Astronomy

What we know and how we know it.

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International Year of Astronomy

- 2009 is the celebration of the 400$^{\text{th}}$ anniversary of Galileo's use of the telescope to study the heavens.
- Galileo made discoveries such as the fact that Jupiter has moons, Venus has phases, and the Milky Way is composed of stars.
- These discoveries only needed the image created by light. Modern astronomy gets a lot more information out of light.
Laws of Physics

- A fundamental tenet of physics and astronomy is that the laws of physics are the same throughout the Universe.
- This has become so fundamental that when we see things that seem to contradict the known laws of physics in the distant reaches of space we conclude it is our understanding of the laws that needs to be revised.
- Few things push this boundary, but they are all in astronomy.
Role of Light

- Almost everything we know in astronomy comes from light.
- The full spectrum contains all types of information that Galileo could never have imagined.
THE ELECTROMAGNETIC SPECTRUM

Penetrates Earth Atmosphere?

Wavelength (meters)

- Radio: $10^3$
- Microwave: $10^{-2}$
- Infrared: $10^{-5}$
- Visible: $0.5 \times 10^{-6}$
- Ultraviolet: $10^{-8}$
- X-ray: $10^{-10}$
- Gamma Ray: $10^{-12}$

About the size of...

- Buildings
- Humans
- Honey Bee
- Pinpoint
- Protozoans
- Molecules
- Atoms
- Atomic Nuclei

Frequency (Hz)

- $10^4$
- $10^8$
- $10^{12}$
- $10^{15}$
- $10^{16}$
- $10^{18}$
- $10^{20}$

Temperature of bodies emitting the wavelength (K)

- 1 K
- 100 K
- 10,000 K
- 10 Million K
Physics of Light

- To get the information out of the light that we see, we have to understand the physics of light.
- This includes emission and absorption, as well as some factors for observing.
Line Emission/Absorption

- This is something you have learned about in this class.
Thermal Emission/Blackbody Emission

![Graph showing the intensity of thermal emission as a function of frequency for different temperatures. The graph includes a visible spectrum section from ultraviolet to infrared, and curves for temperatures of 7000 K, 4000 K, 1000 K, and 300 K. The x-axis represents frequency in Hz, ranging from $10^{12}$ to $10^{16}$, and the y-axis represents intensity in arbitrary units, ranging from $10^3$ to $10^6$. The wavelength on the bottom x-axis ranges from $10^5$ nm to 10 nm.](image-url)
• Doppler shift
   • When an object is heading toward you, the light is blue shifted. When it is heading away it is red shifted.
   \[
   \lambda_0 = \sqrt{\frac{1 + v/c}{1 - v/c}} \lambda_s
   \]

• Diffraction limit
   • The smallest feature you can resolve depends on the size of a telescope and the wavelength you are using.
Big Bang

- Increasing red-shifts with increasing distances
- Cosmic microwave background radiation
Black Holes

- When too much matter is in one place, the gravity is so great not even light can escape.
- This happens when large stars collapse.
- Giant ones exist in the centers of galaxies.
- Q: How do you detect and learn about things that don't emit light?
- A: Look at the effect they have on things around them.
Detecting Black Holes

- Existence of white dwarfs and neutron stars established first.
- Stellar mass black holes
  - Motion of neighboring stars.
  - Black widow stars.
  - X-rays from accretion disks.
- Super-massive blackholes
  - Orbits of nearby stars.
  - X-ray emissions.
Exoplanets

- One of the biggest discoveries of the last 10+ years in astronomy is finding planets around other stars.

- Methods of detection
  - Radial velocity – measure speed of the star; Doppler shift
  - Astrometry – measure location of the star
  - Transit – measure brightness of the star; Kepler mission
  - Direct detection – actually see the planet
Radial Velocity

- Look at Doppler shift of stars.
- Measure velocities down to 3 m/s.
- Figure courtesy NASA/JPL-Caltech
Direct Detection

- Bright stars, dim planets
Star and Planet Formation
Small Bodies = Pluto

- Kuiper belt is like the asteroid belt, but for comets.
How it Formed

- Computer simulations help a lot now too.
Planetary Astronomy

- Planets can be explored with telescopes and probes.
- Most probes just take pictures. Some have other data collection methods.
- Water on Mars.
- Methane on Mars.
- Europa
- Enceladus
- Rings
Questions

- Do you have any questions?