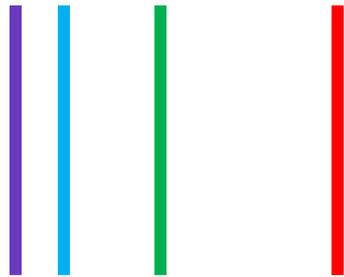
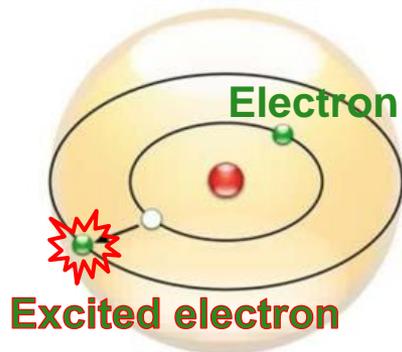


# Gases

atoms far apart

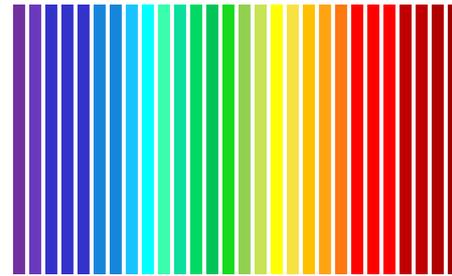


limited set of distinct colors

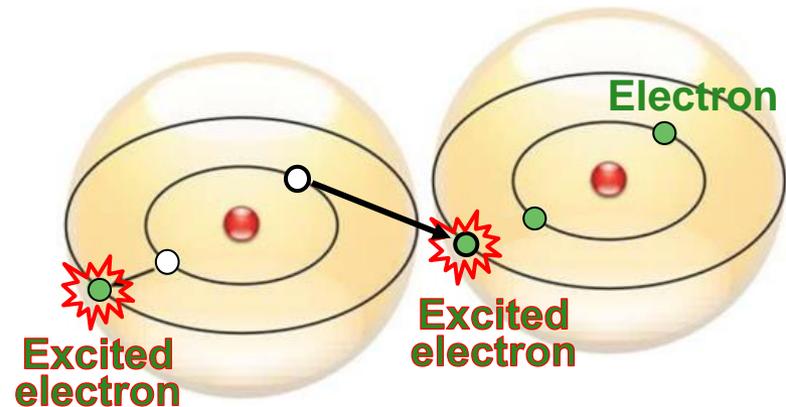


# Solids/Liquids

atoms close to each other



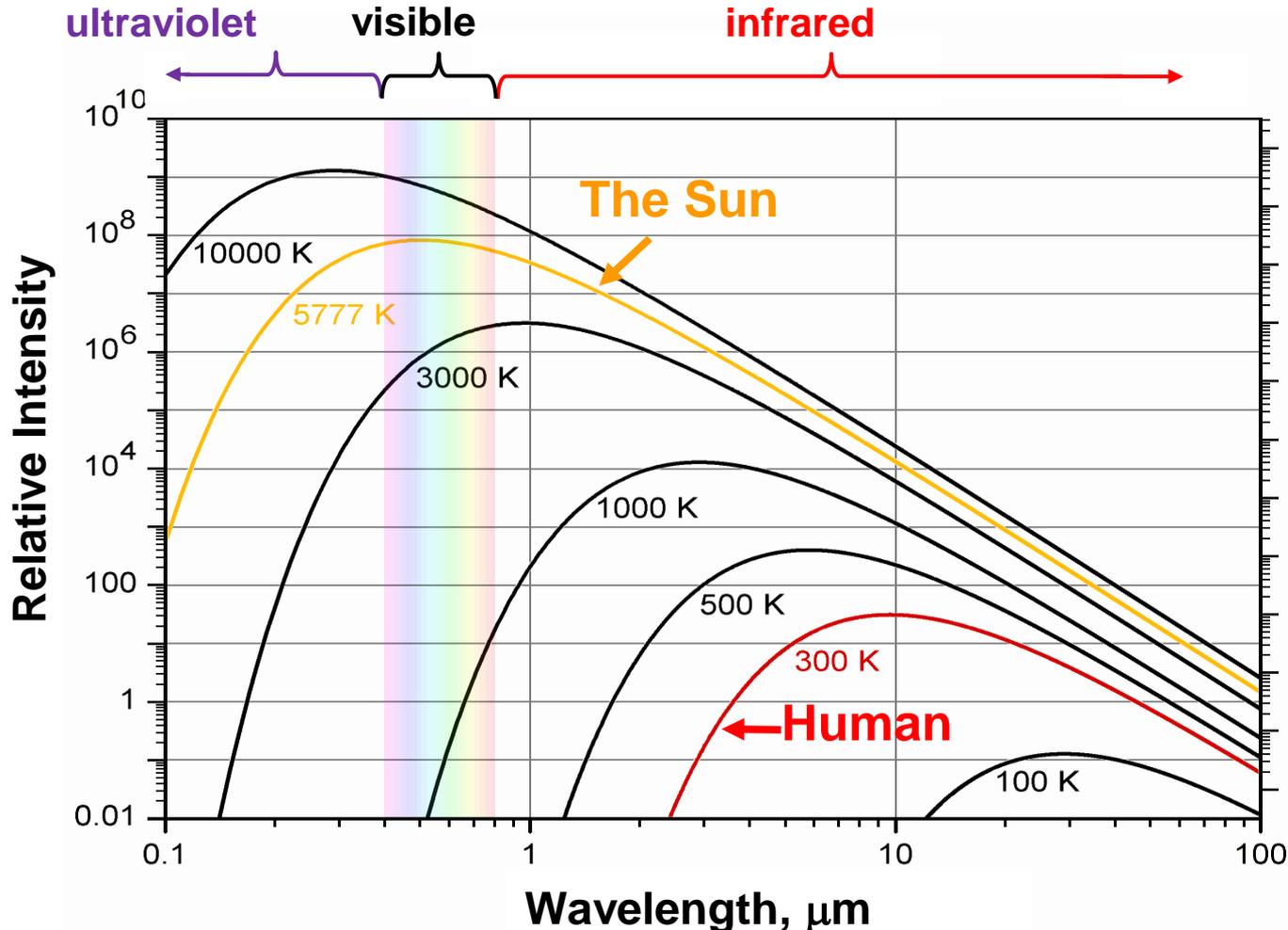
much greater number of possible colors



**VS**

# Thermal Radiation Spectrum

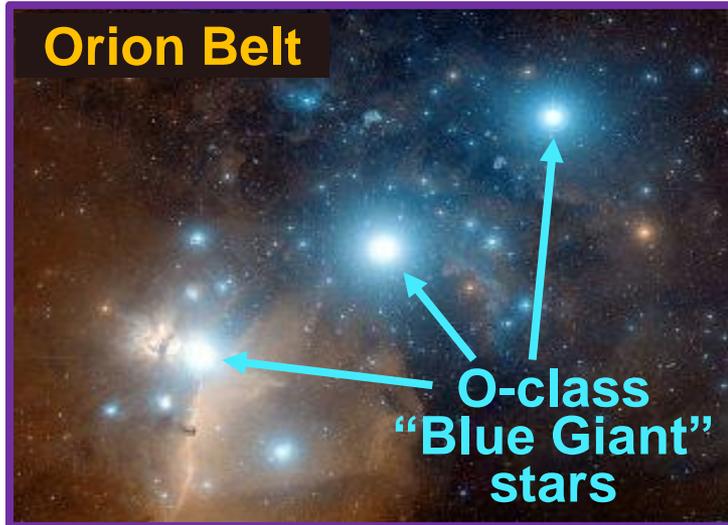
The exact thermal radiation spectrum depends upon **properties of the material** and the **temperature**.



In general, as the temperature increases, the peak of the radiation curve moves to higher intensities and shorter wavelengths.

# Everything Glows!

- The temperature at which all solids glow a **dim red** is about **800 K** (over  $500^{\circ}\text{C}$  or  $900^{\circ}\text{F}$ ).

