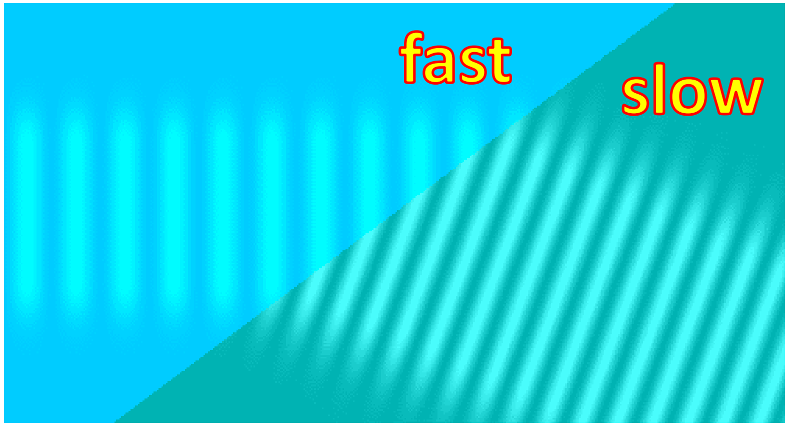
Light Meets Matter

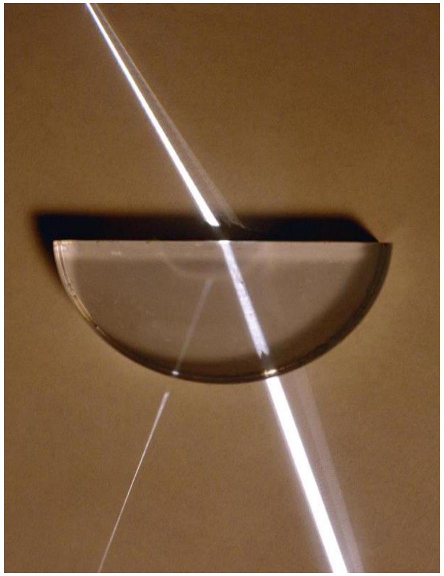
Part 2

Transmission: Refraction

change in the direction of travel at the boundary

Different materials transmit light at different speeds.

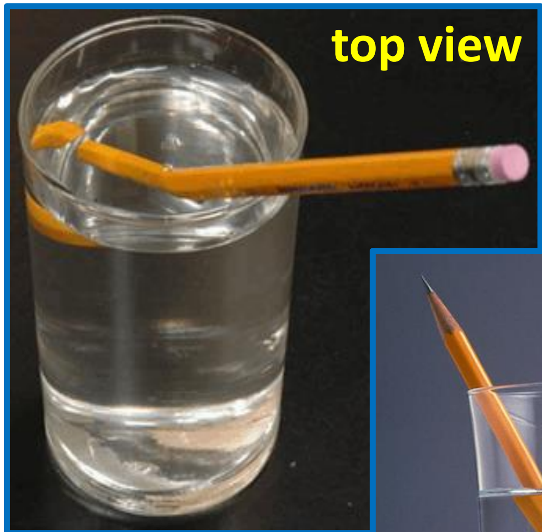


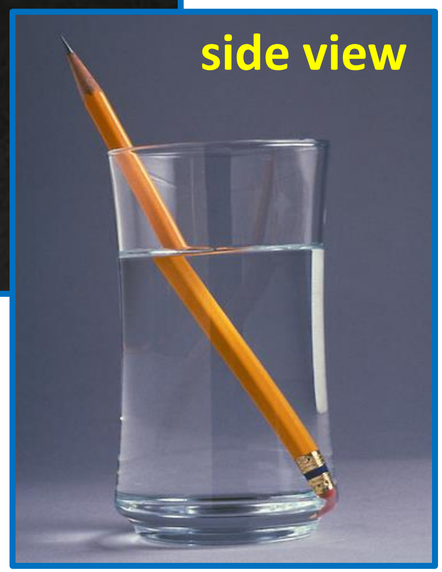


Refraction depends on:

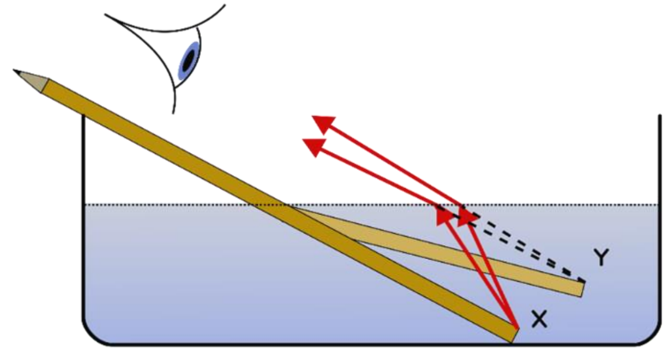
- **the ratio of the speed of light in the two materials** (compared to its speed in the air, in a diamond visible light travels about 2.4 times slower; in water – about 1.33 times slower; in glass – about 1.5 times slower)
- **the angle of incidence; a ray of light that is perpendicular to the surface is not refracted at all.**

