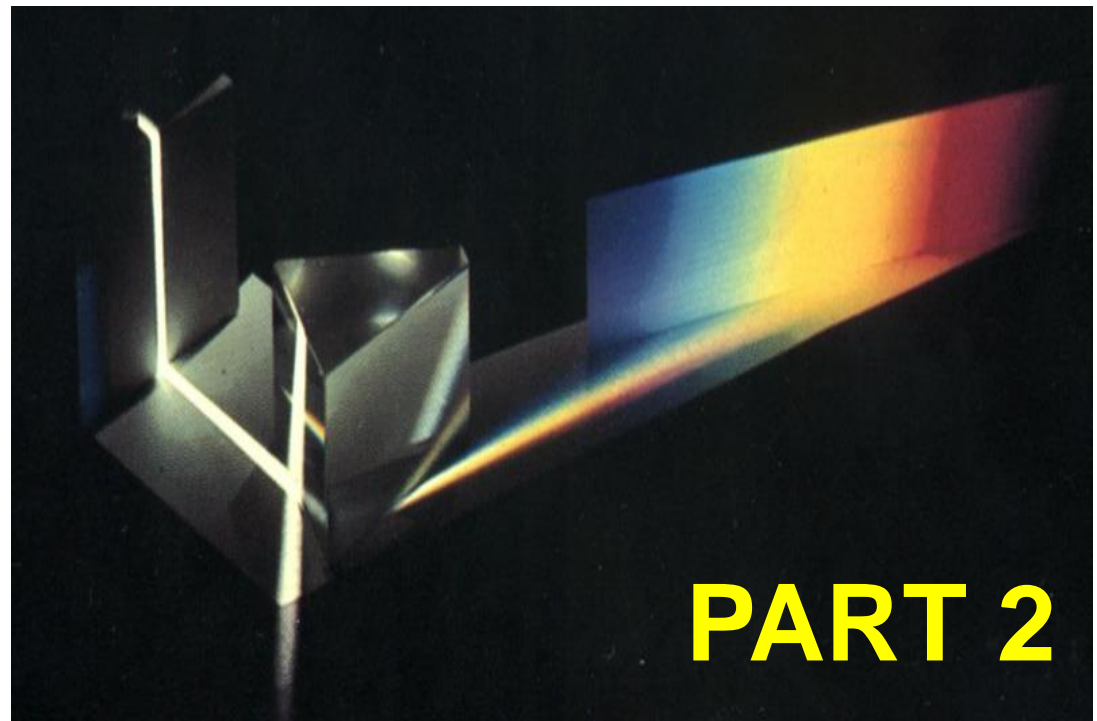
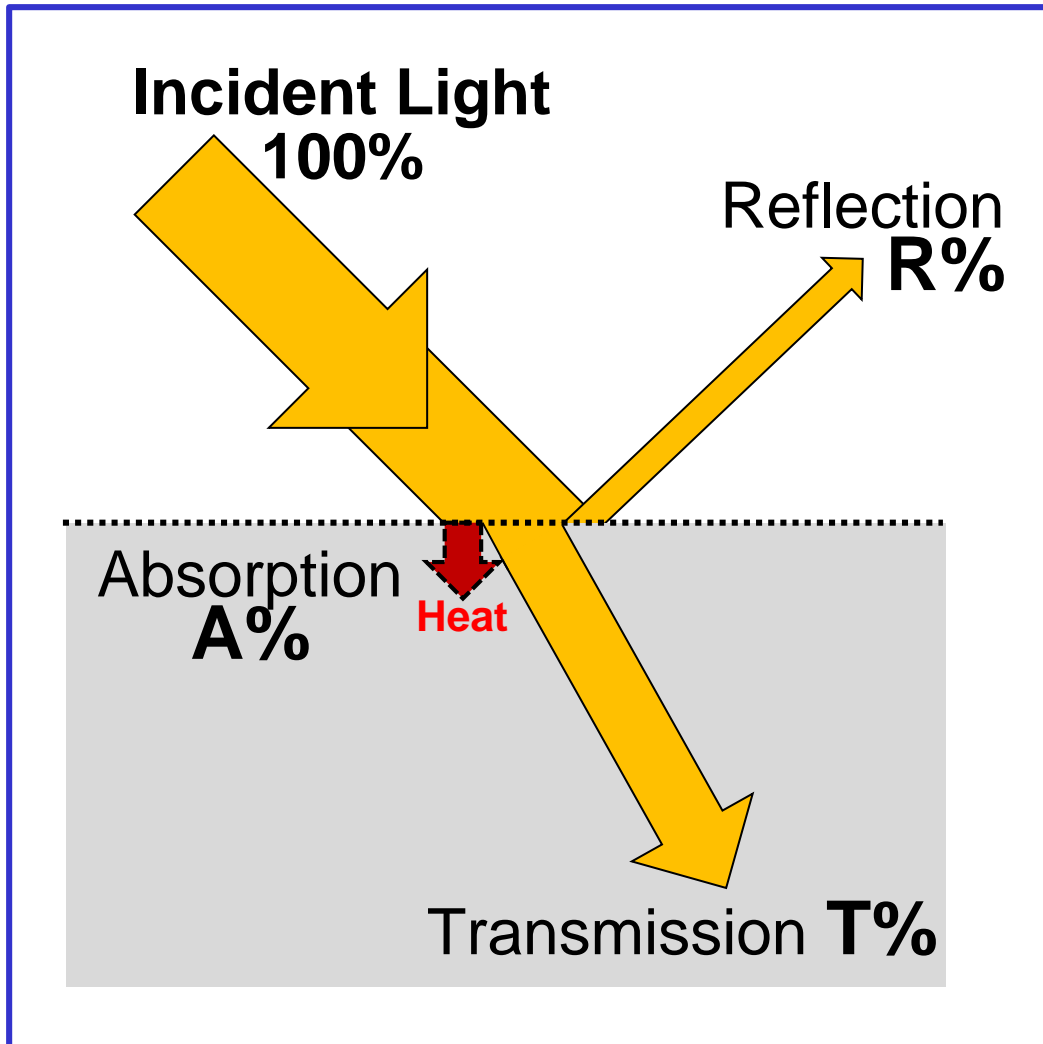


