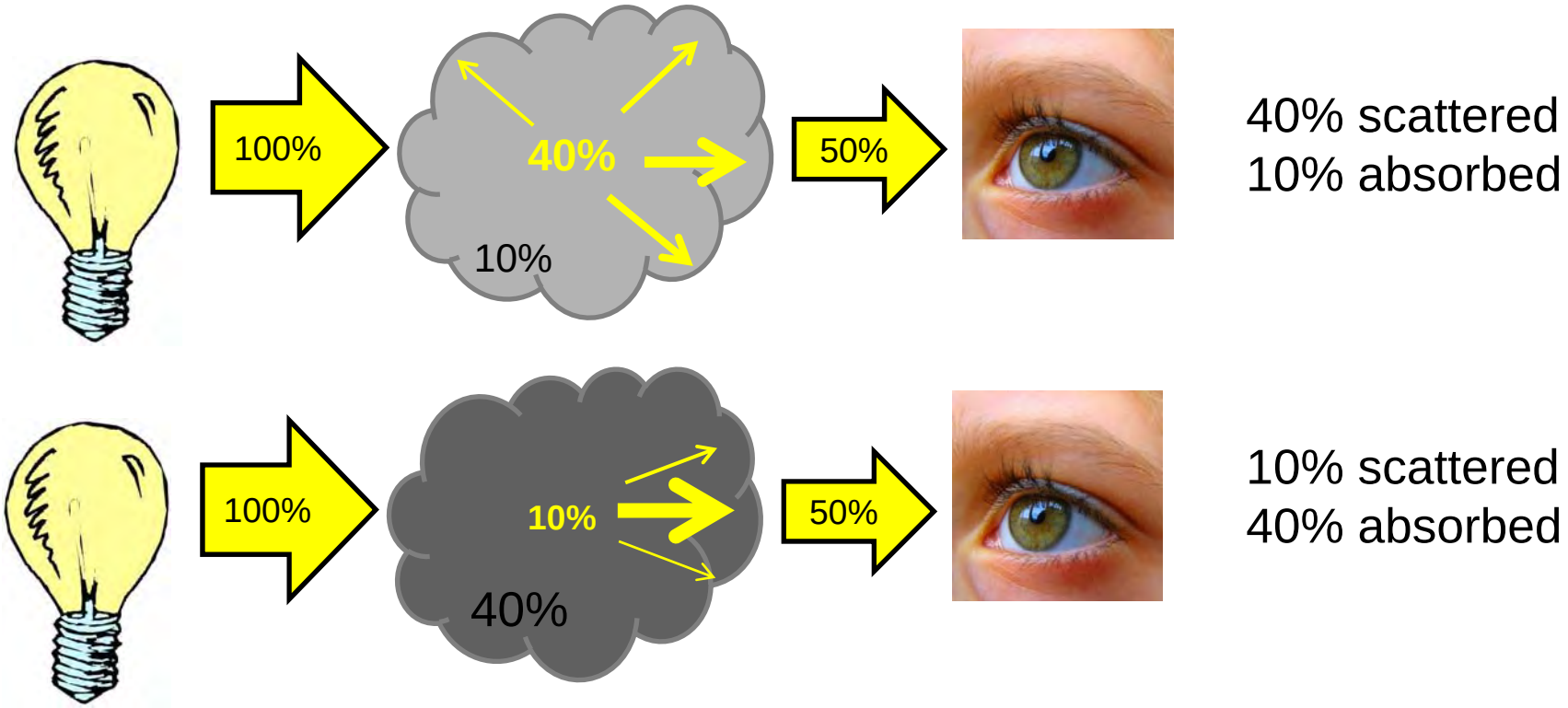
Scattering vs. Absorption

Bottom of a cumulus cloud is dark due to scattering of light by the cloud above it.

Smoke is dark due to absorption of light by carbon particles.

Extinction

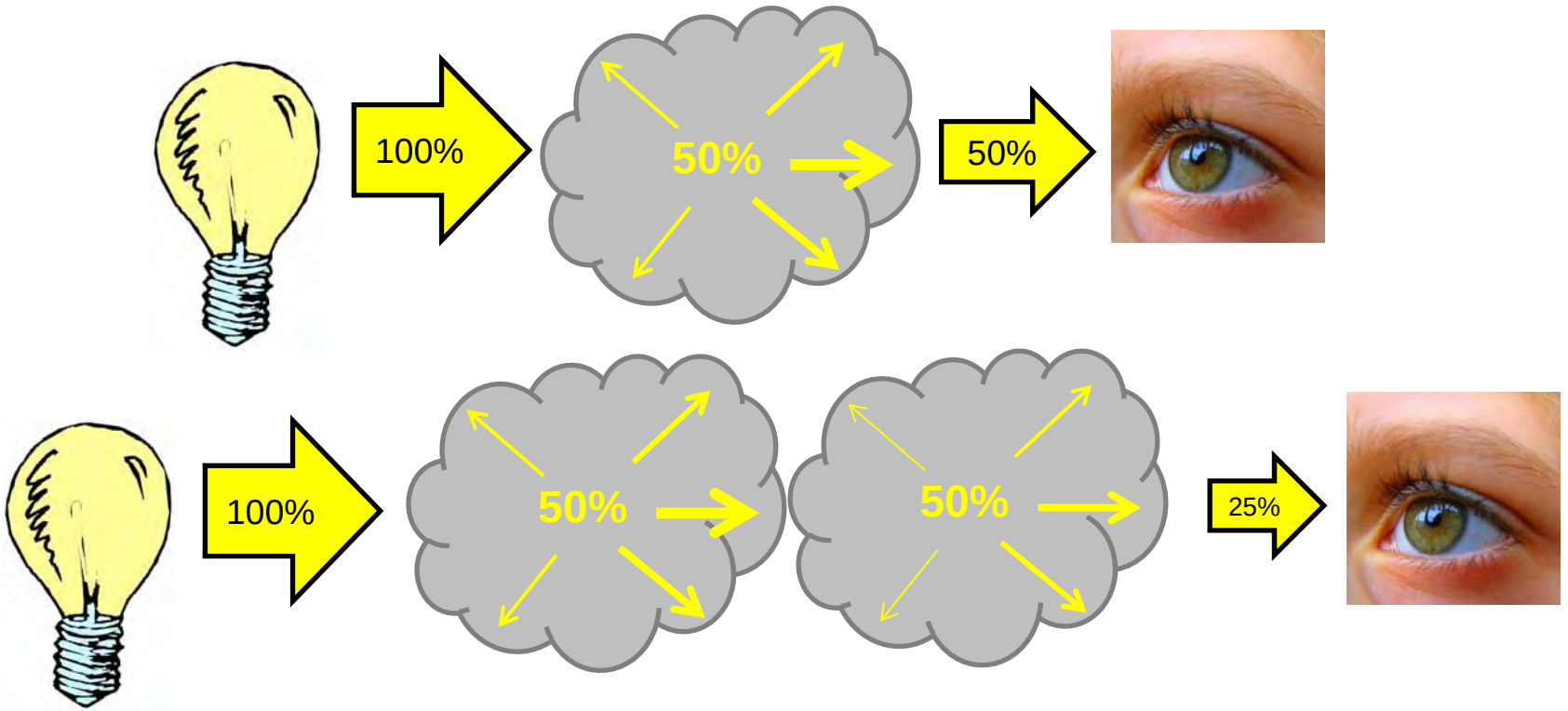
Extinction defined as absorption plus scattering.



Extinction is 50% in both cases.