Pencil Experiment





- The light rays form the upper part of the pencil travel straight to the eye.
- The light rays from the submerged portion of the pencil travel:

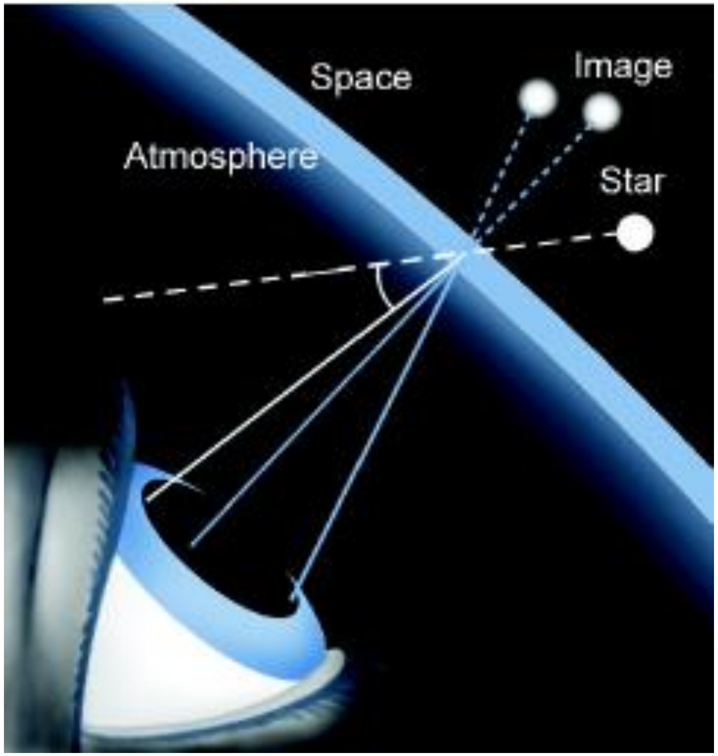


1. through the water,
2. across the water-air boundary, where they <u>refract</u>,
3. through the air ultimately to the eye.

The eye-brain interaction cannot account for the refraction of light: our brain judges the object location to be the <u>location where light rays *appear* to originate from assuming that light rays always travel in straight lines</u>…because when we are babies our brain learns exactly that!

Twinkle, twinkle, little star…

- The scientific term is "astronomical scintillation".
- Observed from the Earth, a star is essentially a pin-point light source.
- As starlight travels from space into the Earth's atmosphere, the rays are refracted.
- Since the atmosphere is constantly changing due to turbulence, the amount of refraction also constantly changes.



- This causes the image of a star to form in a slightly different part of our eye retina every moment – we perceive it as twinkling.
- Planets usually do not twinkle – why?
- You might actually see a planet twinkling if it appears low at the horizon – why?

