The Doppler Effect

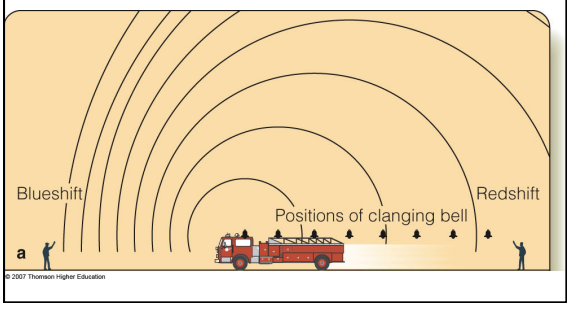
- Definition: "The change in wavelength of radiation due to relative radial motion between the source and the observer."

Real Life Example of Doppler Effect

The change in the pitch of a siren on a police car, fire truck, or ambulance as it zooms past (sound waves)

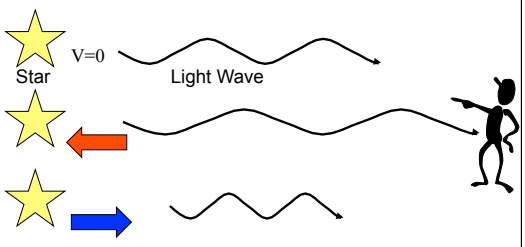
Astronomers deal with the Doppler Effect of light waves

Doppler Effect



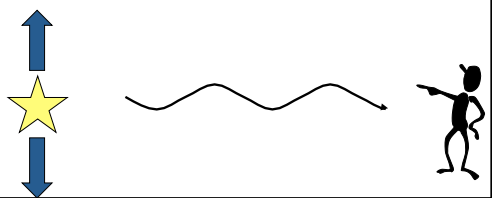
Doppler Effect

When something which is giving off light moves towards or away from you, the wavelength of the emitted light is changed or shifted

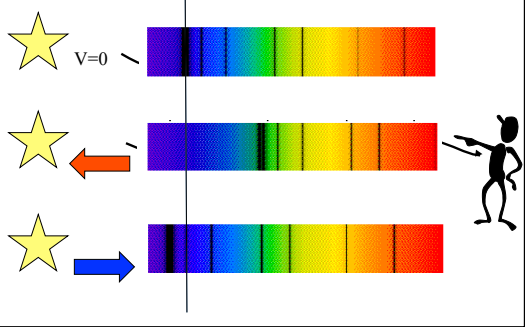


Doppler Effect

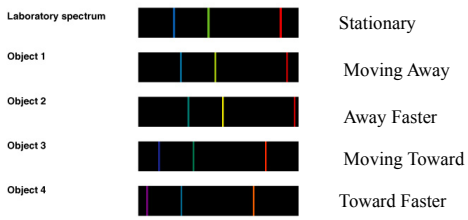
- "Radial" means "along line of sight"
- Doppler Effect happens only if the light source is ***moving towards you or away from you***.



Doppler Effect



Amount of shift tells us speed of source's motion



Doppler Shifts

- Redshift (to longer wavelengths): The source is moving *away from* the observer
- Blueshift (to shorter wavelengths): The source is moving *towards* the observer

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

$\Delta\lambda$= shift in wavelength
λ_0 = wavelength if source is not moving
V = velocity of source
c = speed of light

What can we learn from light?

- Chemical Composition
- Speed towards or away from us
- Temperature
- Total Thermal Energy

All from the spectrum!

Temperature or Heat?

- Temperature: intensity of thermal energy
- Heat: amount of thermal energy (or thermal radiation)

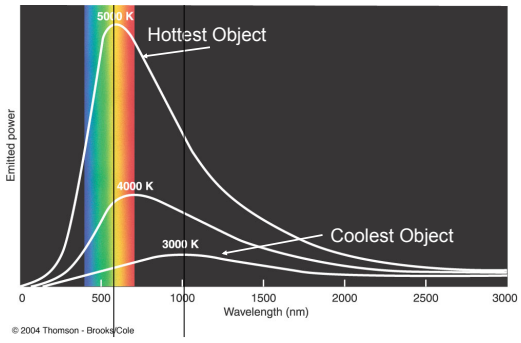
Two objects can be at the same temperature, but have different amounts of heat or thermal energy

Kelvin Temperature Scale

- Zero Kelvin (written 0 K) is absolute zero (-459.7ºF)
  - No heat energy
- Water freezes at 273 K, boils at 373 K.

