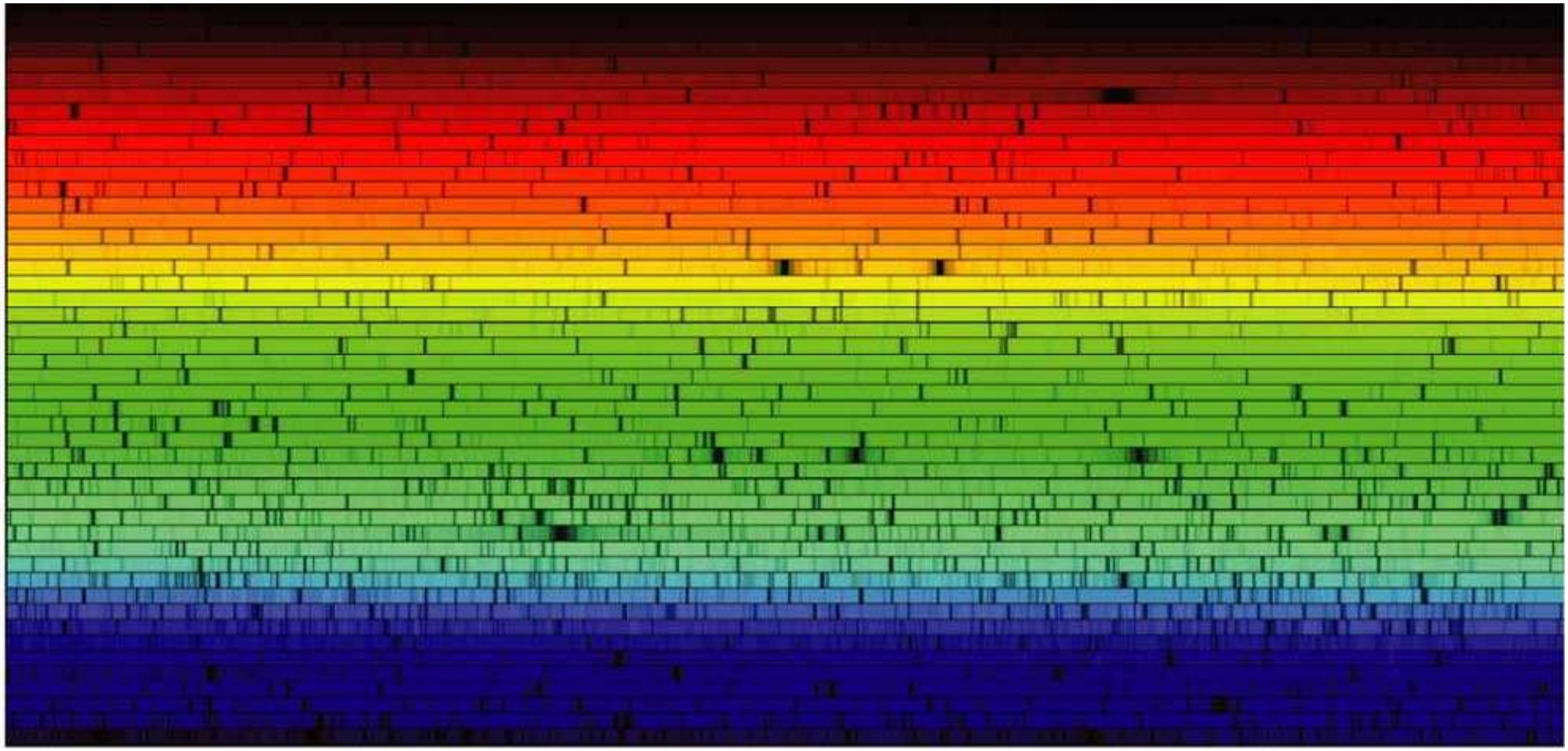


The Solar Spectrum, Chapter 5 Opening Figure

“The universe is full of magical things, patiently waiting for our wits to grow sharper.”