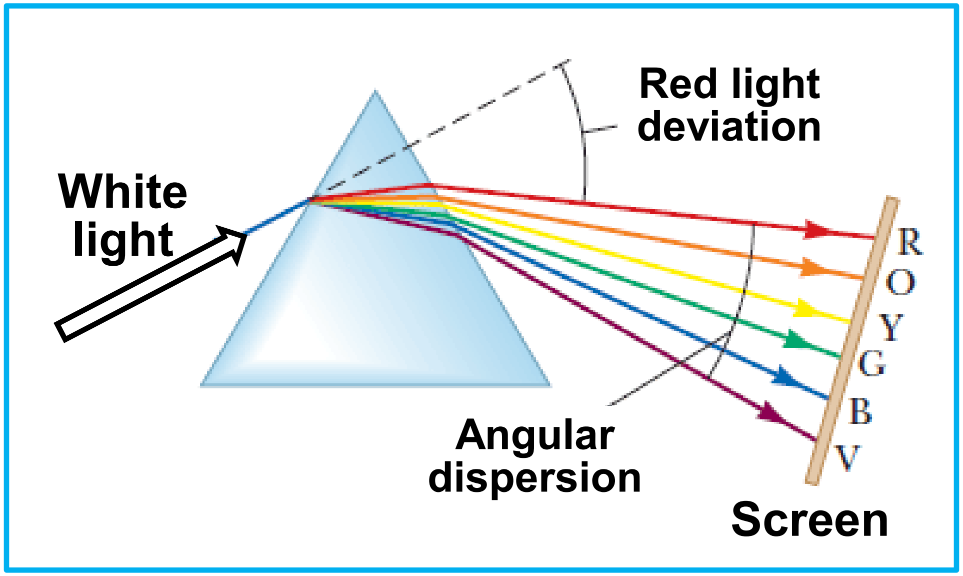
Dispersion of Light

splitting of light into its component colors

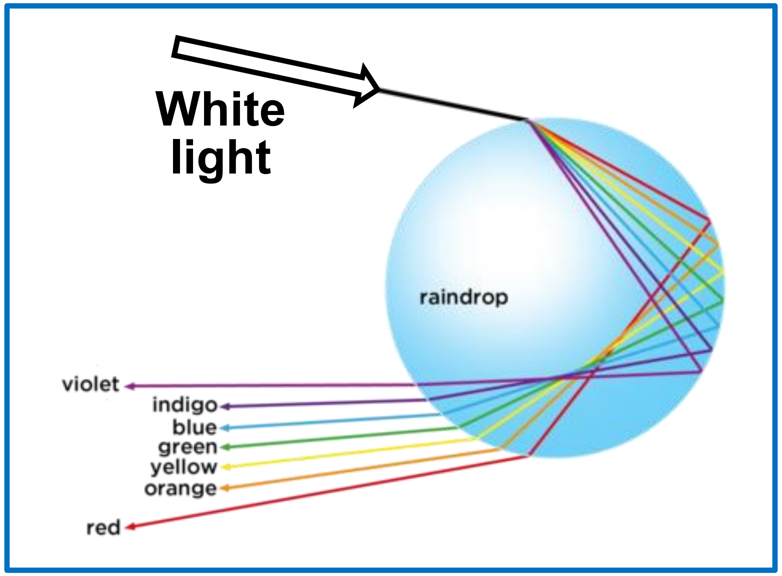
Different colors (wavelengths) of light *travel at different speed in the same material* and therefore refract differently:

- Red (longer wavelength) is bent less.
- Violet (shorter wavelength) is bent more.
- This allows for separation of colors in certain geometries.