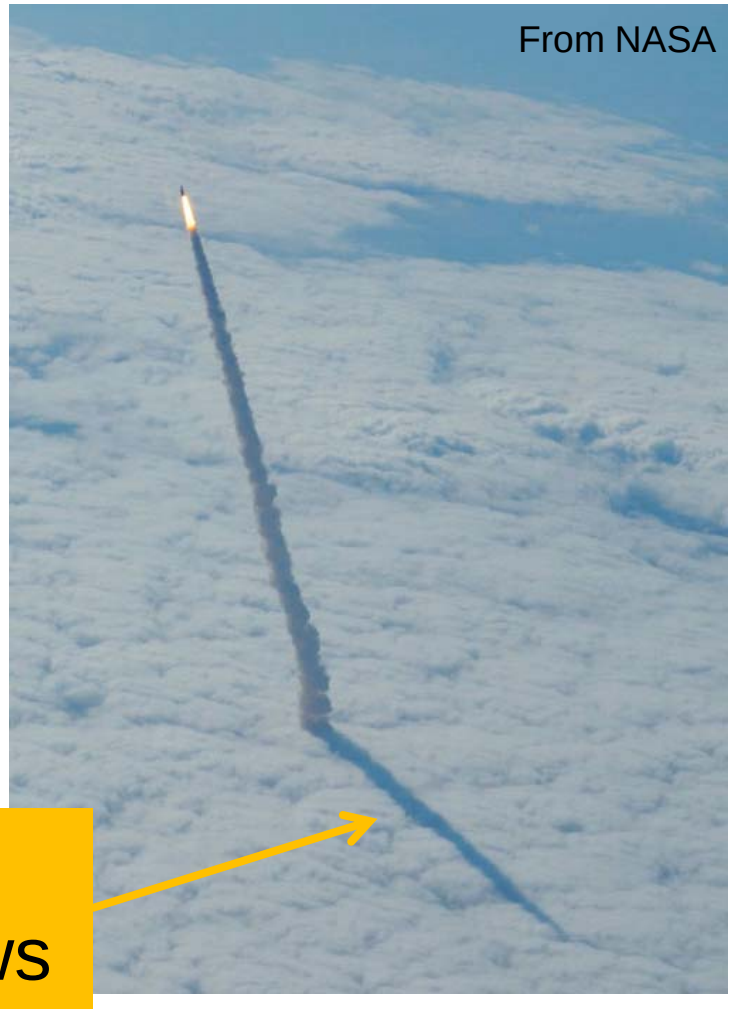
Beer's Law

Intensity decreases exponentially with the distance through which the light travels.



Extinction & Cast Shadows

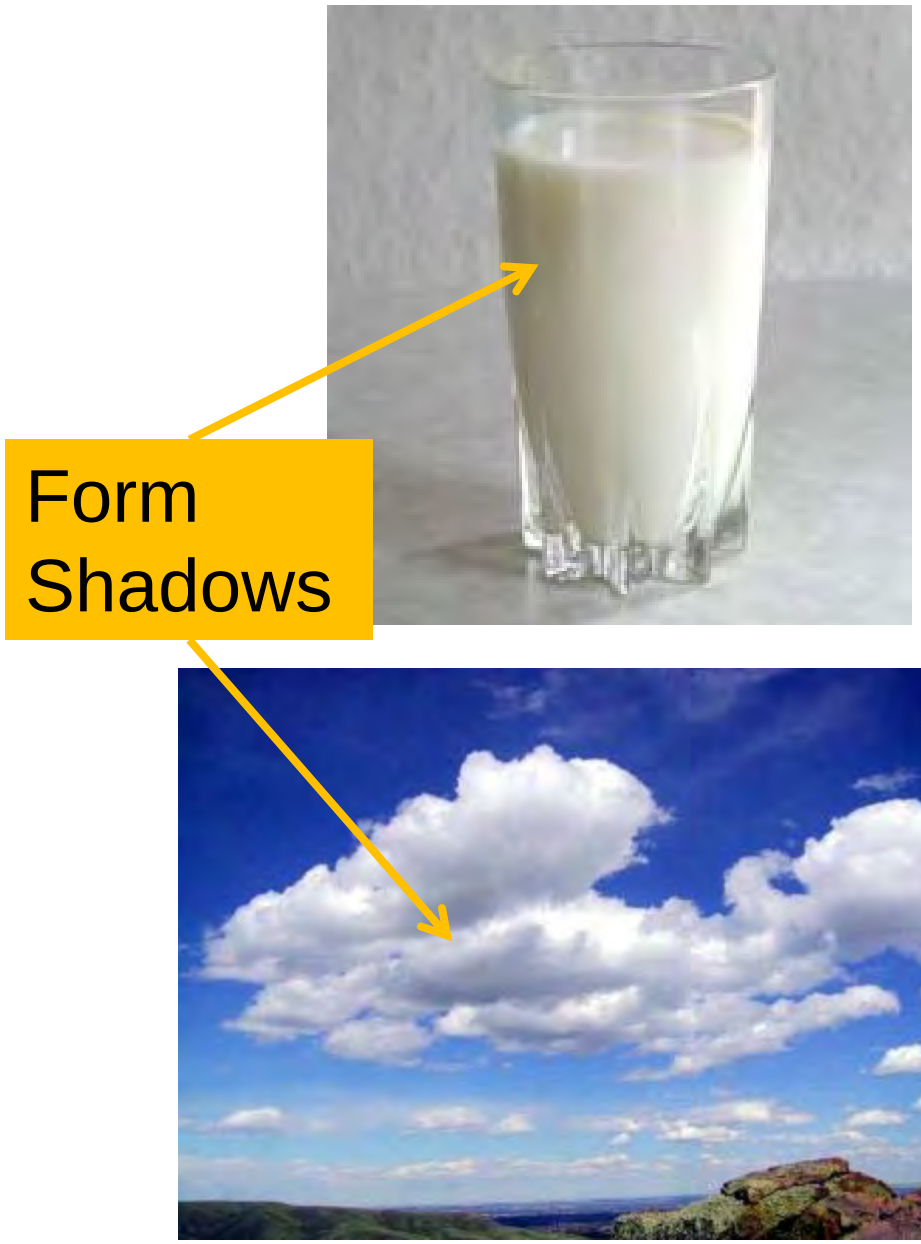
Clouds cast shadows due to extinction (mostly scattering).



Smoke plume from the rocket casts a shadow on a cloud.

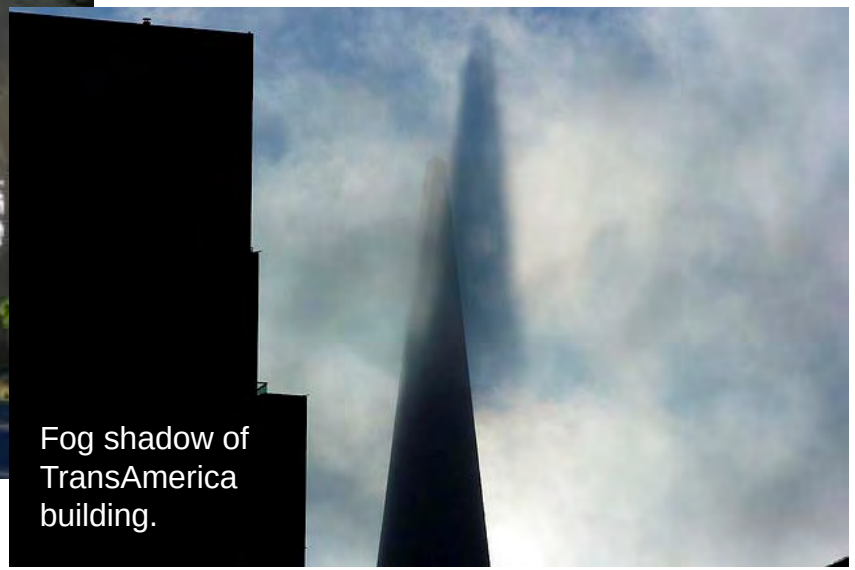
Extinction & Form Shadows

With enough extinction, the side opposite from the light can have a form shadow.