# Light meets Matter



# Light Interaction with Non-Luminescent Matter



- Combination of transmission, reflection, and absorption:

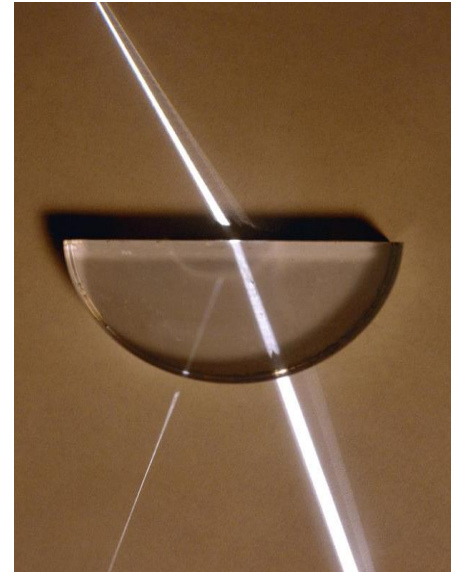
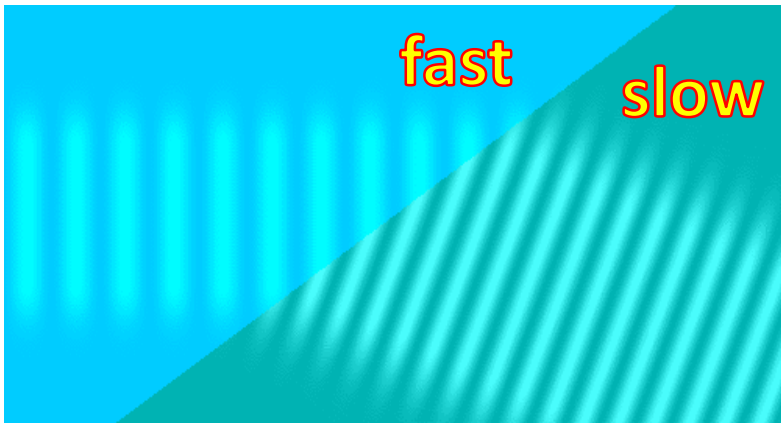
$$T\% + R\% + A\% = 100\%$$