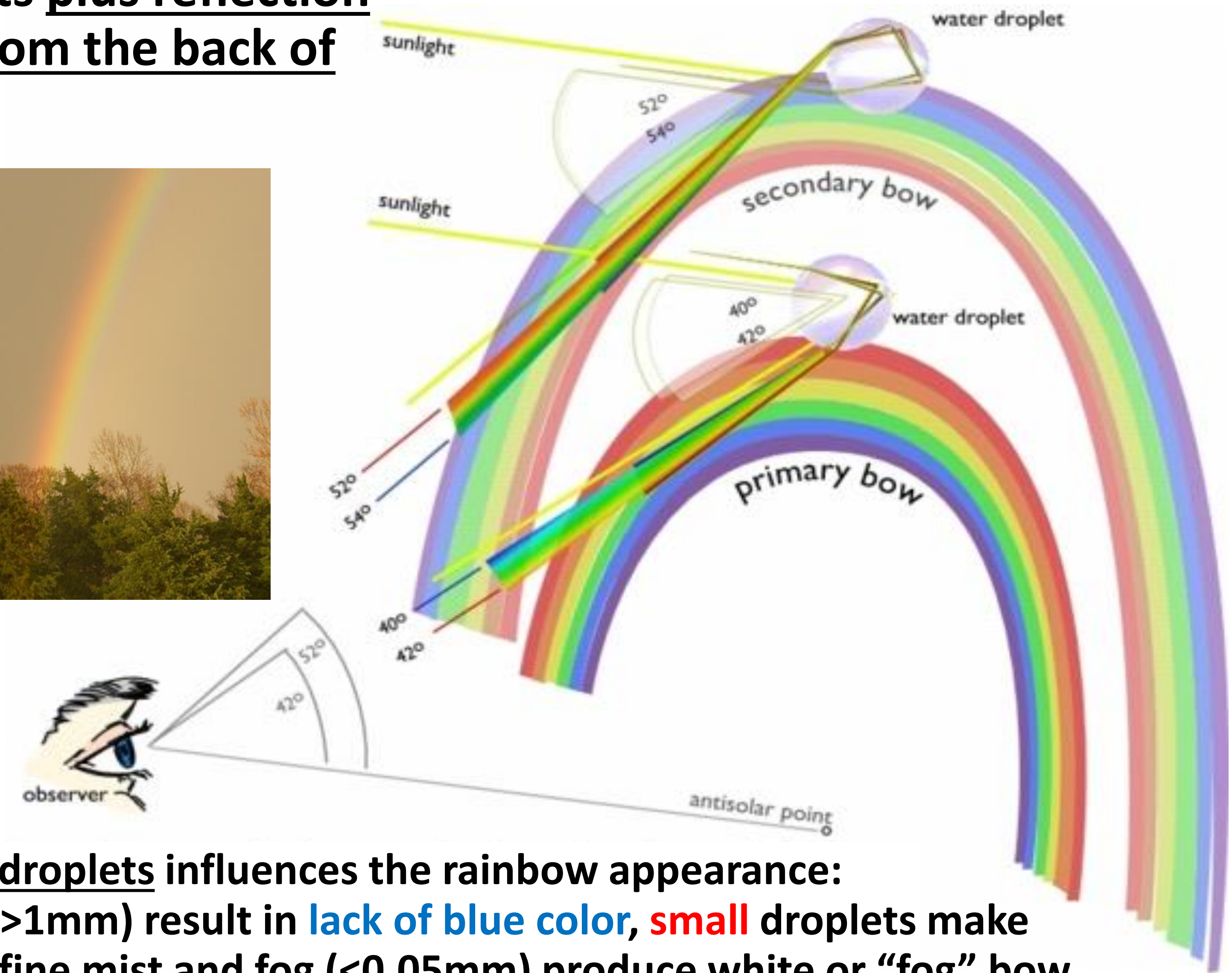
Glass prism



Water droplet



Rainbows result from **refraction of sunlight** in falling water droplets **plus reflection** of the light **from the back of the droplet**.



The size of the droplets influences the rainbow appearance:
large droplets (>1mm) result in lack of blue color, small droplets make red disappear; fine mist and fog (<0.05mm) produce white or "fog" bow.

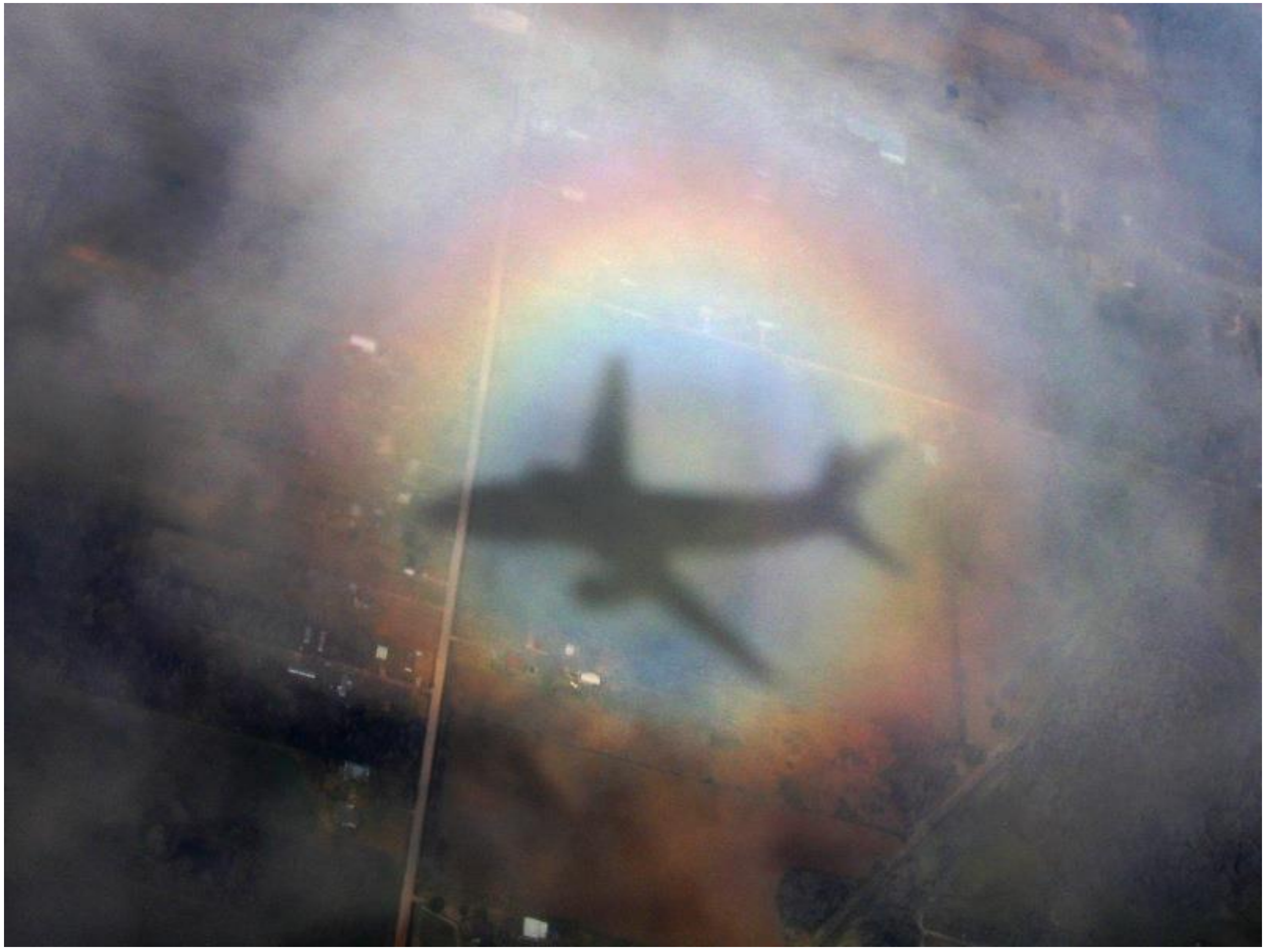
Rainbows…in your backyard!