Fog Shadows

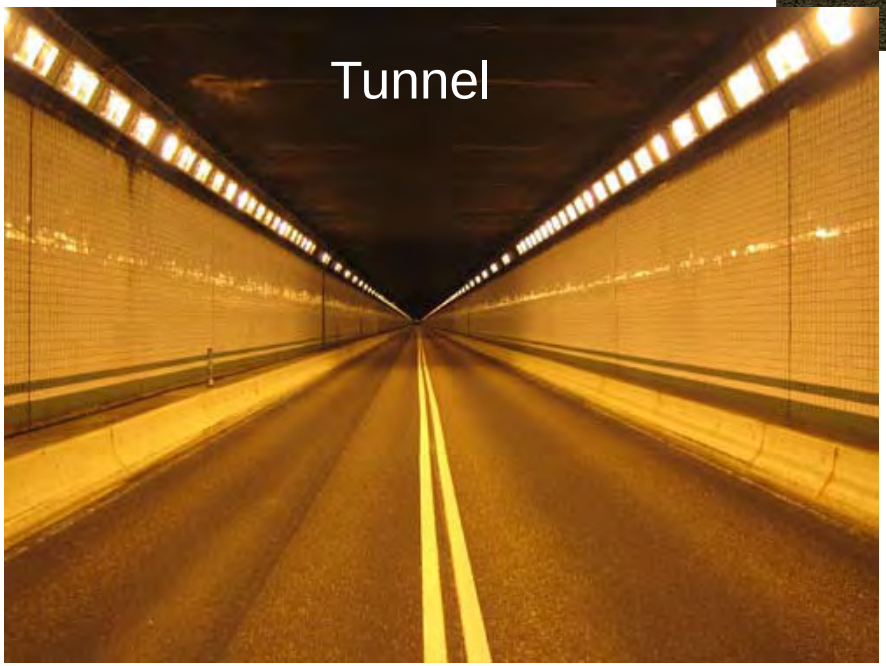
Shadow seen due to scattering by fog of the non-shadowed light rays.

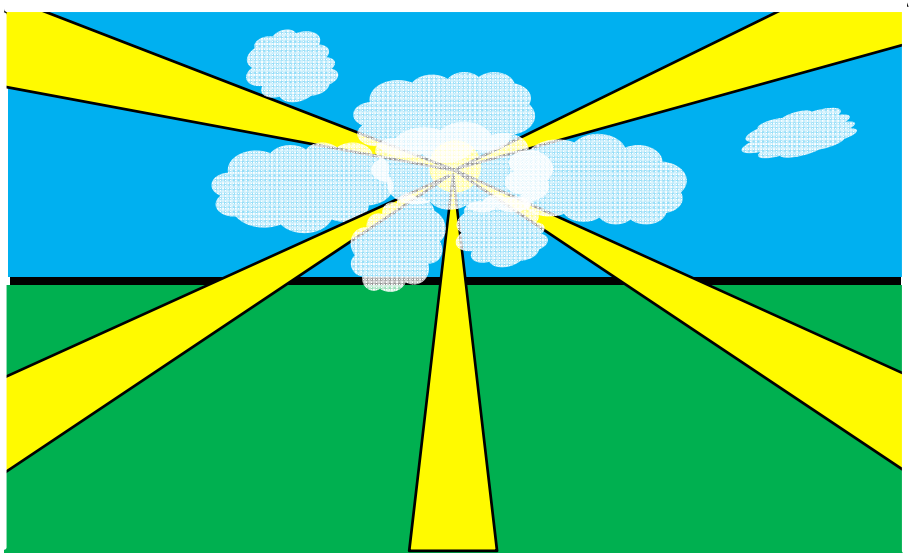


Fog shadow of TransAmerica building.

Sun Rays

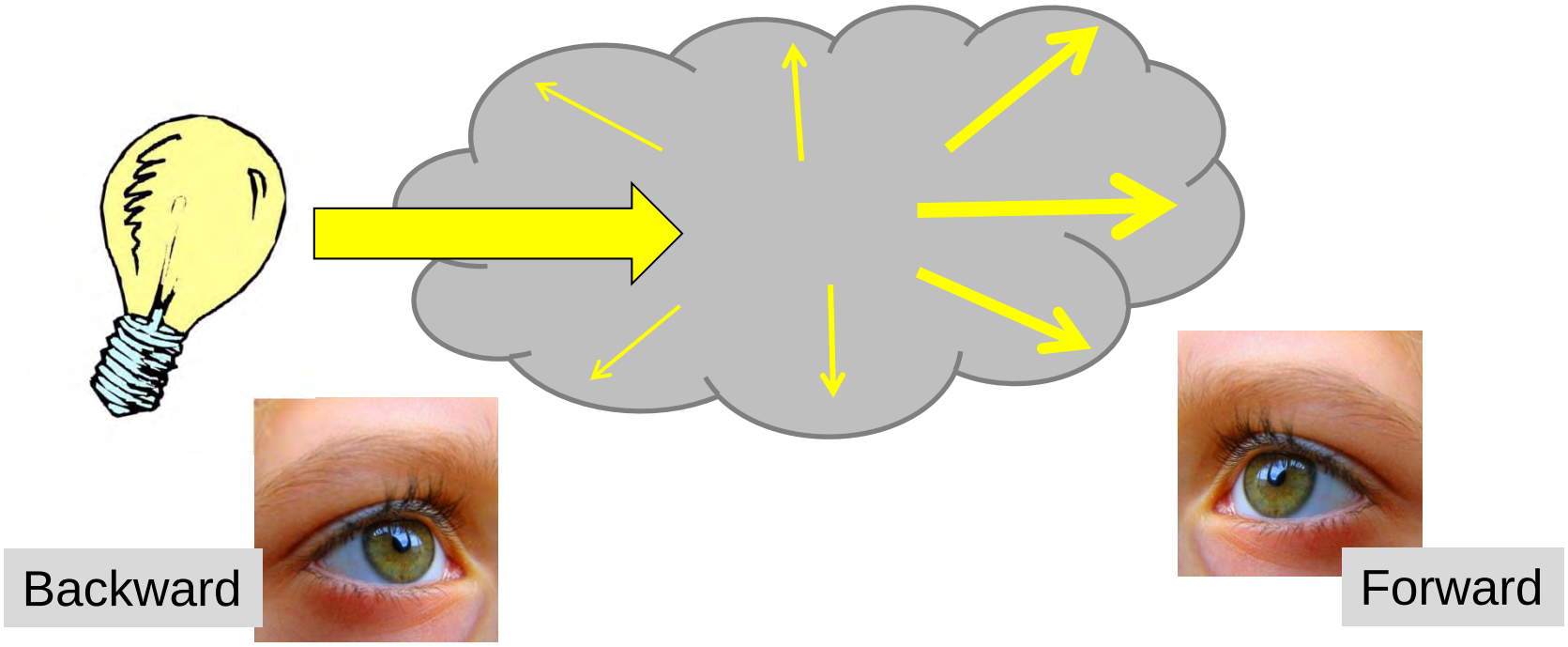
Light from the sun is nearly parallel so the spreading ray pattern is due to perspective.