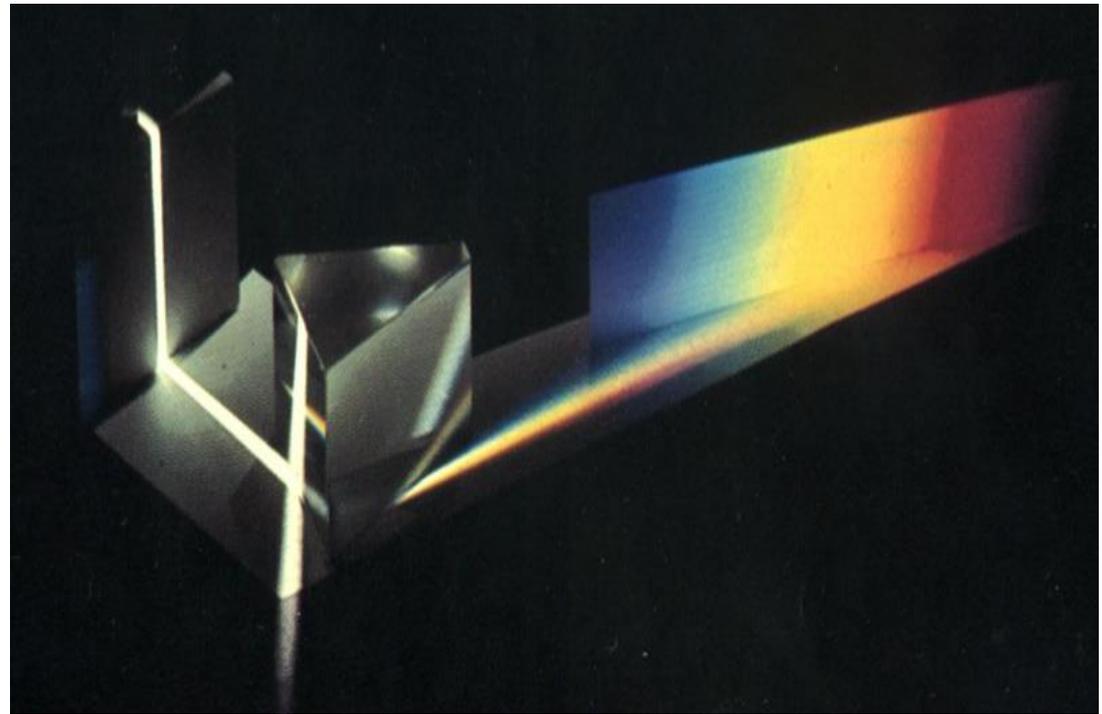


- A very hot object (**10,000 K**) would emit a significant amount of energy in the **ultraviolet and x-ray region** of the spectrum.

- People are emitters of light in the **infrared region** (peak  $\sim 9.5\mu\text{m}$ ).