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

# Refraction

change in the direction of travel at the boundary

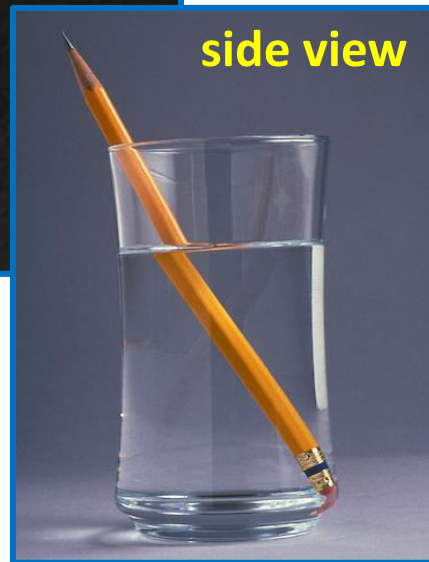
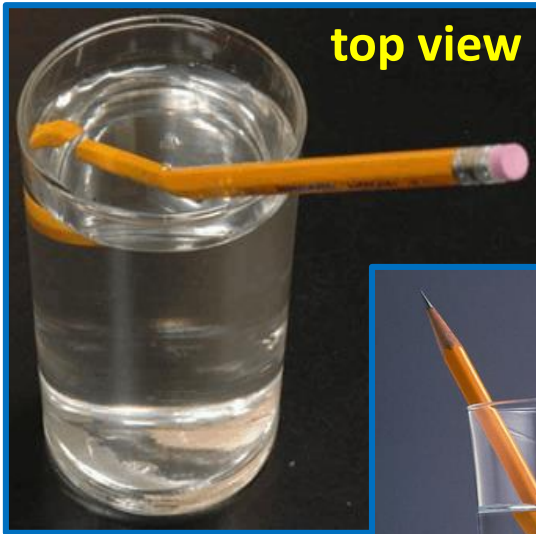
Different materials transmit light at different speeds.



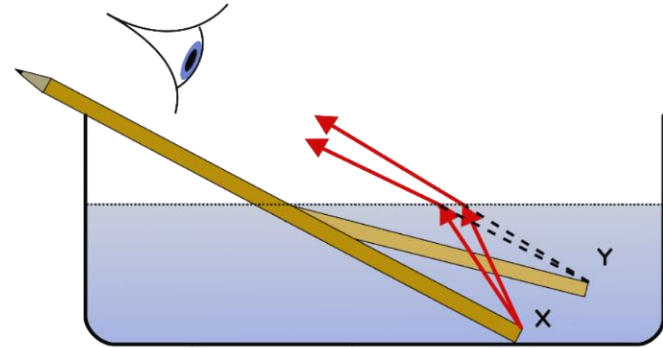
Refraction depends on:

- 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**: the 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.