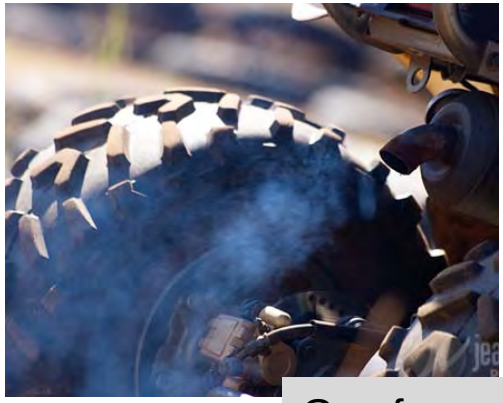
Scattering & Angle

Direction of light scattering is not random.

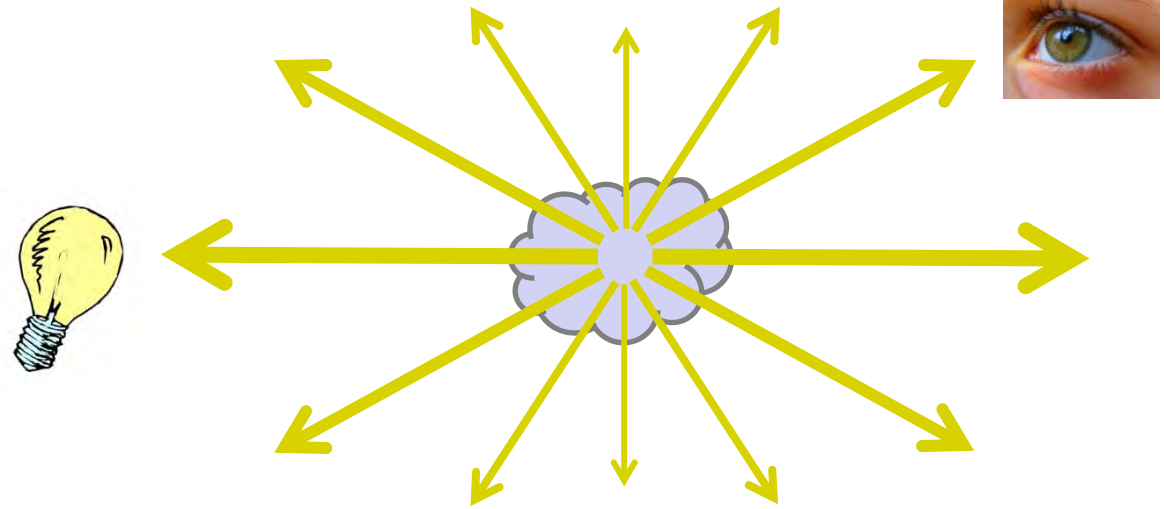


Rayleigh Scattering & Angle

Rayleigh scattering is strongest in the forward and backward directions.
It is weakest to the sides (90 degrees).



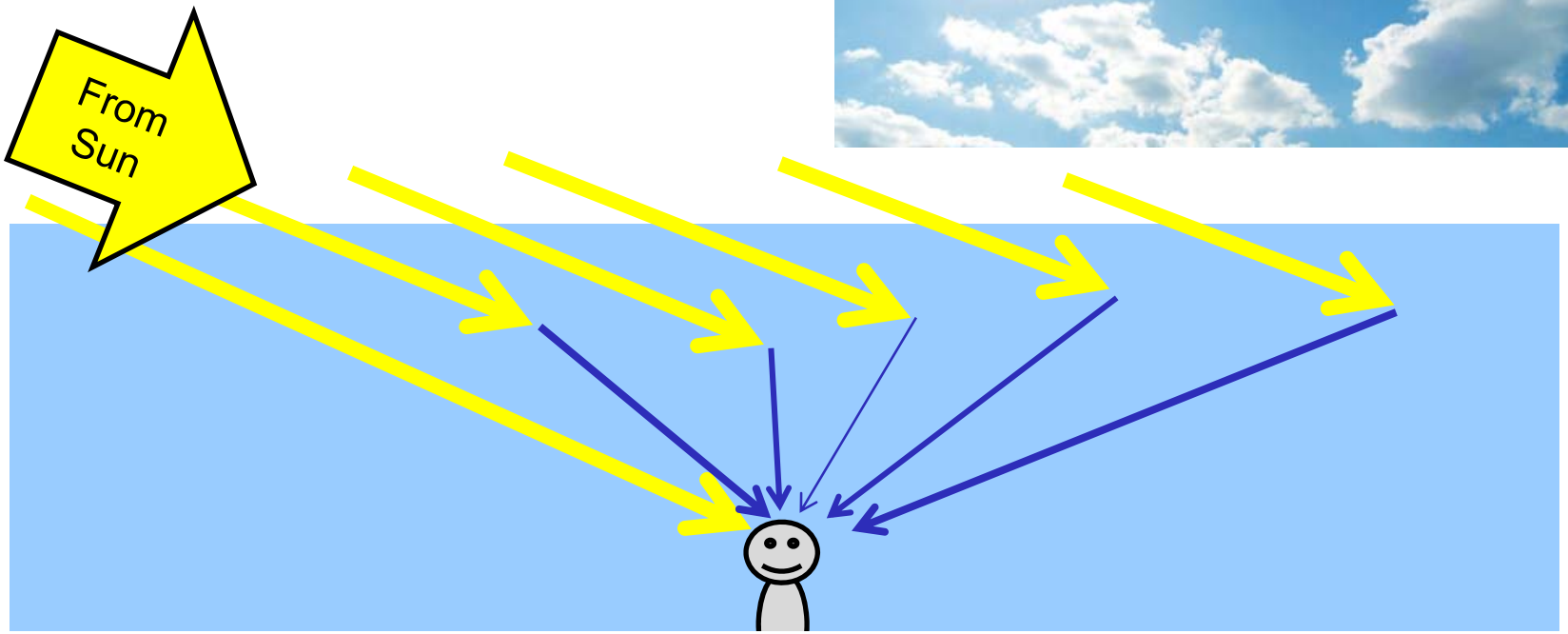
Gas fumes



Brightness of the Sky

The darkest part of the sky tends to be about 90 degrees from the direction of the sun.