Eden Phillpotts

What We Will Learn Today

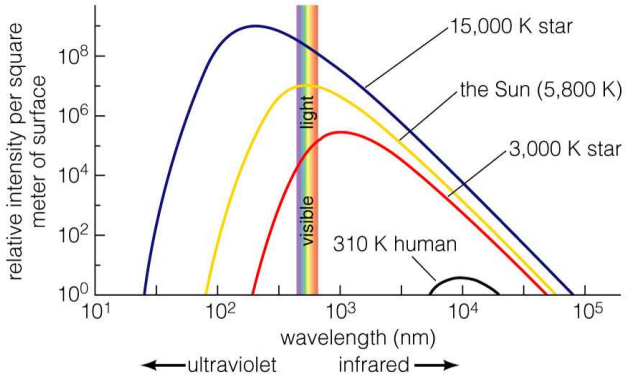
- How do astronomers learn from light?
- How does light help us determine the temperature and composition of objects?
- What are the different types of observational astronomy?

Astronomy is the Study of Light

- Light travels through vacuum
- Light travels far without tiring
- Light interacts with matter
- Light carries clues about the emitter
- Light carries clues about the medium it passes through

All Objects Emit Light

- Light = Entire electromagnetic spectrum
- Wavelength (or frequency) identifies the energy level
  - Radio wave → Gamma rays (RIVUXG)
  - Red → Blue (ROYGBIV)
- Remember $c = \lambda \upsilon$ $E \alpha \upsilon$
- Hotter objects emit higher energy light
  - Higher frequency or lower wavelength



- Hotter objects emit more light per unit area
  - At every frequency or wavelength

$$L \alpha AT^4 \alpha R^2 T^4$$

L = Luminosity
A = Surface Area
T = Temperature
R = Radius

- Intensity of light falls off with distance
  - *Inverse square law*, like gravity
  - Jupiter receives 1/25 of the sunlight Earth receives, per unit area
  - Light per unit area = Flux $F_d \alpha \frac{1}{d^2}$