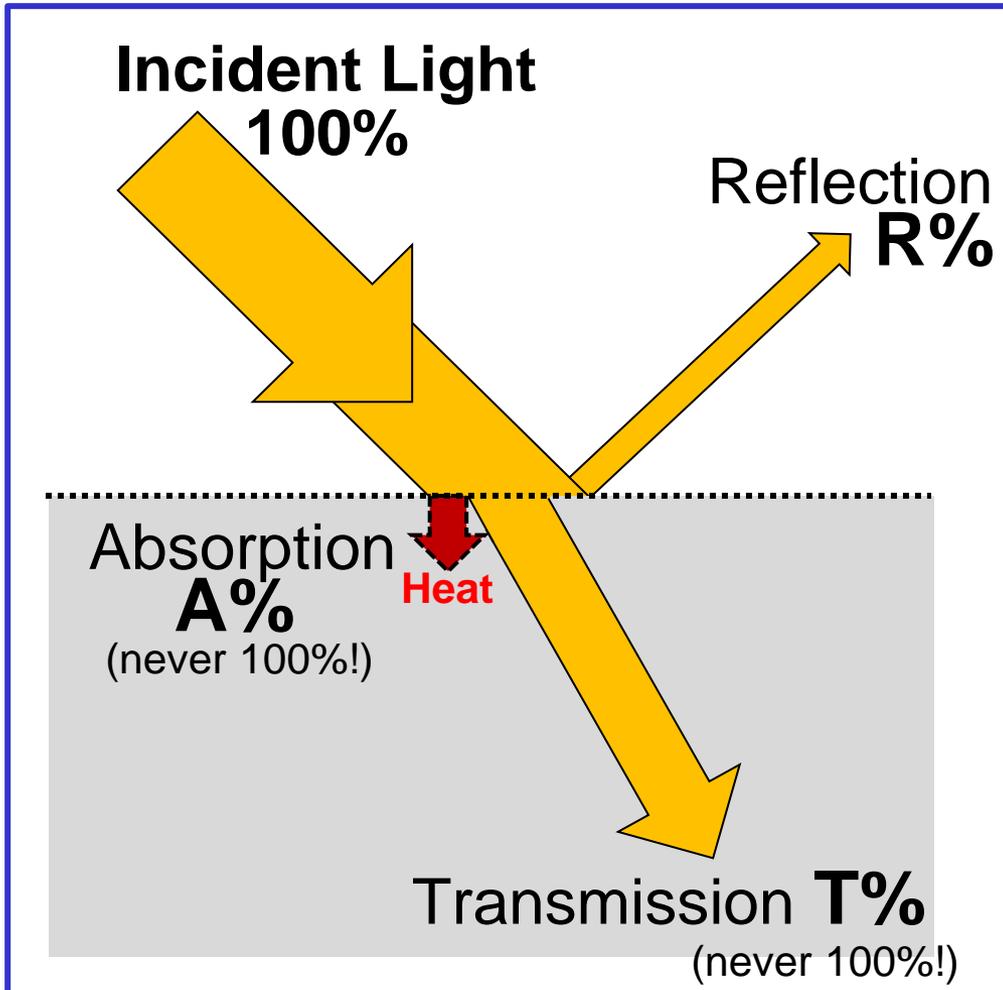


# Light meets Matter



# What (always) happens to light?

The material world around us can be viewed as **objects** (substances, materials) and **boundaries** (surfaces, interfaces).



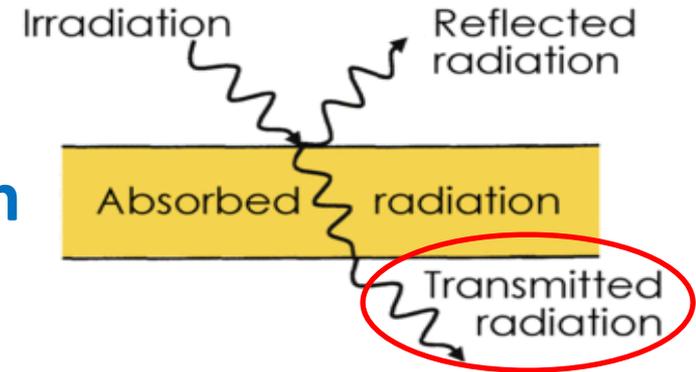
Light (energy!) can be **reflected**, **transmitted** or **absorbed** by matter.

$$T\% + R\% + A\% = 100\%$$

What *exactly* happens to light waves depends on the nature of the material, the smoothness of the surface, the angle of incidence, and the light wavelength.

# Transmission

passage of light in forward direction



All objects around us can be classified as:

## Transparent



(Large T%)



## Translucent

partial or selective transmission

## Opaque

(most materials)  
do not allow transmission of light,  
form shadows



(T%=0)

# Shadows



- Light rays travel in straight lines, radiating out from the light source.
- If rays are blocked by an opaque object, a **shadow** forms where the light cannot reach.
- If the light source is moved relative to the object, different amount of light is blocked, and a different shadow is formed.

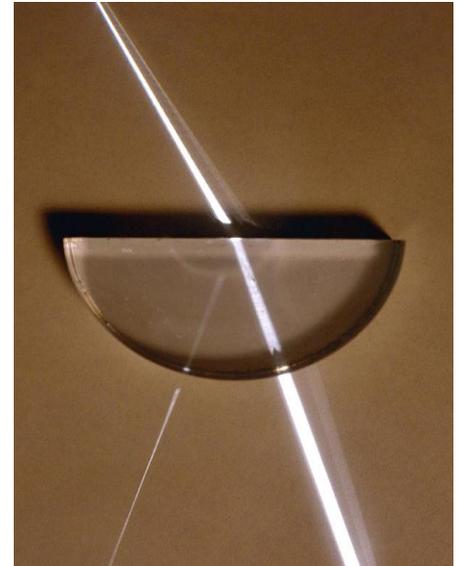
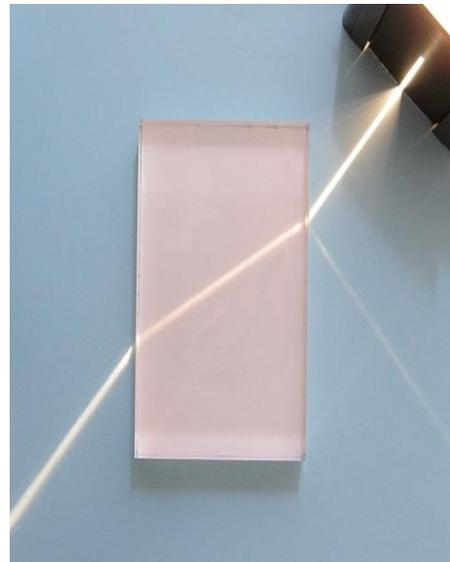
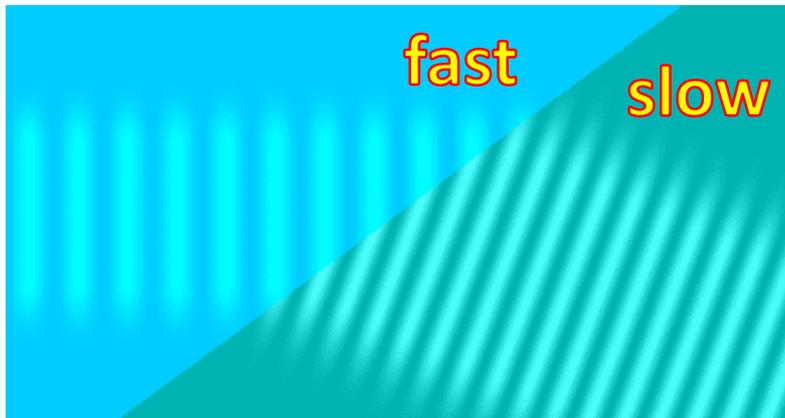


