Light
Our Tool for Understanding the Universe

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OUTLINE

• What is Light?
• A Bit of Terminology
• Atoms & Light
• Determining Compositions of Objects
• How Do We Know Velocities of Objects?
• How Do We Know Temperatures of Stars?
• Examples of Astronomical “En-light-enment”
Light in General

• Can be thought of as an electromagnetic wave or a particle known as a photon

• Light (or “EM”) waves travel at the speed of light for that medium

• A light wave in empty space travels 299,792.458 km/s (186,000 mph) – “c”

• Light waves are refracted as they pass from one medium to another
WAVELENGTH

• The length of a wave - “λ”

• Determined by measuring distances between points on consecutive waves
Frequency

- Number of waves that pass a point each second - "ν"
- Inversely proportional to wavelength – the larger the wavelength, the lower the frequency

Low Frequency | High Frequency
Energy

- Energy is directly related to wavelength and frequency
- Shorter wavelength, more energy, “bluer”
- Higher frequency, more energy
THE ATOM

- Atoms consist of protons, neutrons, and electrons
- Protons and neutrons form the nucleus
- Electrons orbit the nucleus

Image Source: Physics World
Observing Spectra
“Emission Spectra” of Selected Elements

- HYDROGEN
- HELIUM
- OXYGEN
- IRON
- THORIUM
Atomic Energy Levels

- Atoms have electrons in orbitals
- According to quantum mechanics, orbitals have specific energies
- Electrons can gain energy and jump to higher energy orbitals
- Electrons can emit energy and jump to lower energy orbitals
- There is no “in-between” – energies are “quantized”
The Hydrogen Atom Energy Levels

- 0.7 eV
- 1.9 eV
- 10.2 eV
- 12.1 eV
- 12.8 eV
The Hydrogen Atom
Energy Levels

0.7 eV
1.9 eV
10.2 eV
12.1 eV
12.8 eV
Emission From Hydrogen

Lyman Series – UV
- Jump down to n=1

Balmer Series – Visible
- Jump down to n=2

Paschen Series – Infrared
- Jump down to n=3

Brackett Series – Infrared
- Jump down to n=4

Pfund Series – Infrared
- Jump down to n=5

Image Source: FlatWorldKnowledge.com
Ionization – Electrons are Stripped
A Continuous Spectrum
An Emission Spectrum
A Continuous Spectrum
Electron orbit energies are distorted, smearing the emission lines.
The Solar Spectrum
The Solar Spectrum
The Doppler Effect
The Doppler Effect

Velocity \[\frac{\text{Wavelength Shift}}{\text{Rest Wavelength}}\] = \[\frac{\text{Speed of Light}}{\text{Speed of Light}}\] [Image Source: Wikipedia]
The Doppler Effect

Unshifted

Redshifted

Blueshifted

Image Source: Cornell University
Doppler Shift – Redshift/Blueshift

Blackbody (Planck) Spectrum
Wien’s Law

Temperature = \frac{2,900,000}{\lambda_{\text{max}} (nm)}

Temperature = \frac{2,900}{\lambda_{\text{max}} (\mu m)}
Spectrum of a Hot, Young Star

Image Source: NOAO
Spectrum of a Cool, Old Star

Image Source: NOAO
THE ELECTROMAGNETIC SPECTRUM

Image Source: www.cerneea.net
Example Spectrum – GM Aurigae

The left hump is due to the star, while the right “extra” hump is generated by a circumstellar disk of material.

Image Source: Schneider et al. (2003)
Star

Star with continuous dust disk

Star with dust belt

Image Source: NASA/Spitzer Space Telescope
The Chandra X-ray Observatory (CXO)

- Solar Arrays
- Sunshade
- Science Instrument Module (SIM)
- High-Resolution Mirror Assembly (HRMA)

Image Source: Harvard CfA
Focusing X-rays

Image Source: Harvard CfA
X-Ray Astronomy – Cassiopeia A

Image Source: NASA/STScI, Harvard CfA
Greenbank Radio Observatory

Image Source: NRAO
Radio Astronomy – Fornax A

Image Source: NRAO