K = ºC + 273.2

Temp: Peak in Thermal Radiation



Temperature and Color

- Higher temperature objects = produce more high E photons = higher E photons have higher frequency = high f photons have shorter λ
- What color has shorter wavelength?
  - Blue/Violet!
  - Opposite of faucet handles…

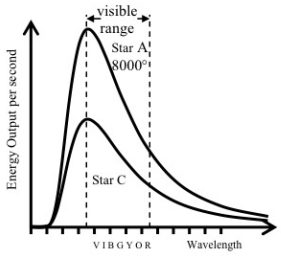
400 nm 700 nm

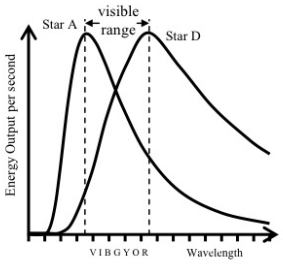
Comparing Thermal Radiation Spectra

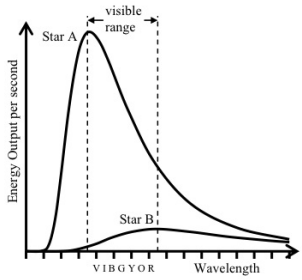
- Peak at shorter wavelength = higher temperature
- Higher temperature = bluer in color
- Larger total area under curve = higher total energy output

Blackbody Radiation Lecture-Tutorial: Pgs. 59-62

- Work with a partner or two
- Read directions and answer all questions carefully. Take time to understand it **now**!
- Come to a consensus answer you all agree on before moving on to the next question.
- If you get stuck, ask another group for help.
- If you get **really** stuck, raise your hand and I will come around.

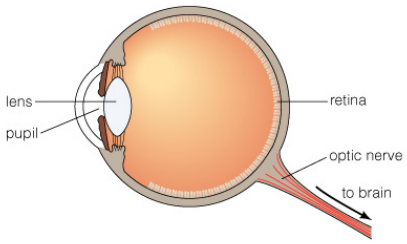




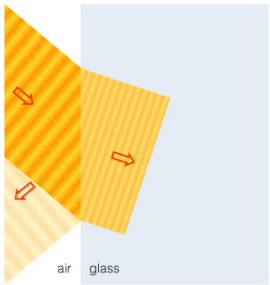


Astronomical Instruments

How does your eye form an image?

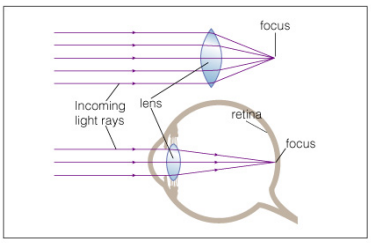


Refraction



- Refraction is the bending of light
- Eye uses refraction to focus light

Focusing Light



- Refraction can cause parallel light rays to converge to a focus

Main Functions of a Telescope

Most important

- **Gather More Light** – (bigger is better) *making objects appear brighter*

followed by

- to see fine detail

  (called resolution or angular resolution)

and least important (not really important at all)

magnify

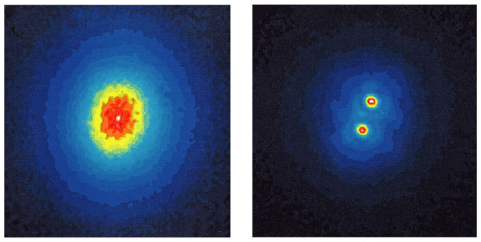
magnification = (objective lens focal length / eyepiece lens focal length)

Light Collecting Area

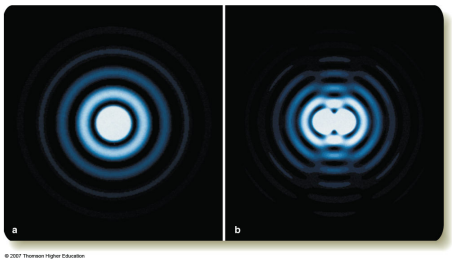
- A telescope's diameter tells us its light-collecting area: Area = $\pi(\text{diameter}/2)^2$
  - Aperture
- The largest telescopes currently in use have a diameter of about 10 meters

Angular Resolution or Resolving Power

- What is the smallest separation a telescope can detect?