All you need is small water droplets and bright sunlight!

Can you see the rainbow when the **Sun is overhead**?
Can you see the **full circle**?

Think again ☺

All you need to do is position yourself between the Sun and the raincloud and look down!

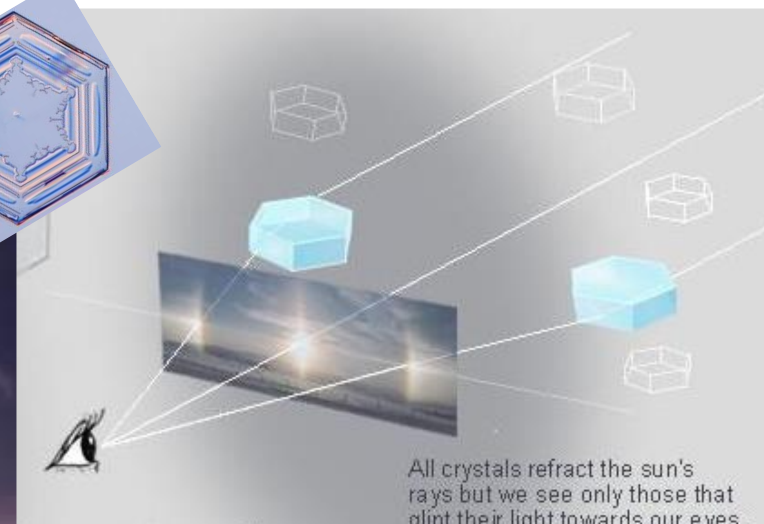


The Glory

What happens to light if we have ice crystals in the air instead of water droplets?

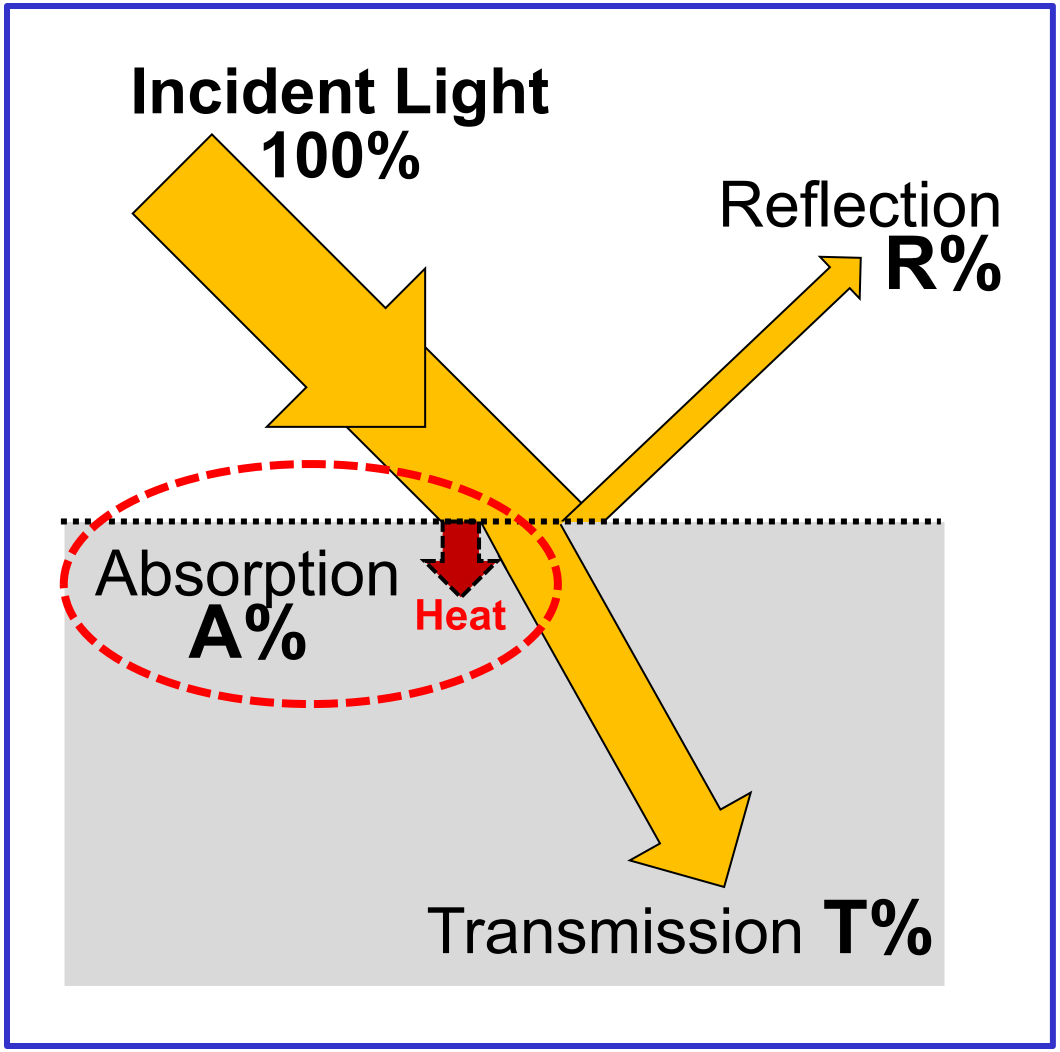
The Sun Halo and the Sun Dogs

formed by light refraction in horizontally floating hexagonal plate ice crystals high in the cirrus clouds.