F = Flux
d = distance from light source

Thermal Radiation

- Idealized blackbody radiation curve
  - Spectrum: Light across wavelength

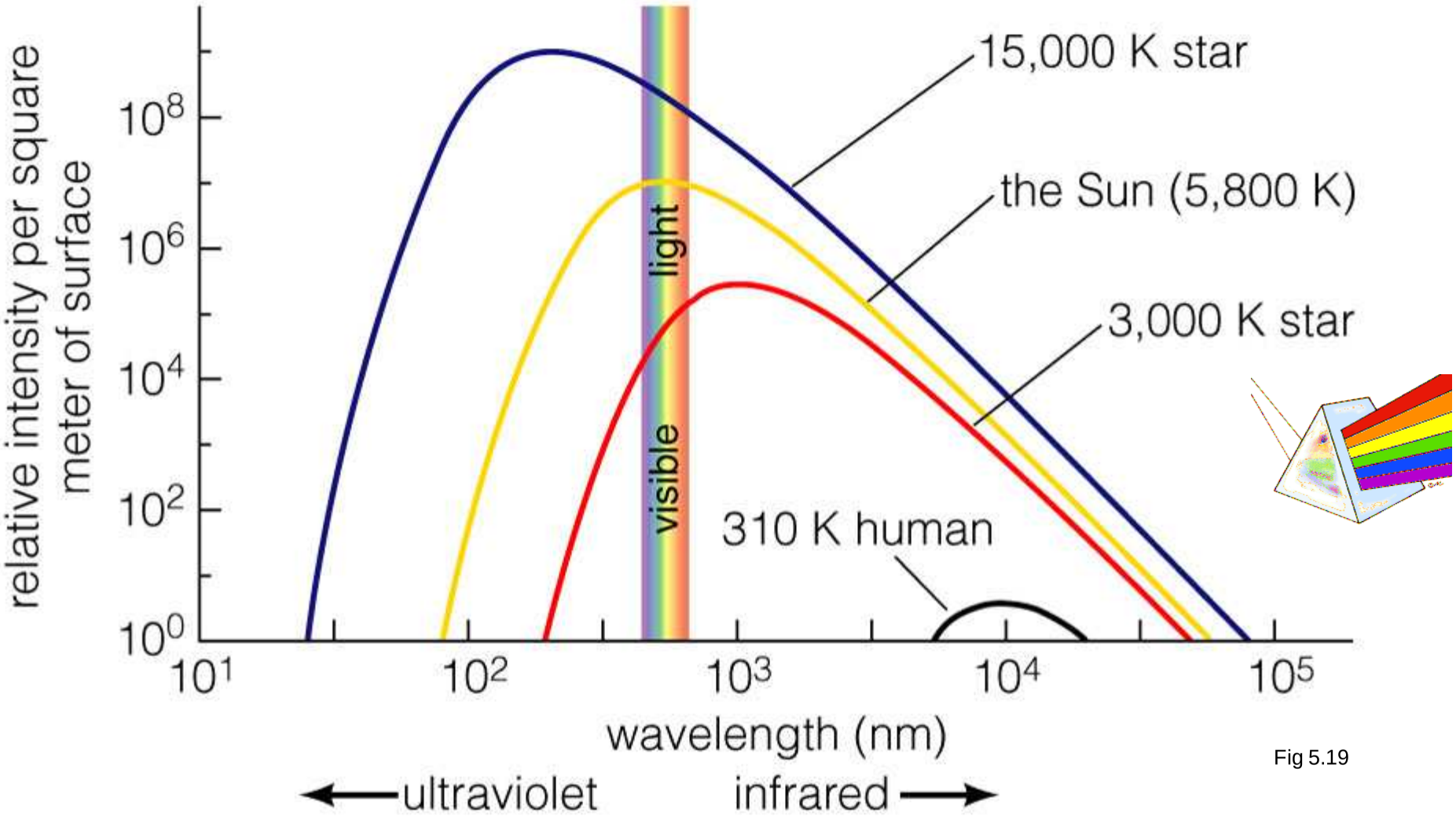


Fig 5.19

Peak Indicates Temperature

Wien's Law

$$T_{in\,K} = \frac{2{,}900}{\lambda_{peak,\,in\,microns}}$$

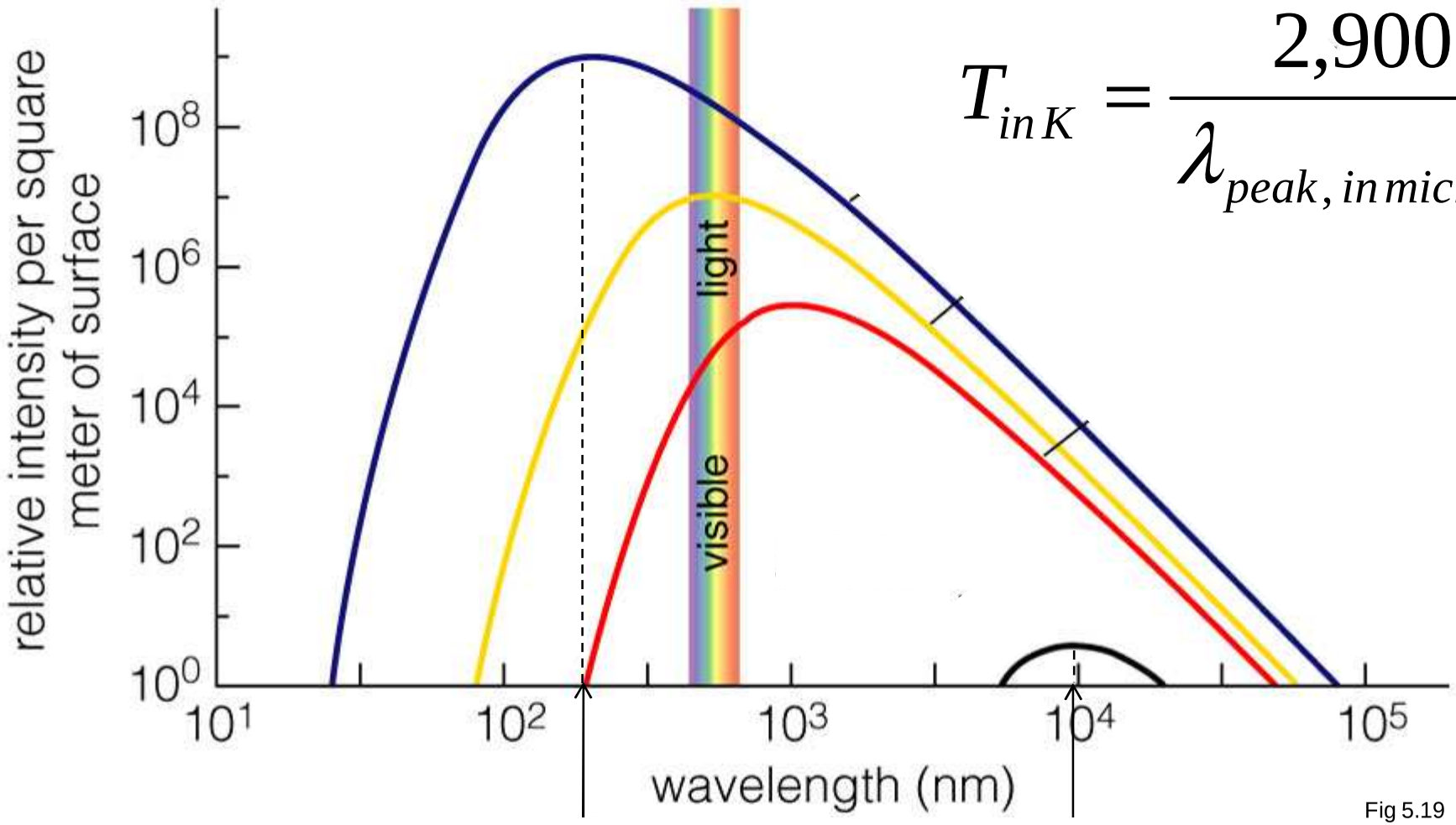


Fig 5.19

λ_p=193 nm, T = 15000 K

λ_p=9355 nm, T = 310 K

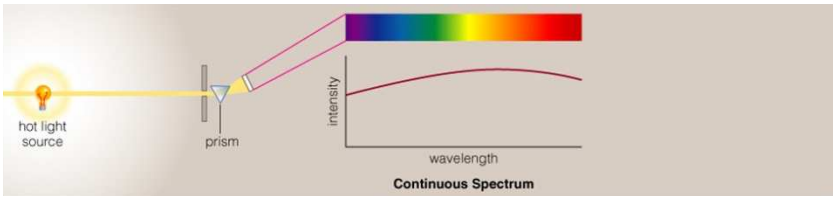
Temperature Scales