# Refraction *in Water*

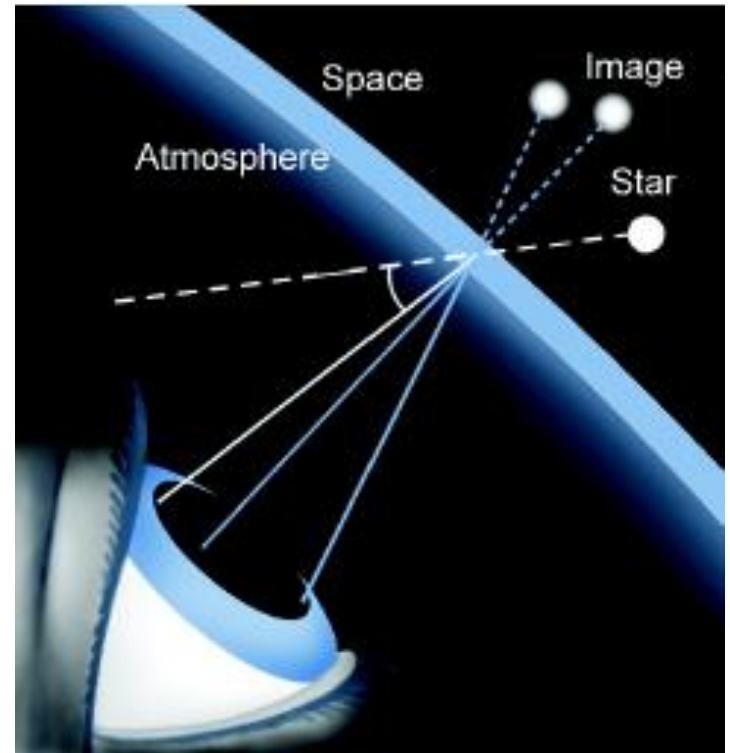


**Bent, Broken, Magnified...**



# 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?

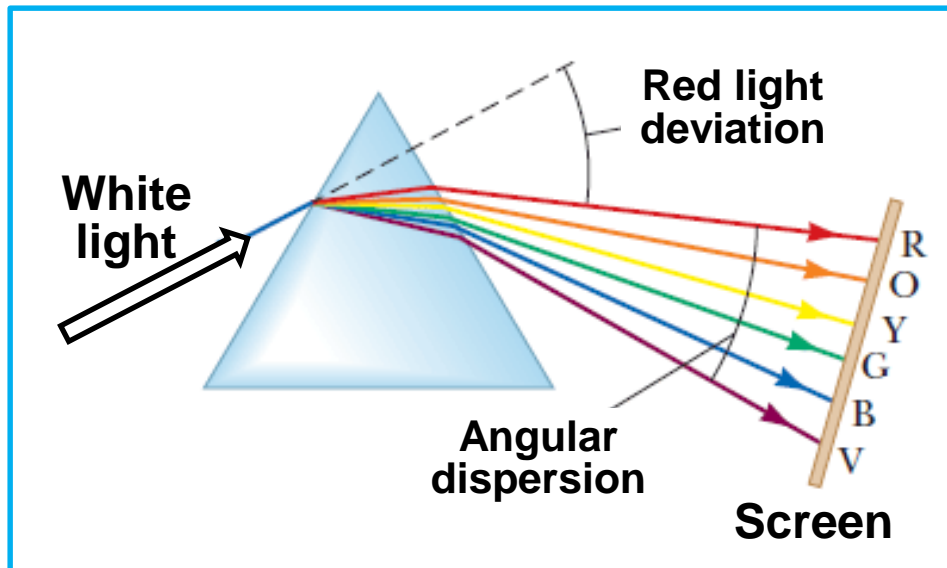
# Dispersion of Light

splitting of light into its component colors

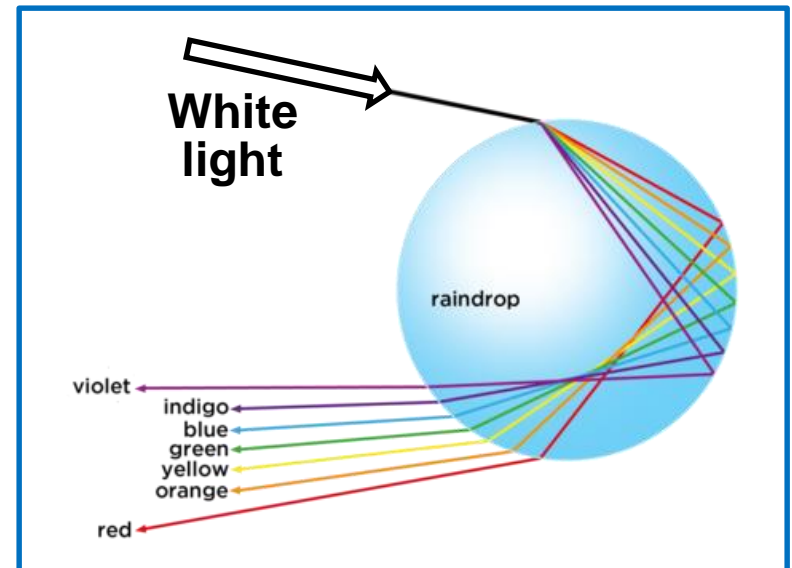