The Sun Halo and the Sun Dogs <u>occur world-wide</u> but more common in cold climates.

Light Interaction with Non-Luminescent Matter



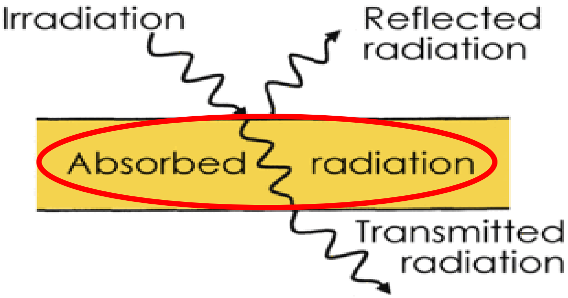
- **<u>Combination</u> of transmission, reflection, and absorption:**

T%+R%+A%=100%

- **No material is 100% transparent.**
- **No material is 100% absorbing either.**

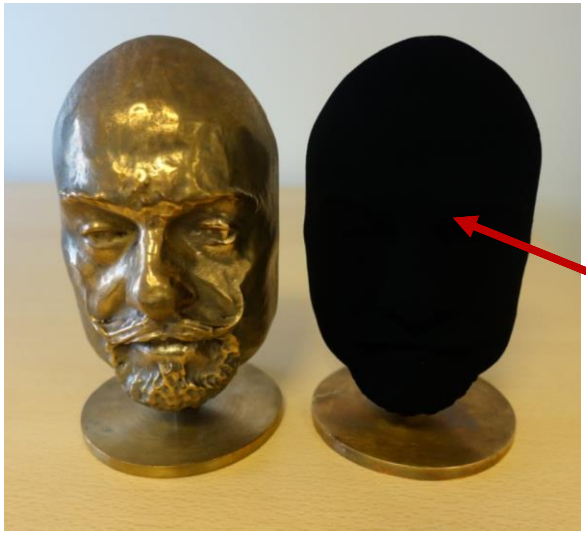
Absorption

disappearance of a light wave



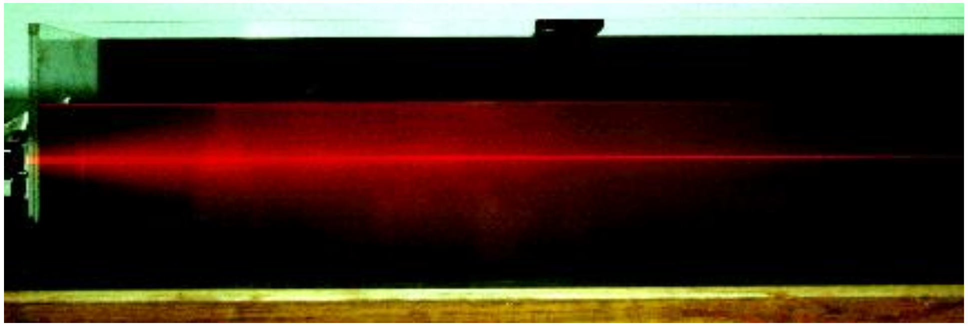
- The **energy of a light wave is taken up by matter** and in most cases converted into heat.

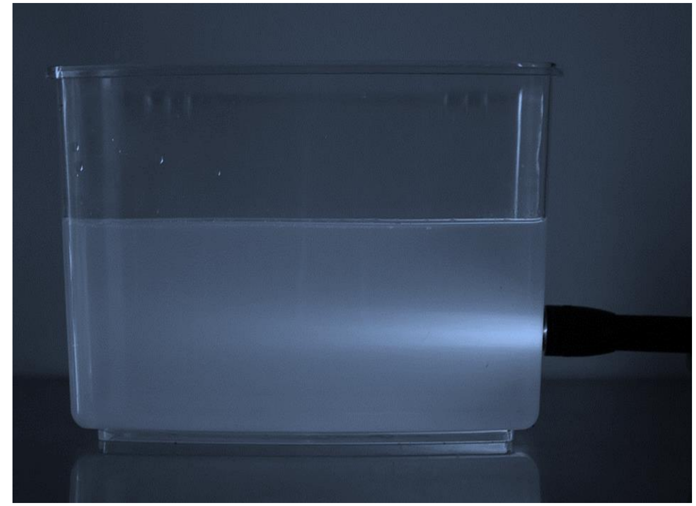
- **Dark opaque** objects **absorb most** of the incident light.