Temperature is the measure of the *average* kinetic energy of particles in a substance

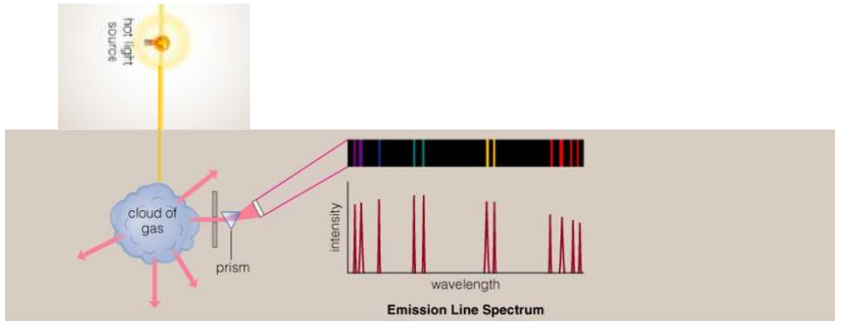
- Fahrenheit Will not use in this course
  - Based on freezing (32 ^{o}F) and boiling (212 ^{o}F) points of water
- Celsius
  - Based on freezing (0 ^{o}C) and boiling (100 ^{o}C) points of water
- Kelvin
  - Based on “absolute zero” (0 K), the point at which molecules stop moving
  - T (K) = T (^{o}C) + 273.15