Different colors (wavelengths) of light *travel at different speed in the same material* and therefore refract differently:

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

## Glass prism



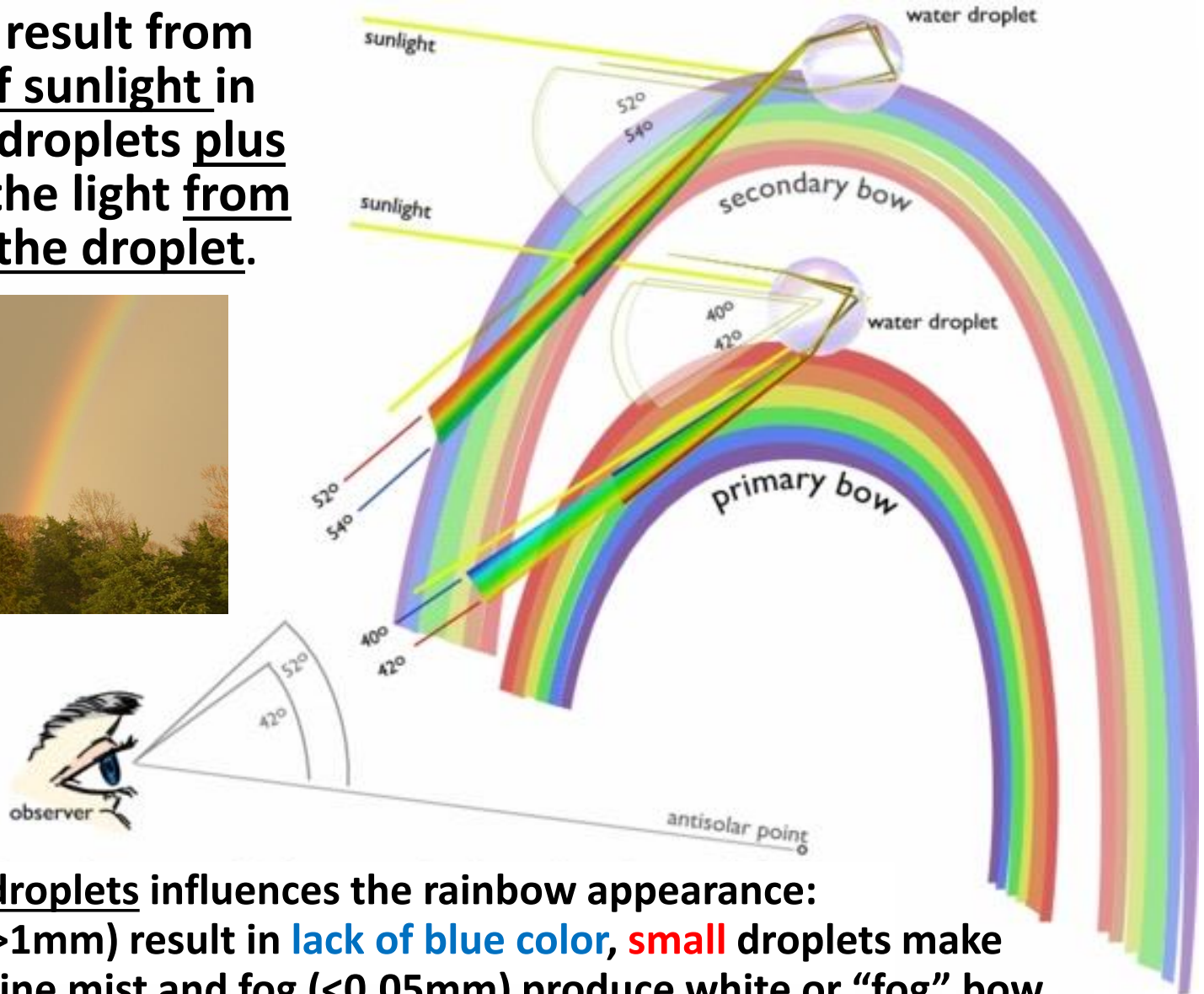
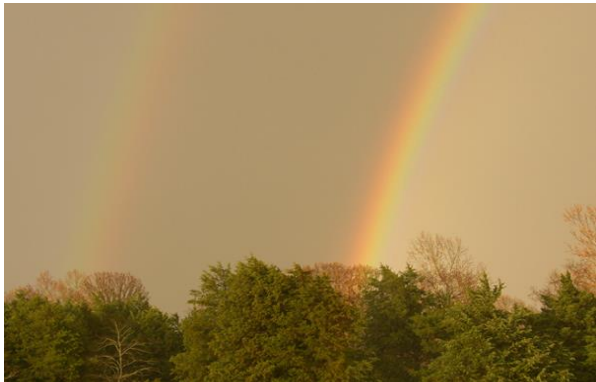
## Water droplet