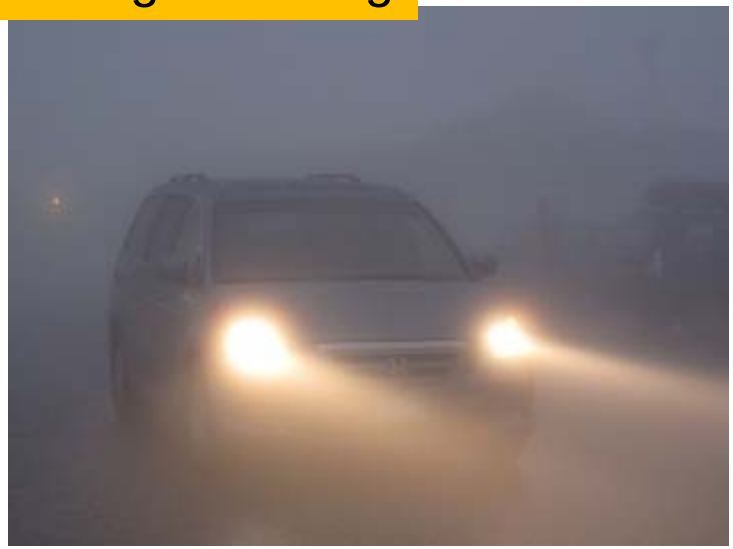
Rayleigh scattering by air molecules

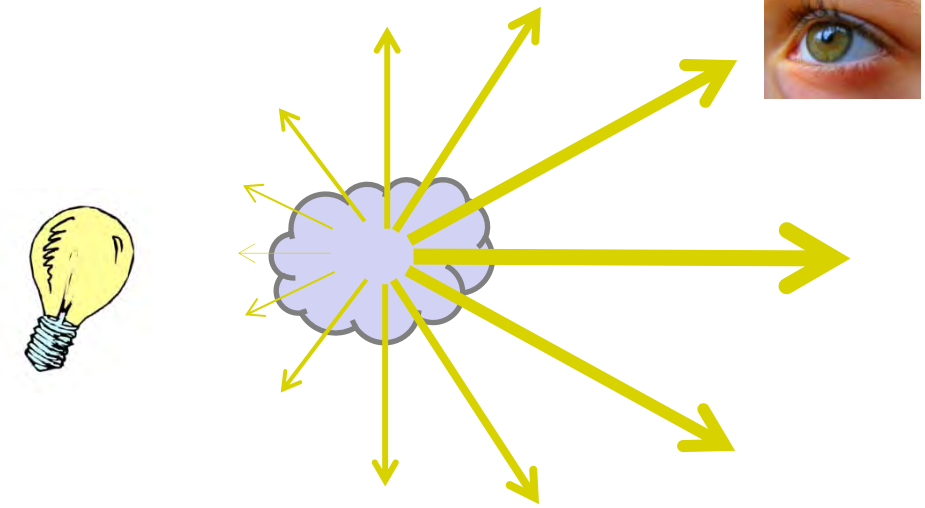


Mie Scattering & Angle

Mie scattering is strongest in the forward and weakest backward directions.