Types of Spectra (Kirchoff's Laws)

- Continuous Spectrum
  - Ideal blackbody radiation
  - Smooth



- Emission Line Spectrum
  - Light pumps up electrons
  - Electrons emit specific light when they jump down



- Absorption Line Spectrum
  - View light source through medium
  - Electrons absorb specific light to jump up
  - All stars are seen like this
    - View hot, dense core through cool, sparse "atmosphere"

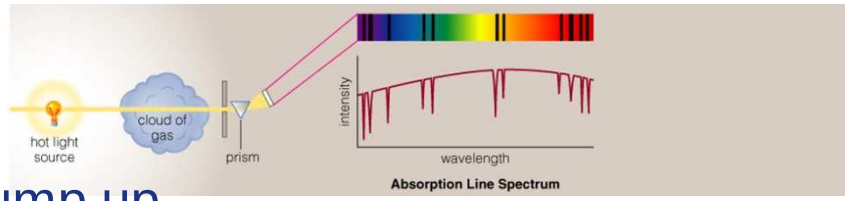


Fig 5.14

Spectra Are “Fingerprints” of Matter

- Transition levels in atoms correspond to very specific energy levels
- The wavelength of absorption or emissions lines tell us about the matter the light passed through

Fig 5.16

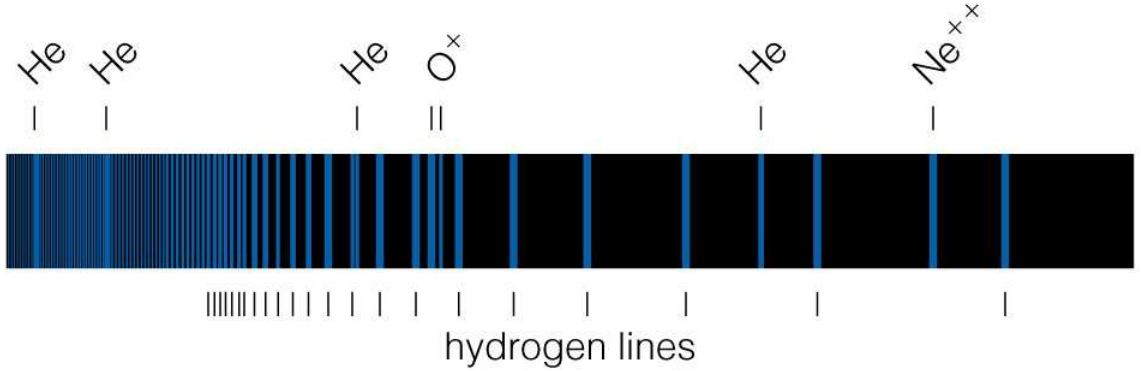


Fig 5.17, Orion nebula emission spectrum (350 – 400 nm)

Let's Play Detective!