# Rainbow

**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 😊**

## **The Glory**

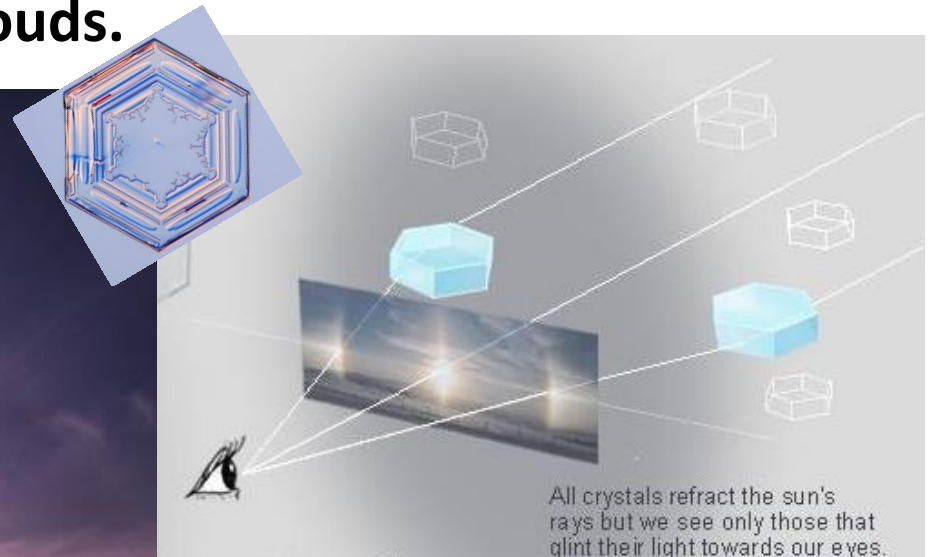
All you  
need to do  
is  
**position  
yourself  
between  
the Sun  
and the  
raincloud!**



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 occur  
world-wide but  
more common  
in cold climates.**