Headlights in Fog



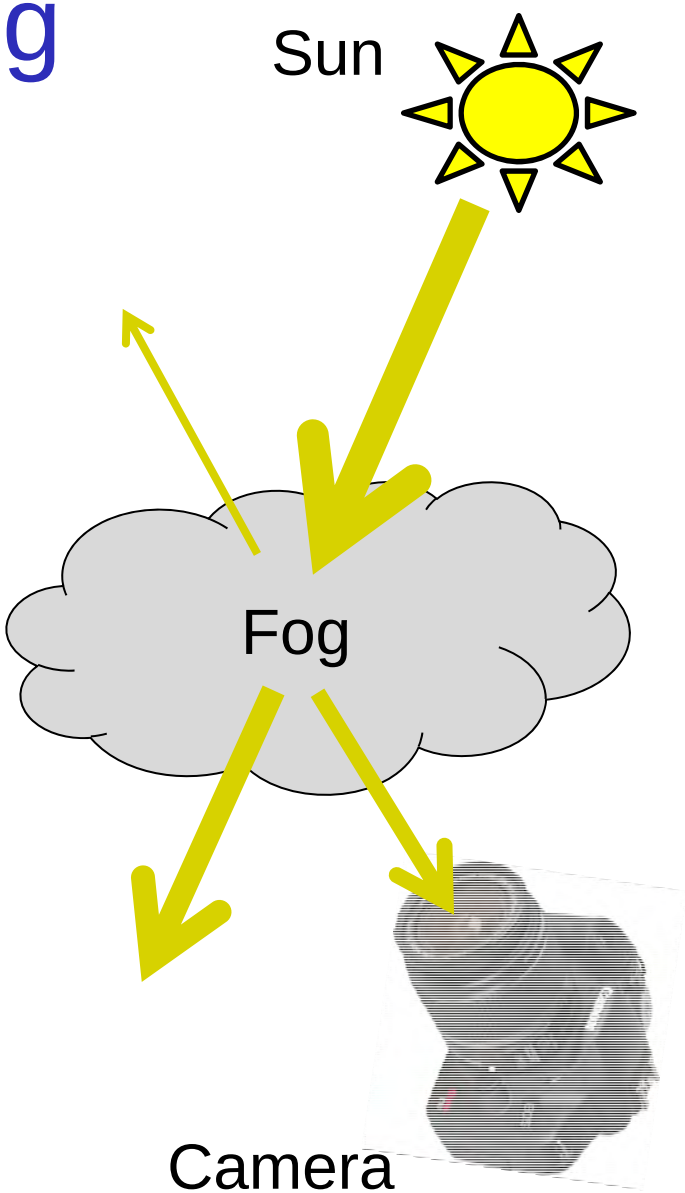


Mie Forward Scattering

Sun is behind the fog in this photo

Mie scattering
from drier fog

Drier Vent

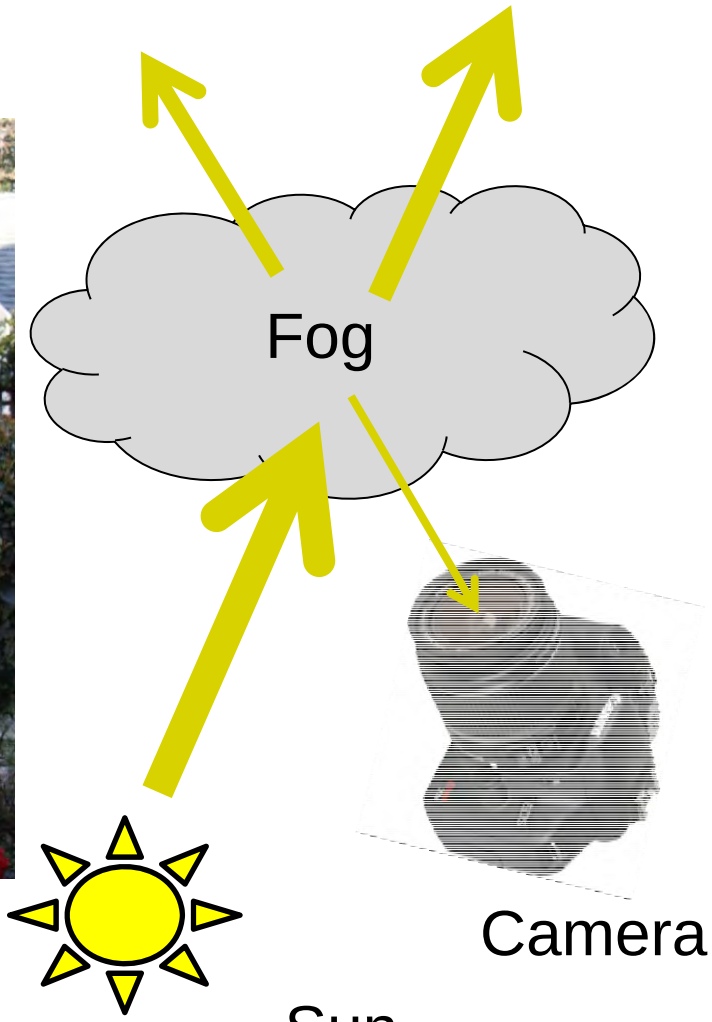


Mie Backward Scattering

Sun is behind the camera in this photo

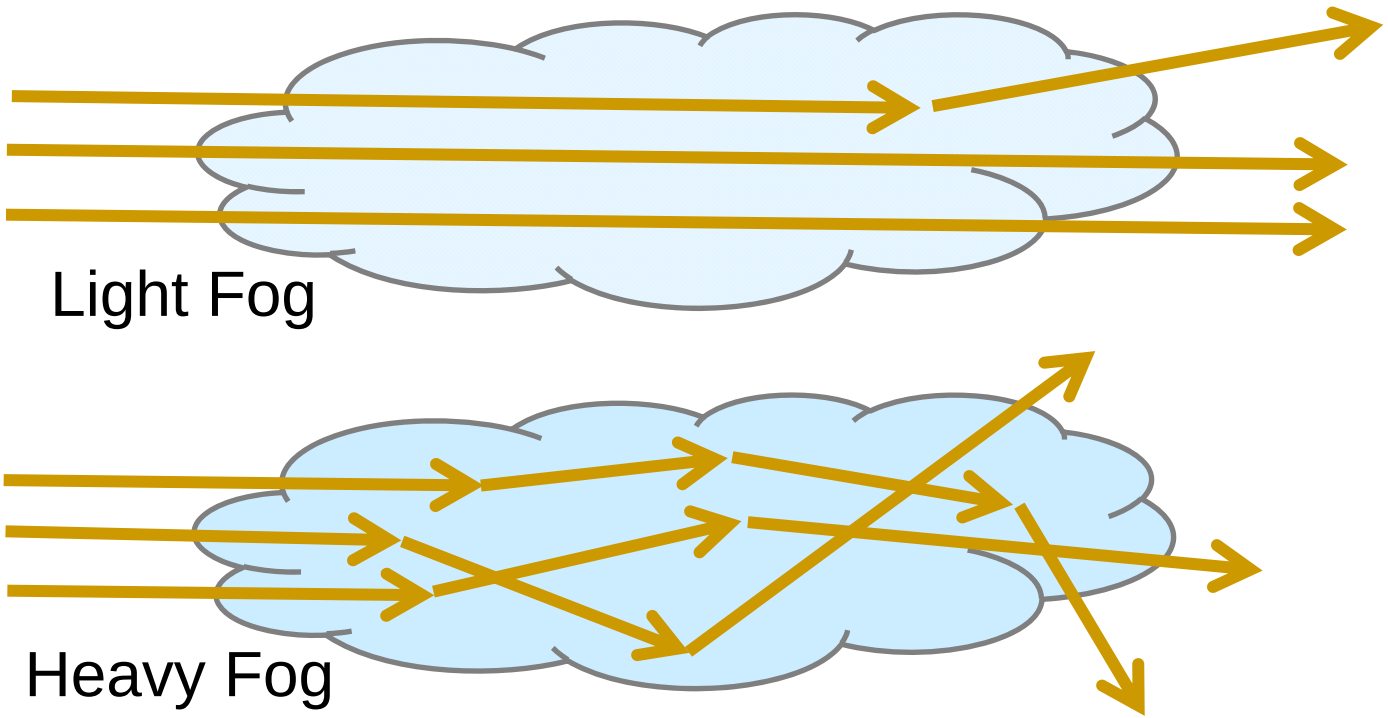
Drier Vent

Mie scattering
from drier fog

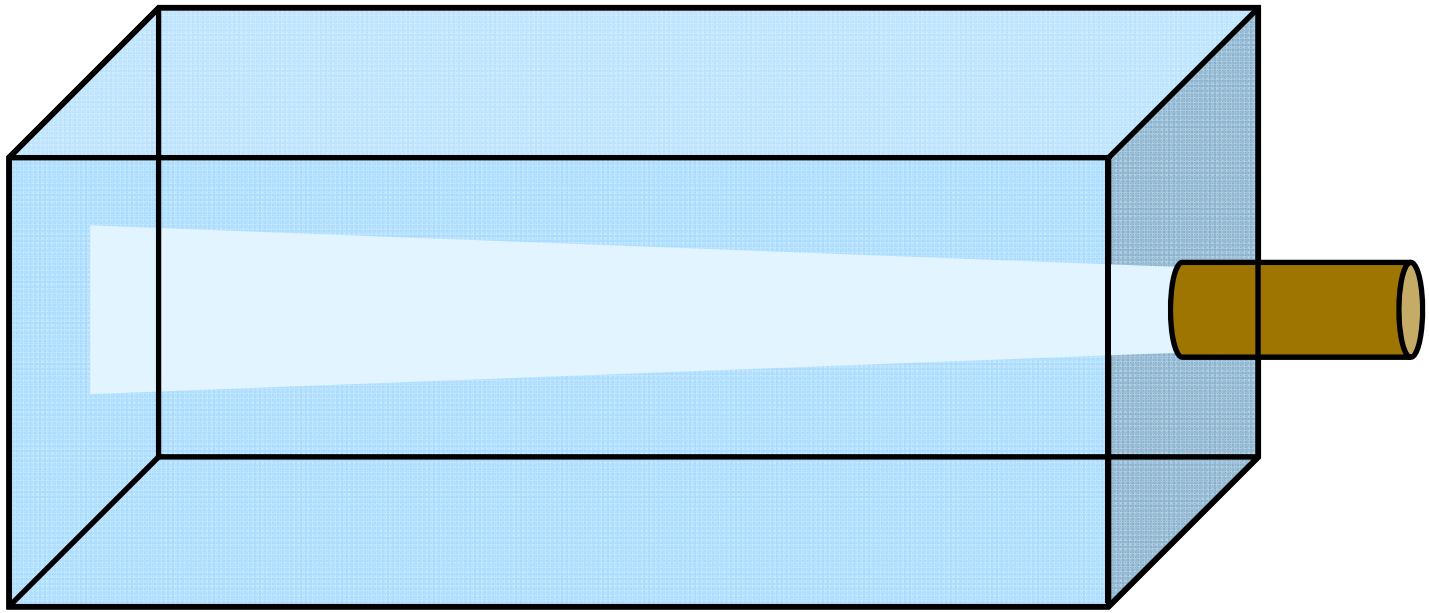


Single vs. Multiple Scattering

Light rays may scatter multiple times, if the scattering medium is dense.



Scattering in a Fish Tank



Single versus multiple scattering is nicely shown by shining a flashlight into an aquarium filled with clean water then adding more and more milk.