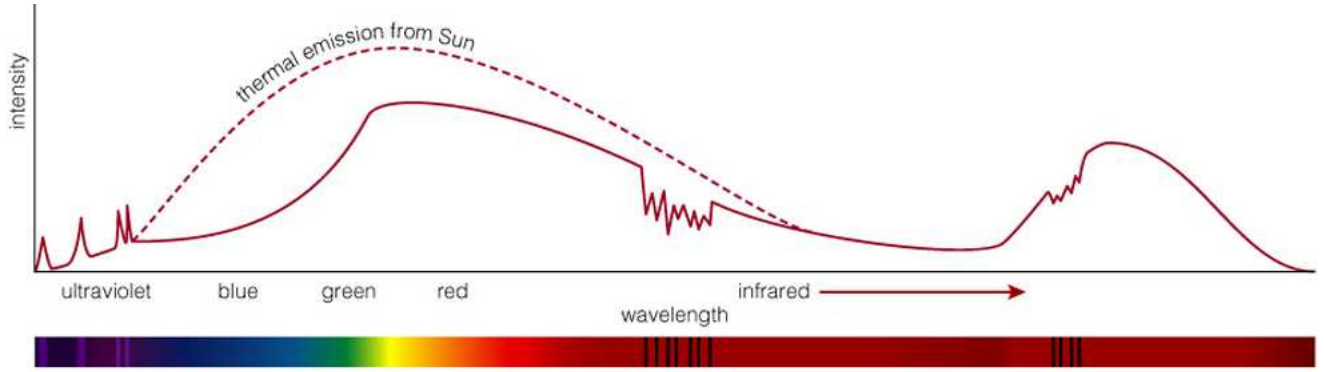


Fig 5.20

- We see
  - Two humps
    - Right one peaks at 12.9 microns
    - Left one at 0.5 microns
  - Emission lines in UV
  - Absorption lines in infrared
  - Absorption band in UV

This is the spectrum of Planet Mars

- We conclude
  - Object looks red
    - Absorbs more blue than red
  - Absorption lines are from CO_2
    - Atmosphere is principally CO_2
  - Emission lines in UV
    - Hot upper atmosphere
  - Right hump corresponds to 225K
    - Temperature of the object
  - Left hump corresponds to 5800K
    - Reflected light from the Sun

Doppler Shifts

- A Complication, but also a Clue
  - Lines move along wavelength
  - Towards longer wavelengths (redshift)
    - Source moving away from observer
  - Towards shorter wavelengths (blueshift)
    - Source moving towards observer

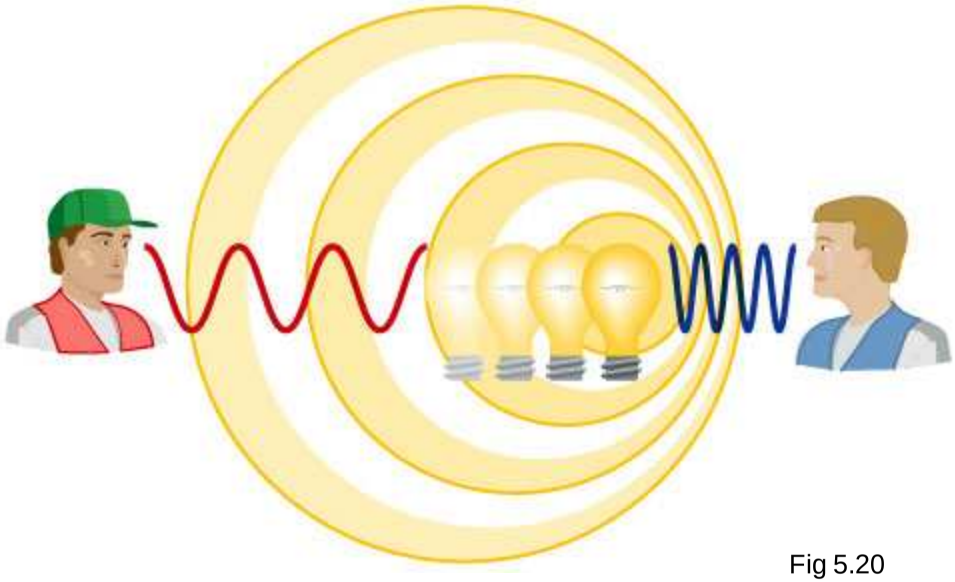
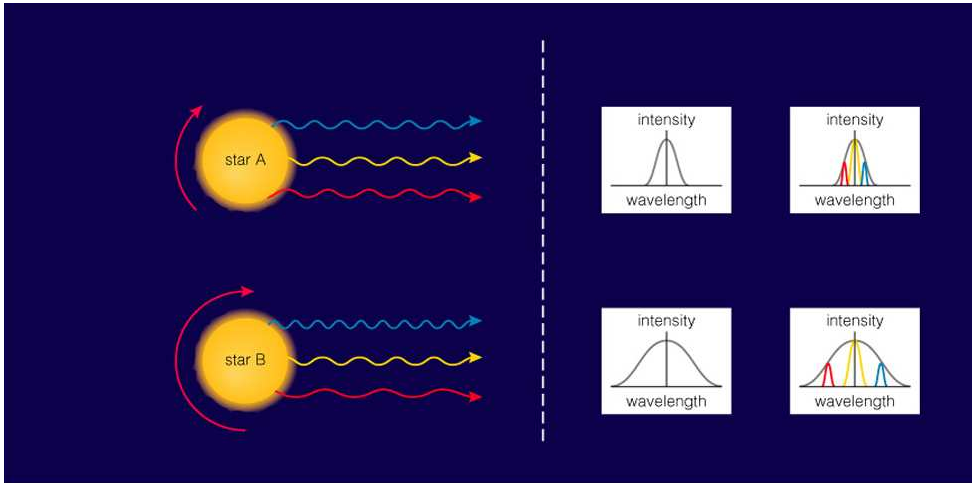