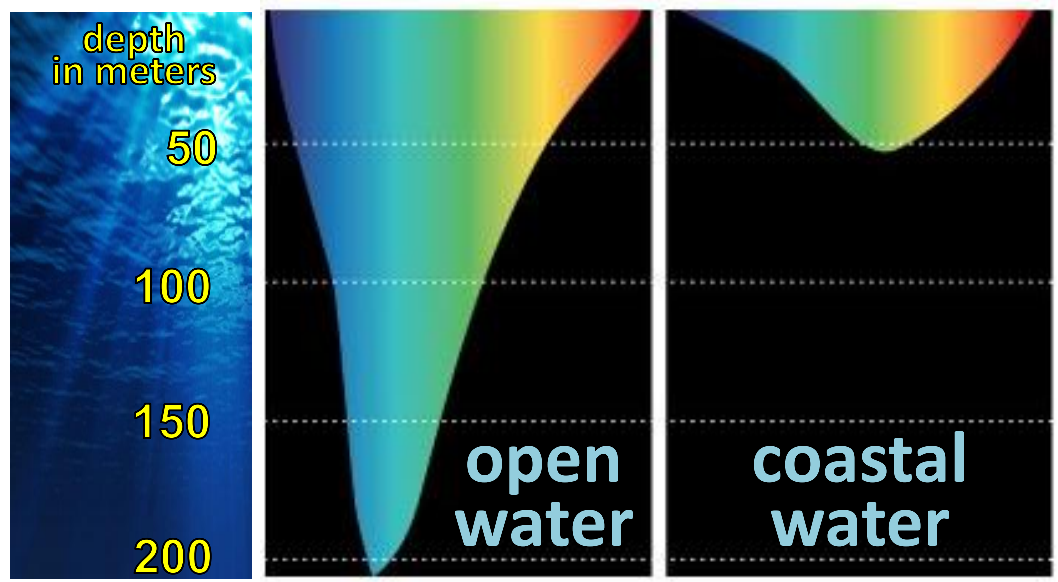
Vantablack – one of the darkest substances known, absorbing up to 99.965% of visible light!

Transparent and **translucent** objects always **absorb some part** of the incident light.



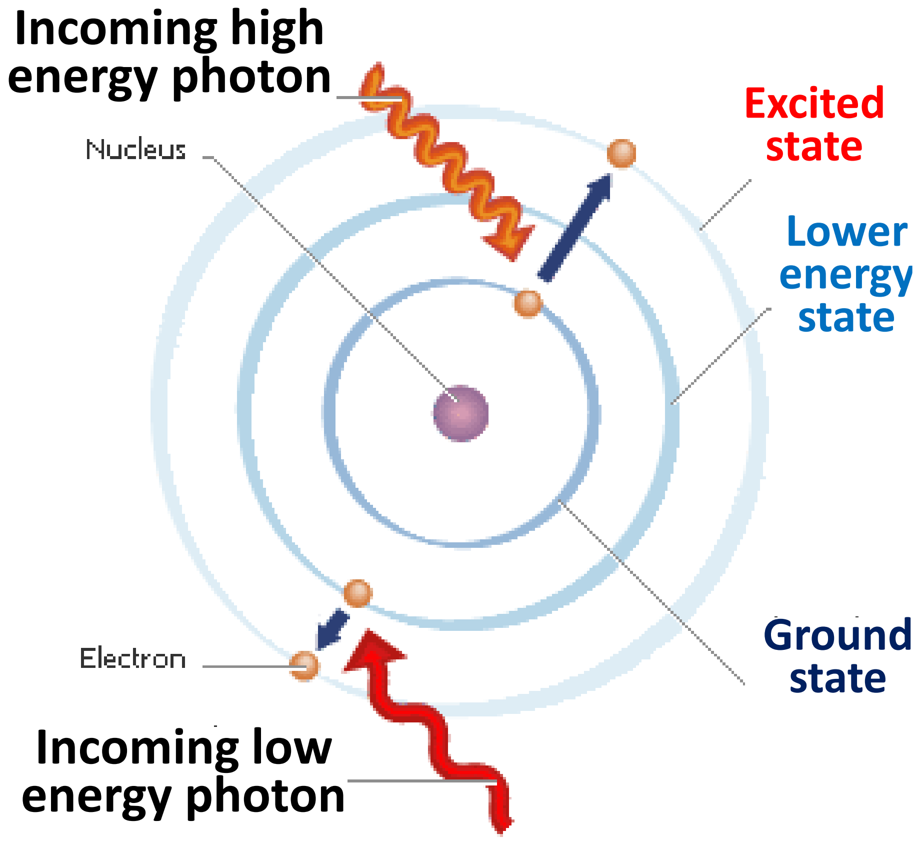


Absorption of Sunlight by Water

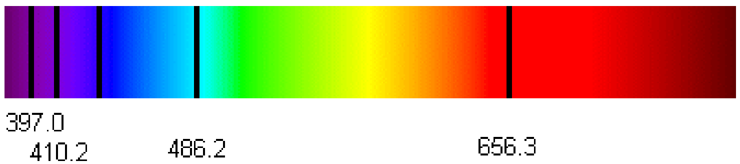


Absorption Spectrum

Absorption of light can happen when the photon energy (i.e. *frequency*) matches one of the allowed transitions between energy levels of a particular atom.