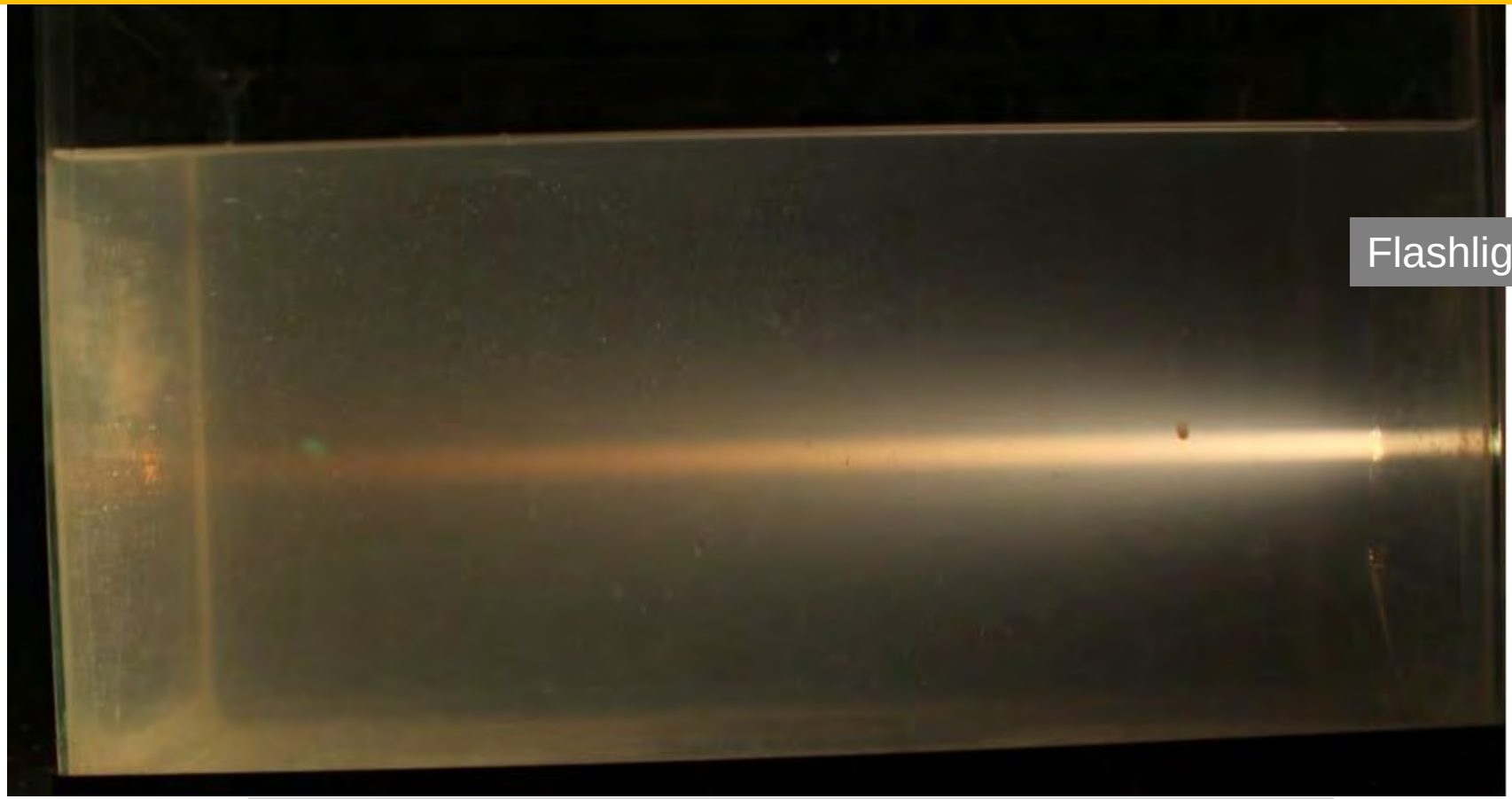
Single Scattering in a Fish Tank

Single scattering produces a narrow beam of light.

Mie scattering by very dilute water/milk mix.

Multiple Scattering in a Fish Tank

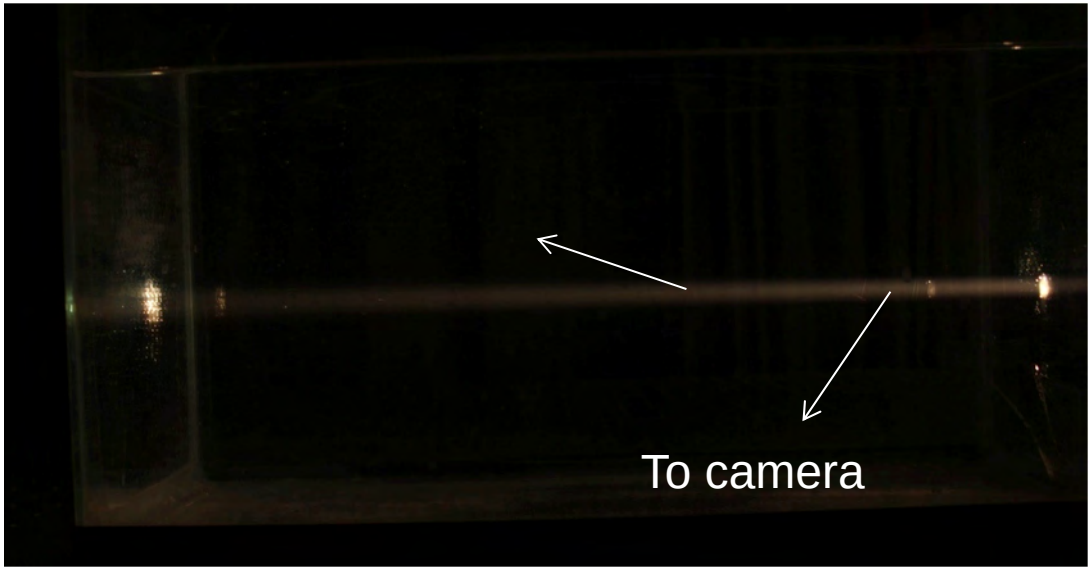
Multiple scattering produces a diffuse beam of light.



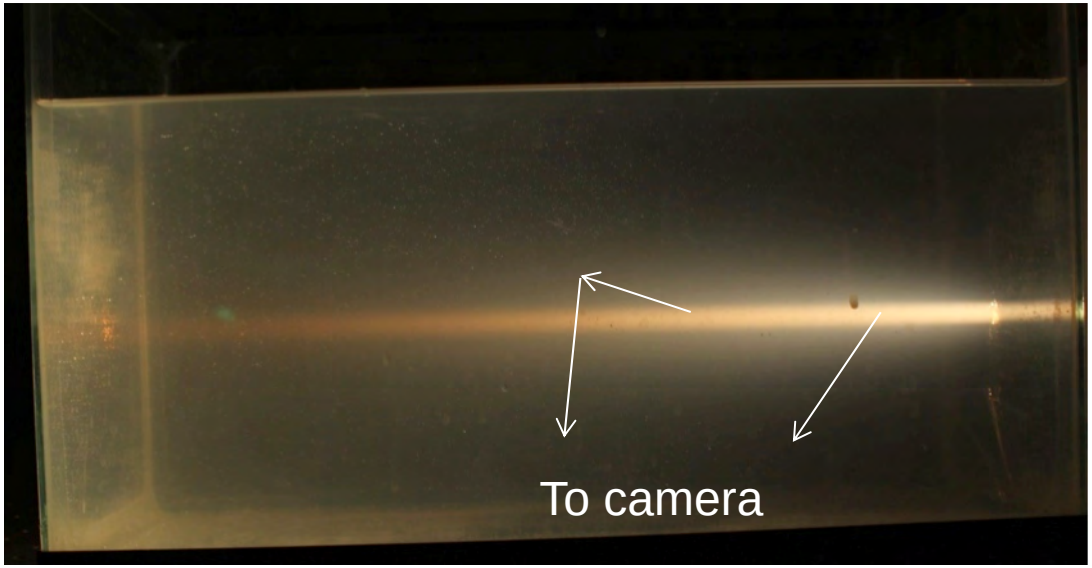
Hue shift from white (near flashlight) to orange-red on the opposite side.

Scattering in a Fish Tank

With single scattering only particles in the direct beam are scattering the light.