Interference

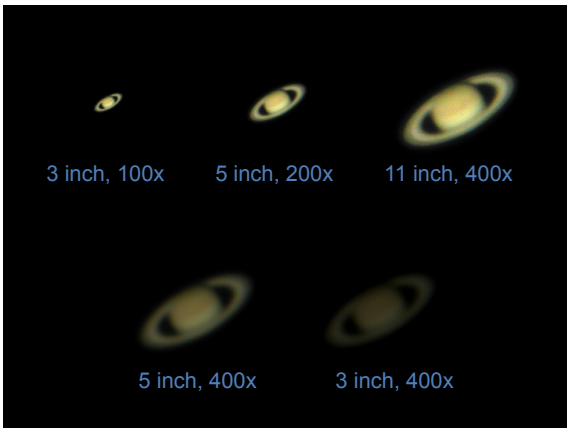


One light source Two close light sources

Magnification

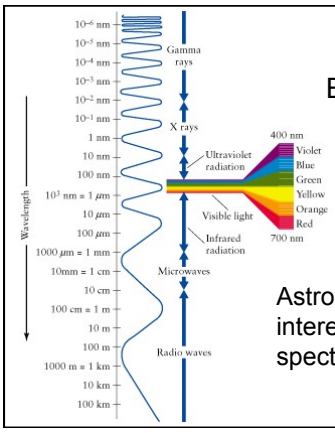
- Depends on both the objective lens and the eyepiece lens.
- M = focal length$_{obj}$ / focal length$_{eye}$
- A bigger objective lens has a larger area, but not necessarily a larger focal length
  - Focal length depends on curvature of the lens

A larger objective lens provides a *brighter* image



There are two different types of optical telescopes

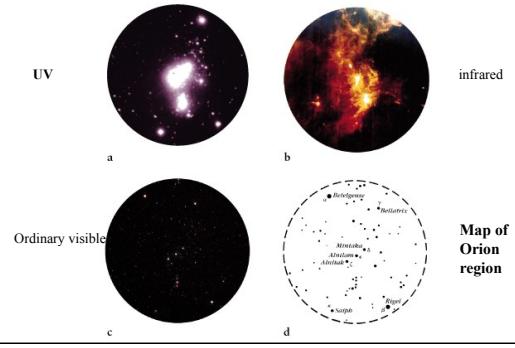
- A **refracting** telescope uses a *glass lens* to concentrate incoming light
- A **reflecting** telescope uses *mirrors* to concentrate incoming light



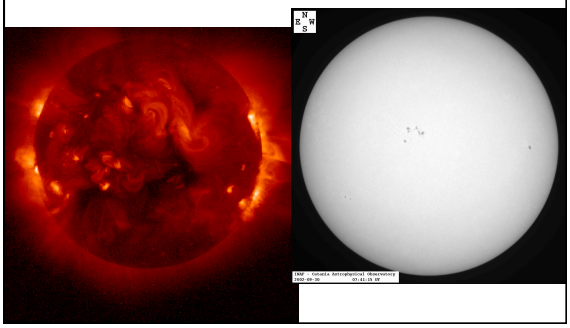
But visible light is only one type of electromagnetic radiation (light) emitted by stars

Astronomers are truly interested in the entire spectrum of Light!

Observations at other wavelengths reveal previously invisible sights



The Sun as seen in visible light from Earth and from space in X-rays by satellites



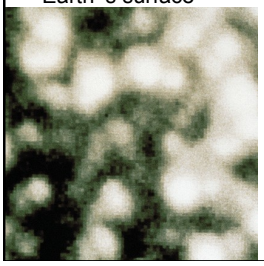
Why do we put telescopes into space?

Hubble Space Telescope

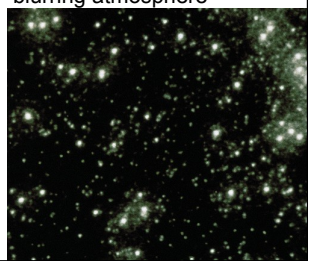
Main Mirror: 2.4 m

Earth's atmosphere gets in the way!

Image of stars taken with a telescope on the Earth's surface



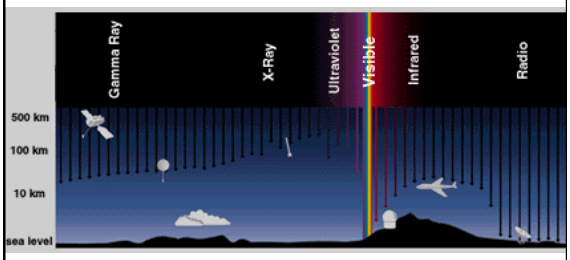
Same picture taken with Hubble Space Telescope high above Earth's blurring atmosphere



Calm, High, Dark, Dry

Summit of Mauna Kea, Hawaii

- The best observing sites are atop remote mountains



Astronomers use different instruments to look at light of different wavelengths - sometimes, we even have to go above Earth's atmosphere.

Telescopes and Earth's Atmosphere Lecture Tutorial: Pages 51-53

- Work with a partner or two
- Read directions and answer all questions carefully. Take time to understand it **now**!
- Come to a consensus answer you all agree on before moving on to the next question.
- If you get stuck, ask another group for help.
- If you get **really** stuck, raise your hand and I will come around.