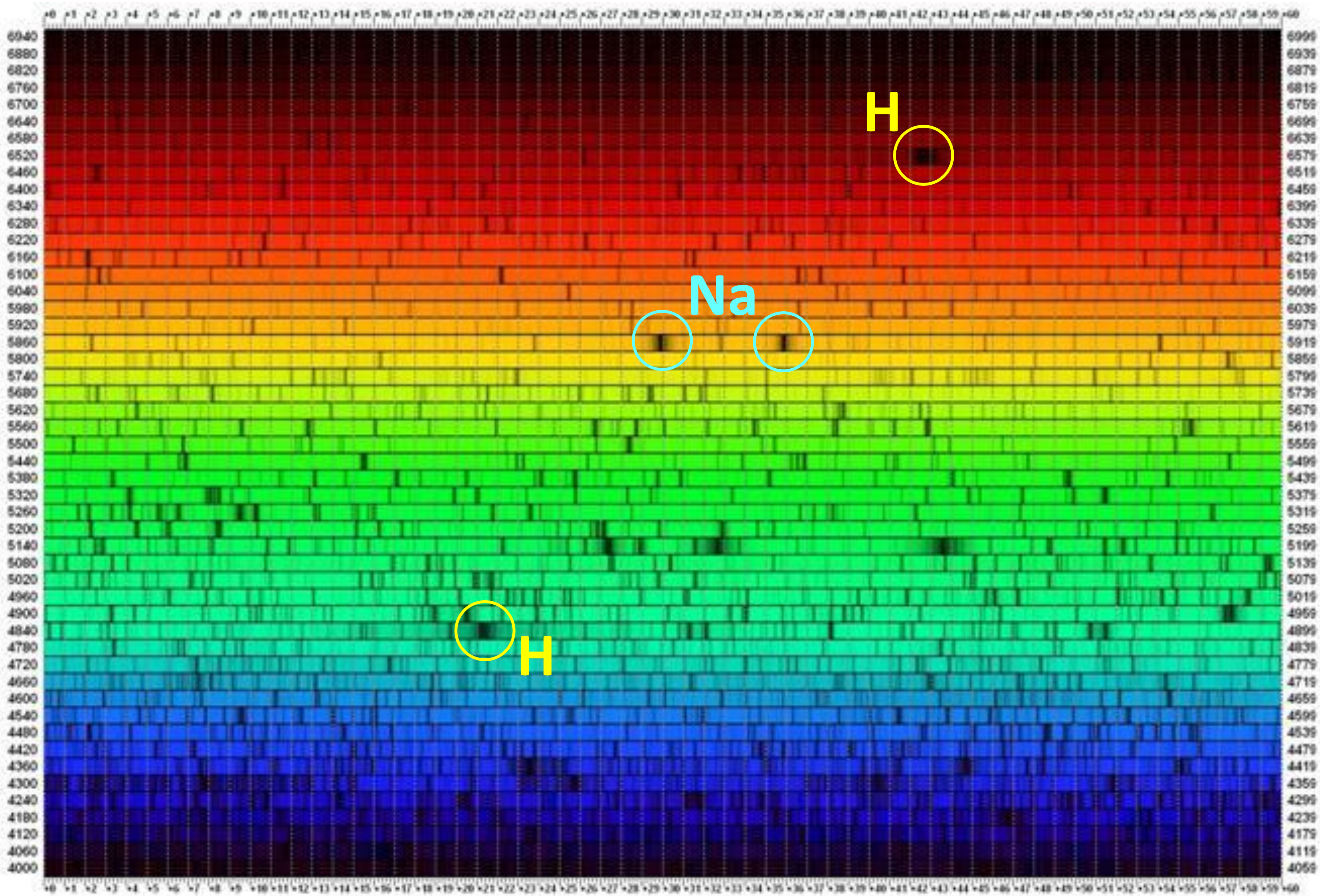


Example: Hydrogen



A star will create an absorption line spectrum because the continuous spectrum emitted by the dense, opaque gas that makes up most of the star passes through the cooler, transparent atmosphere of the star.

Absorption Spectrum of the Sun



Sunlight Filtered through Atmosphere

Absorption of sunlight by various gas molecules that are present in the Earth's atmosphere is seen as absorption bands in the Sun spectrum.