**Why is Light so useful in Astronomy?**

- It can tell us many properties of planets and stars:
  - How warm / hot they are (Surface temperature)
  - What they’re made of (Chemical Composition)
  - How they’re moving (Radial Velocity and Spin)

**Interaction of Light and Matter: Four Ways**

1. **emission** – matter releases energy (E) as light
2. **absorption** – matter takes E from light
3. **transmission** – matter allows light to pass
4. **reflection** – matter repels light in another direction

**CONSERVATION OF ENERGY**

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**Emission - Continuous**

- Hot, dense objects give off continuous thermal blackbody radiation
  - Warm objects emit infrared
  - Hotter ➔
    - More light
    - Shorter wavelengths
    - e.g. Stars emit visible light!
- IR Spectrum ➔ We can measure planet’s surface temperature!

**Reflection: Application**

- When light passes through matter, or reflects off of matter, some wavelengths may be absorbed
- Resulting spectrum tells us about the matter!
  - Example: Mars appears red because it’s surface absorbs more blue light than red (reflects more red light than blue) ➔ tells us something about what surface is made of

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**Blackbody Activity**

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**Application to Stars: Thermal Radiation**

- Bluer Stars are hotter than redder ones!
Emission & Absorption

- Photons can be absorbed / emitted by matter:
  - Photon energy matches “jump” in energy levels
- Atoms absorb photon & gain energy → Absorption-line spectrum
- Atoms emit photon & lose energy → Emission-line spectrum

Kirchhoff’s Laws: Kinds of Spectra

- Absorption-line spectrum
- Emission-line spectrum

Types of Spectra Activity

Element Identification

- Only photons whose energies (colors) match the “jump” in electron energy levels can be emitted or absorbed.
- Each element has a unique signature because of its energy level structure

Application: Chemical Composition

- Presence of absorption lines of a particular element indicates the presence of that element in the absorbing material
  - e.g. atmosphere of a star!

Application to Stars: Absorption spectra

- Outer layers of a star are cooler than the dense inner part (i.e. they are the “cool cloud”)
Application: Emission Spectra

- **Tails of Comets** consist of dust which reflects sunlight, and excited gas which produces an emission-line spectrum.

Application: Chemical Composition

- Presence of emission lines of a particular element indicates the presence of that element in the excited gas.

The Doppler Effect

How is light affected by the velocity of a source? (Alternate views:
http://www.fearofphysics.com/Sound/dopwhy2.html
and
http://lectureonline.cl.msu.edu/~mmp/applist/doppler/d.htm)

- Motion toward observer shortens wavelength (Blue Shift)
- Motion away from observer lengthens it (Red Shift)
- Faster speed $\rightarrow$ bigger change in $\lambda$

Measuring Radial Velocity

- Measure Doppler shift of emission or absorption lines in a spectrum $\rightarrow$ *radial velocity* of object

Doppler Effect Activity

- No Motion
- Motion away
- Motion towards
Measuring Radial Velocity

- **Laboratory spectrum**
- **Object 1** (line redshifted): Object moving away from us.
- **Object 2** (greater redshift): Object moving away faster than Object 1.
- **Object 3** (line blue-shifted): Object moving toward us.
- **Object 4** (greater blue-shift): Object moving toward us faster than Object 2.

From: [http://woodahl.physics.iupui.edu/05-22_anno.jpg](http://woodahl.physics.iupui.edu/05-22_anno.jpg)

Application: Orbiting Stars

- Motions of stars moving towards & away from us
  - Binary Stars
  - Extrasolar planets


More Applications

- Spin of Venus and/or asteroids:
  - Radar measurements

- Expansion of Universe:
  - Distant galaxies moving away from us

Why is Light so Useful?

- Thermal / continuous spectrum $\rightarrow$ temperature
- Reflected light $\rightarrow$ properties of reflecting object
- Absorption features $\rightarrow$ composition of absorbing material (e.g. star, planet atmosphere)
- Emission lines $\rightarrow$ composition of thin gas (e.g. nebula, tail of comet)
- Doppler effect on lines $\rightarrow$ radial velocity, spin!