“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 \( c = \lambda \nu \) \( E \propto \nu \)
- Hotter objects emit higher energy light
  - Higher frequency or lower wavelength
- Hotter objects emit more light per unit area
  - At every frequency or wavelength
    \[ L \propto AT^4 \propto R^2T^4 \]
- 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 \( F_d \propto \frac{1}{d^2} \)

\( L = \) Luminosity
\( A = \) Surface Area
\( T = \) Temperature
\( R = \) Radius

\( F = \) Flux
\( d = \) distance from light source
Thermal Radiation

- Idealized blackbody radiation curve
  - Spectrum: Light across wavelength

![Graph showing thermal radiation spectrum](image)

- 15,000 K star
- The Sun (5,800 K)
- 3,000 K star
- 310 K human

**Fig 5.19**
Peak Indicates Temperature

Wien’s Law

\[ T_{\text{in}K} = \frac{2,900}{\lambda_{\text{peak, inmicrons}}} \]

- \( \lambda_p = 193 \text{ nm, } T = 15000 \text{ K} \)
- \( \lambda_p = 9355 \text{ nm, } T = 310 \text{ K} \)
Temperature Scales

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

- **Fahrenheit**  
  - Based on freezing (32 °F) and boiling (212 °F) points of water  
  
- **Celsius**  
  - Based on freezing (0 °C) and boiling (100 °C) points of water  

- **Kelvin**  
  - Based on “absolute zero” (0 K), the point at which molecules stop moving  
  - T (K) = T (°C) + 273.15

Will not use in this course.
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”
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

![Spectra Diagram](image-url)
Let’s Play Detective!

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

Fig 5.20 This is the spectrum of Planet Mars
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