Egyptian obelisk at St. Peter's Square, Vatican City

# Transmission: Refraction

change in the direction of travel at the boundary

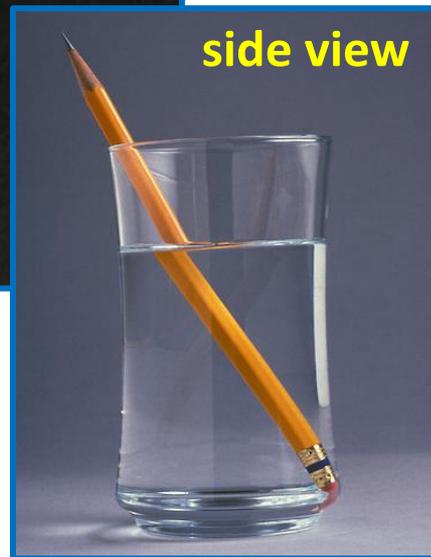
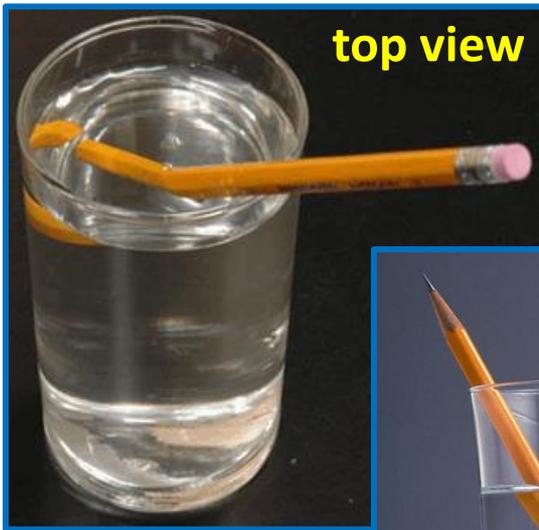
Different materials transmit light at different speeds.



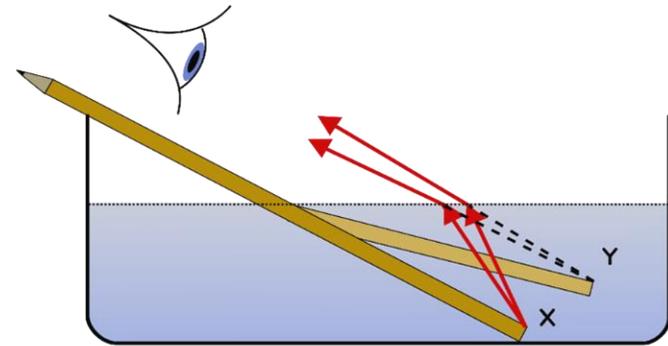
Refraction depends on:

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

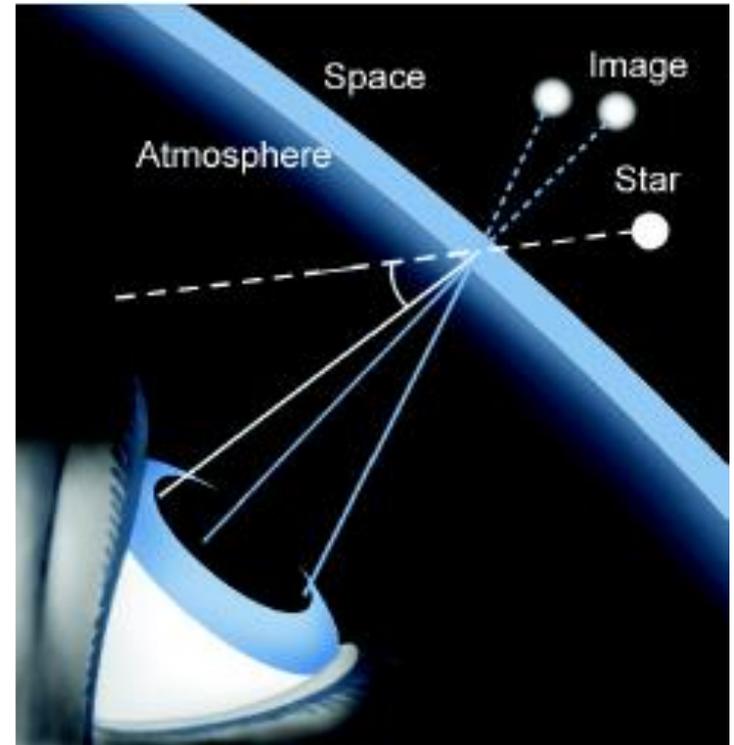


1. through the water,
2. across the water-air boundary, where they refract,
3. through the air ultimately to the eye.

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

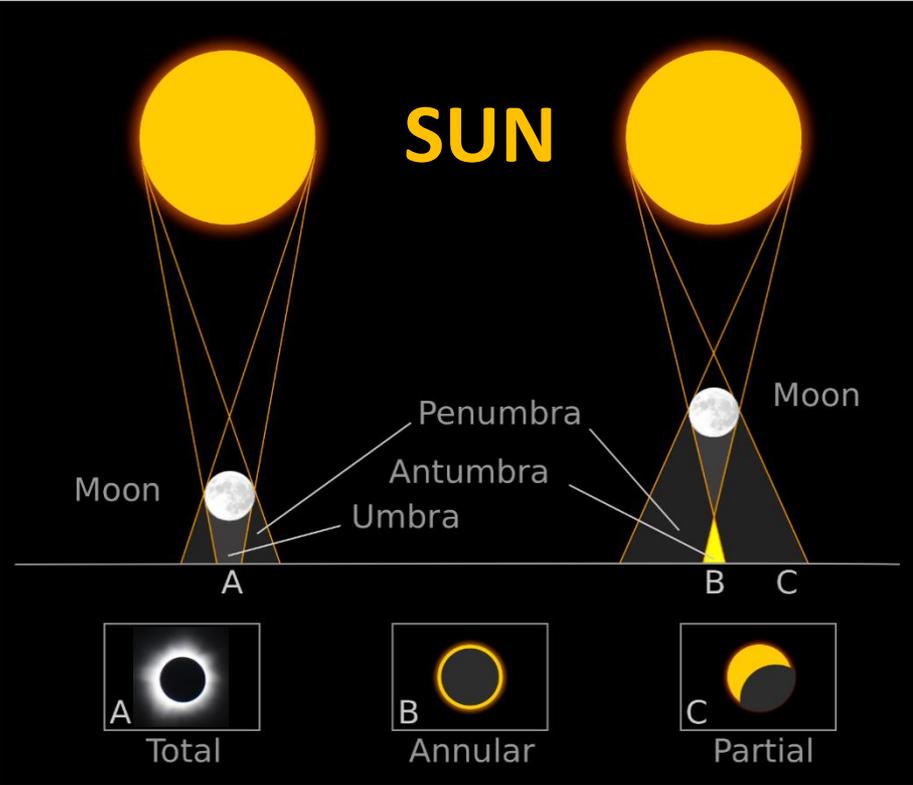
# Twinkle, twinkle, little star...

- 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?

# Solar Eclipse



# Translucent Creatures

*(partial transmission)*



Mantis shrimp larva



**How do you  
hide in the  
ocean?**

**You become  
see-through!**

# Light Filters *(selective transmission)*



**Rashad Alakbarov, Azerbaijan**



**Tom Fruin, USA**

**Rose Window  
St. Patrick's Cathedral, New York**



# Refraction in Water

