Astro 18 – Section Week 2

EM Spectrum
ElectroMagnetic Radiation

- Energy moves in waves with electrical and magnetic components
- All EMR travels at speed of light in a vacuum
ElectroMagnetic Radiation

- Energy = $h \nu$  where $\nu = \frac{c}{\lambda}$

  $h = 6.626068 \times 10^{-34} \text{ m}^2 \text{ kg} / \text{s}$

- 21cm line (HI) has what frequency & energy?

  - $1427583133.3 \text{ Hz}$
    - Or $1.4276 \text{ GHz}$
  - $E = 9.4592 \times 10^{-25} \text{ J}$
ElectroMagnetic Radiation

THE ELECTROMAGNETIC SPECTRUM

- Wavelength (in meters)
- Size of a wavelength
- Common name of wave
- Sources
- Frequency (waves per second)
- Energy of one photon (electron volts)

- Radio Waves
- Infrared
- Visible
- Ultraviolet
- "Hard" X Rays
- Gamma Rays

- Longer
- Shorter

- AM Radio
- FM Radio
- Microwave Oven
- Radar
- People
- Light Bulb
- The ALS
- X-Ray Machines
- Radioactive Elements

- Lower
- Higher
ElectroMagnetic Radiation

Multiwavelength Milky Way
Wien’s Law

- Distribution of radiated energy from blackbody at $T_1$ has same shape as distribution at $T_2$ except it’s displaced on the graph

$$\lambda_{\text{max}} = \frac{b}{T}$$

$b = 2.8977685 \times 10^{-3} \text{ m} \cdot \text{K}$

$T = \text{temp in Kelvin}$
Wien’s Law - Sun

- First need temperature of sun
  - Total power radiated = $4 \times 10^{26}$ Watts
  - Radius = $7 \times 10^8$ meters

\[ T = 6000 \, K \]

- Then, $\lambda_{\text{max}} = \frac{b}{T}$
  - $b = 2.8977685 \times 10^{-3} \, \text{m} \cdot \text{K}$

\[ \lambda_{\text{max}} = 500 \, \text{nanometers} \]
Wien’s Law - Sun
Wien’s Law - Student

- Body temp $\sim 98^\circ F$
  - Convert to Kelvin

- $\lambda_{max} = \frac{b}{T}$
  - $b = 2.8977685 \times 10^{-3}$ m·K

- So $\lambda_{max} = 10\mu m$ which is far-IR
Spectral Lines

- 2 Types:
  - Emission
  - Absorption

Continuous Spectrum

Emission Lines

Absorption Lines
Emission Lines

- Cloud of gas, warmer than background
Emission Lines
Absorption Lines

- Hot source behind cloud of cold gas
Absorption Lines

- Useful in planetary atmospheres

- The deeper absorption line at 760nm is caused by our atmosphere's oxygen molecule. The two absorption lines at 720 and 890nm (from methane) appear on Saturn and Titan, but the rings do not have them.
Doppler Shift

- Classic sound example:
- Because the source of the sound is moving towards/away from you
Doppler Shift

- Same thing occurs with light from stars, etc
  
  \[ z = \frac{\lambda_{\text{obs}} - \lambda_{\text{emit}}}{\lambda_{\text{emit}}} \]

- In H, the transition from level 2 → 1 has a rest wavelength of 121.6 nm. Suppose you see this line at a wavelength of 121.3 nm in star A and 122.9 nm in star B. Calculate each star’s speed and state if it’s moving towards or away from us.

\[ z = \frac{\text{velocity}}{c} \]
Red Shift & Distance

- In general everything is moving away from us - expanding universe
- Red shift can be used to calculate distance to objects (Hubble’s Law)

The recessional velocity of a few galaxies, plotted against their distance from Earth.

$V = H_0 \times D$

The farther the galaxy, the faster its motion away from us.

On this graph, the slope of the line is equal to Hubble’s Constant ($H_0$)
Redshift & Distance

\[ Z = \frac{\lambda_{\text{obs}} - \lambda_{\text{emit}}}{\lambda_{\text{emit}}} \]
\[ Z = \frac{\text{velocity}}{c} \]

- For this galaxy, the measured wavelength of the Ca K line was 3962.0 Å, rest wavelength for Ca K is 3933.7 Å

\[ z = \frac{3962.0 \text{ Å} - 3933.7 \text{ Å}}{3933.7 \text{ Å}} = 0.0071 \]

\[ v = zc = 0.0071 \times 3 \times 10^8 \text{ m/s} \]
\[ = 2,128,526 \text{ m/s} \]

\[ d = \frac{v}{H_o} = \frac{2,128,526 \text{ m/s}}{70000 \text{(m/sec)/Mpc}} \]
\[ = 30 \text{ Mpc} = 97,849,088 \text{ lightyear} \]
Redshift & Distance

- NGC 1357
Exoplanet Detection

The chart shows the number of exoplanets detected each year from 1989 to 2010. The years are listed horizontally at the bottom, while the vertical axis represents the number of exoplanets detected. The chart indicates a significant increase in detections in recent years.
Exoplanet Detection

- Star's velocity shows a periodic variance of ±1 m/s, suggesting an orbiting mass that is creating a gravitational pull on this star.

- Use Kepler’s third law – period of planet (equal to period of variation in star’s spectrum) used to get radius.
Exoplanet Detection

- **Kepler:**
  \[ r^3 = \frac{GM_{\text{star}}P_{\text{star}}^2}{4\pi^2} \]

- **Orbit Eqn:**
  \[ V_{pl} = \sqrt{\frac{GM_{\text{star}}}{r}} \]

- **Mass Eqn:**
  \[ M_{pl} = \frac{M_{\text{star}}V_{\text{star}}}{V_{pl}} \]
Exoplanet Detection

- Planet orbiting 51Peg has an orbital period of 4.23 days, the star’s mass is $1.06M_{\text{sun}}$. What is the planet’s orbital distance?

$$r = 7.81 \times 10^9 \text{ m or } 0.052 \text{ AU}$$

- And it’s mass?

$$m = 8.97 \times 10^{26} \text{ kg or } 150M_{\text{earth}}$$
Exoplanet Detection