Fig 5.20

Uses of Doppler Shift

- Measure rotation of stars
- Measure orbits of stars
  - Detect planets around other stars!



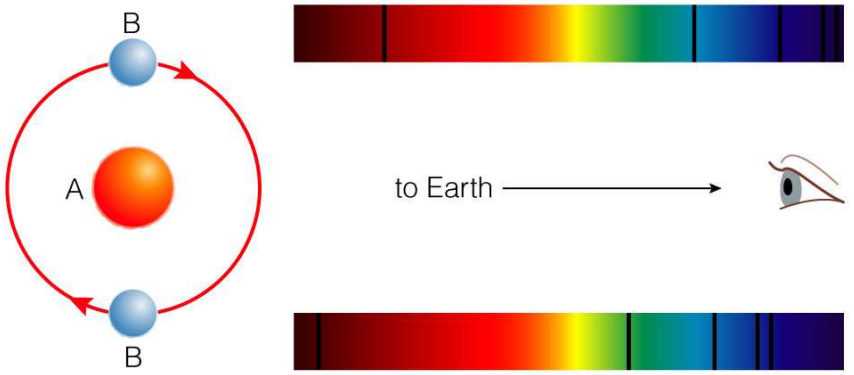
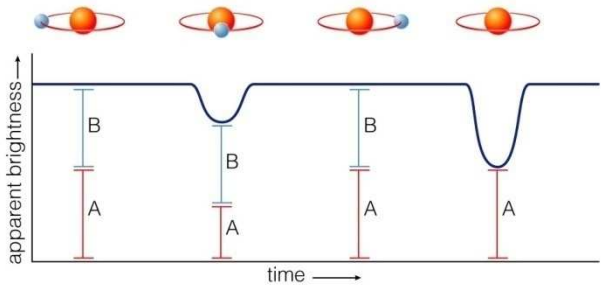


Fig 5.24

Other Methods

- Photometry
  - Measure of the amount of light
  - In total, or at specific wavebands
  - Study variations with time, eclipses etc.
- Astrometry
  - Precise position of stars, objects
  - Parallax, i.e. distance
  - Binary orbits
- Interferometry
  - Combine light from multiple telescopes
  - Very high precision
- Polarimetry
  - Study of magnetic fields



GSU's CHARA Array, Mount Wilson, CA

Exam 1 Review

- Bring #2 pencils!
- 40 Multiple Choice questions
  - 6 points each
- 20 True/False questions
  - 3 points each
- 2 bonus questions
  - 10 points each
- Emphasize topics covered in Class

Exam 1 Topics

- Chapters 1 – 5 & S1
  - Our place in the universe
  - Size & Scale of the universe
  - History of the universe
  - Light travel time
  - The universe as viewed from Earth
  - Path of Sun & stars in our sky
  - Special latitudes
  - Seasons
  - Phases of the Moon
  - Moon's position in the sky
  - Solar & Lunar eclipses
  - Geocentric Model
  - The scientific method

- Chapters 1 – 5 & S1
  - The Copernican Revolution
  - Kepler's Laws
  - Motion: speed, velocity, acceleration
  - Mass & Weight
  - Momentum, Force
  - Newton's Laws
  - Conservation Laws
  - Newton's Law of Gravity
  - Tides
  - Light: wave nature
  - Light, matter interaction
  - Doppler effect