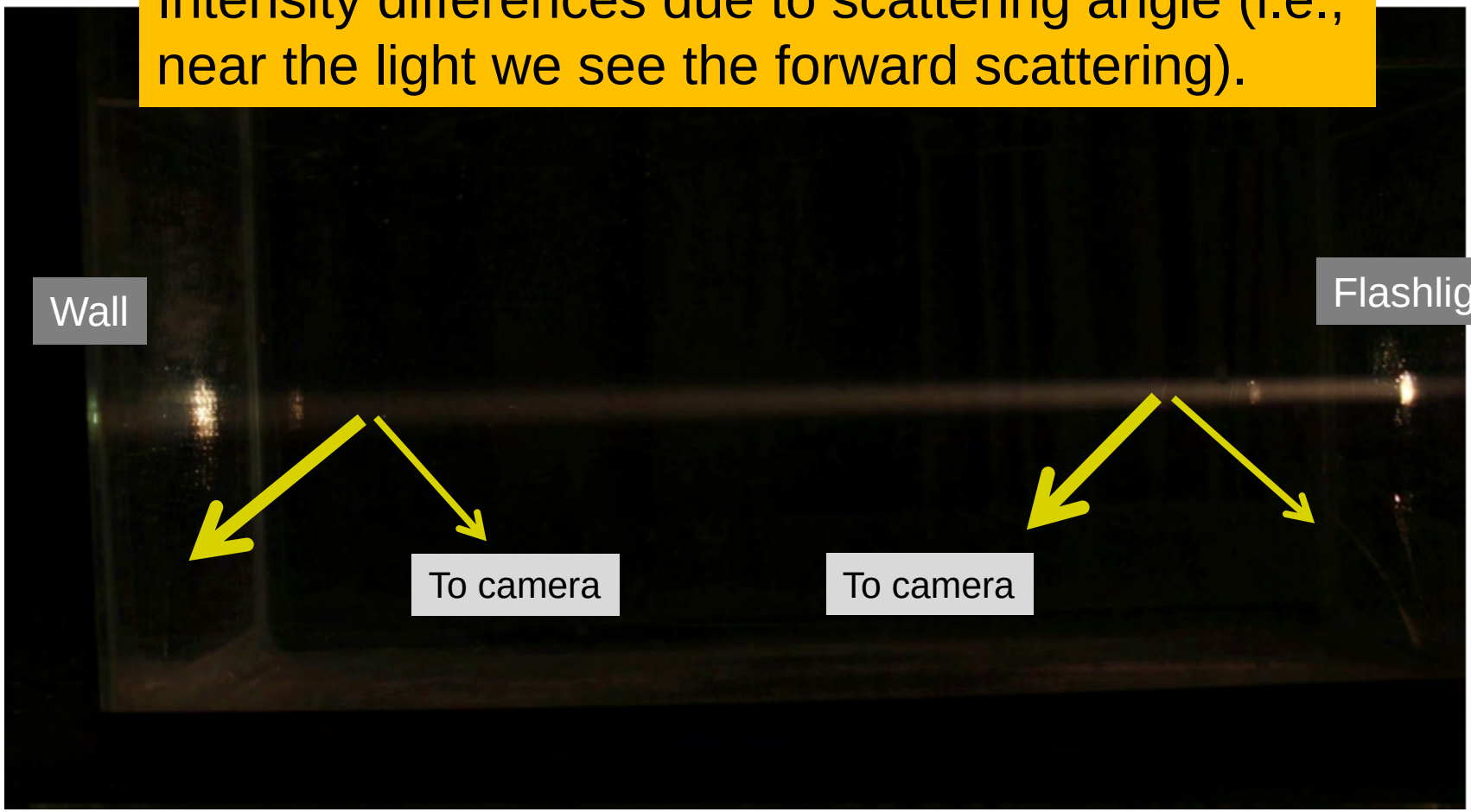


With multiple scattering particles outside the beam are illuminated by light scattered from out of the beam.



Single Scattering in a Fish Tank

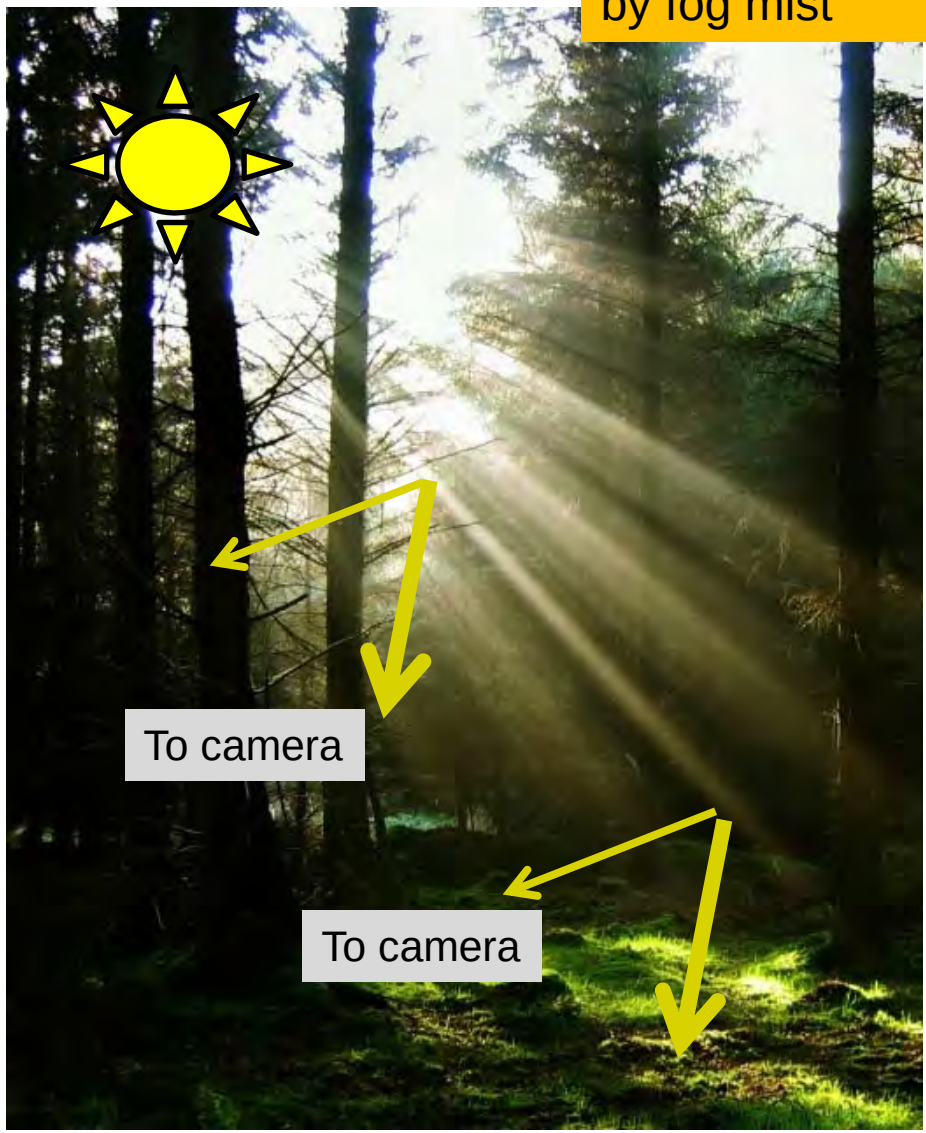
Intensity differences due to scattering angle (i.e., near the light we see the forward scattering).



Sun Rays

Intensity of sun rays varies with the angle between sun and viewer.

Notice that the light on the ground is bright even though the ray's intensity appears to taper off along the sun ray.



Summary

- Scattering is a deflection of the light, absorption is an elimination of light, and extinction is the combination of the two for transmitted light.
- Extinction exponentially reduces the intensity of transmitted light with distance (Beer's Law).
- Extinction can lead to cast and form shadows.
- Rayleigh scattering is strong in the forward and backward directions, weak to the sides.
- Mie scattering is strongest in the forward direction and weakest in the backward.
- Multiple scattering makes bright, diffuse beams.