“If the whole universe has no meaning, we should never have found out that it has no meaning; just as, if there were no light in the universe and therefore no creatures with eyes, we should never know it was dark. Dark would be without meaning.”

C.S. Lewis
What We Will Learn Today

• What are you seeing right now?
• What are the basic properties of light?
• What is the Electromagnetic Spectrum?
• What are the basic building blocks of matter?
• How does light interact with matter?
• Everything we see is light!
• We only see a tiny window of all the light there is!
• All of astronomy is the study of light!
• So, let’s understand light, matter, and how the two interact!
What We See Around Us

- Light **emitted** from the Sun or light bulb
- **Transmitted** light
- **Reflected** light
- Colors of objects (partly **absorbed**)

![Diagram](image)
The Nature of Light

• Light is made up of tiny particles
  – Photons
• Each photon demonstrates a wave-like behavior
• Thus, light is both a particle and a wave at the same time!
Young’s Double Slit Experiment

• Proof of the wave nature of light
Wave Properties of Light

- Wavelength ($\lambda$)
- Frequency ($\nu$)
- Speed ($c$) – constant for all flavors of light
  \[ c = \lambda \nu \]
- Higher wavelength implies lower frequency
  - And vice-versa
- Energy carried by light (radiative energy, $E$)
  \[ E = h \nu \]
  - $h$ = Planck’s constant
- Higher frequency implies higher energy
  - Also implies smaller wavelength
The Electromagnetic Spectrum

G X U V I R

400 – 700 nm

visible spectrum of light

Fig 5.7
The Building Blocks of Matter

- Smallest to largest
  - Quarks & Leptons
  - Nucleus (Protons, Neutrons) & Shells (Electrons)
  - Atoms
  - Molecules

$10^{-10}$ meter
Atoms

- Incredibly small
  - Millions can fit in one period at the end of a sentence in a typical book
  - Number of atoms in a drop of water exceeds the number of stars in the Universe!
- Atoms are mostly empty
  - If nucleus is the size of your fist, electron clouds are many miles away!
- Nucleus contains most of the mass
- Electrons inhabit specific shells based on energy levels
Phases of Matter

- Loosely bound to tightly bound
  - Hottest to coolest
  - Fully ionized plasma (stellar cores)
  - Plasma (stellar interiors)
  - Molecular disassociation (Earth core)
  - Molecular phases (Earth surface)
    - Gas phase
    - Liquid phase
    - Solid phase
Chemical Elements

- Defined based on number of protons in the nucleus (atomic number)
- In general, number of electrons and neutrons equal the number of protons (exceptions exist)
  - Different number of electrons: ions
  - Different number of neutrons: isotopes
- Molecules are combinations of elements
  - \( \text{H}_2\text{O} \) = one molecule of water
    - 2 atoms of H, plus
    - 1 atom of O

Periodic Table of the Elements

![Periodic Table Image]
Important Elements in Astronomy

• Hydrogen (H, \( n = 1 \))
  – Simplest element: 1 proton + 1 electron
  – Most abundant element in the universe (74%)
  – Over 90% of the Sun’s mass

• Helium (He, \( n = 2 \))
  – 2 protons, 2 neutrons, 2 electrons
  – 24% of the universe, 9% of the Sun

• Carbon (C, \( n = 6 \))
  – 0.05% of the universe, 0.03% of the Sun
  – Basis of all life forms on Earth

• Nitrogen (N, \( n = 7 \))
  – Principal component of Earth’s atmosphere

• Oxygen (O, \( n = 8 \))
  – 0.1% of the universe, 0.08% of the Sun

• Iron (Fe, \( n = 26 \))
  – Densest nucleus, reason for Supernovae

Key Molecules

\[
\begin{align*}
H_2 \\
H_2O \\
CH_4 \\
NH_3
\end{align*}
\]
Interaction of Light with Matter

- **Absorption line**
  - Photon absorbed by electron to jump to higher energy level
  - Only specific energy levels of photons absorbed or emitted
  - i.e. only specific wavelengths or colors

- **Emission line**
  - Photon emitted by electron to jump back to lower energy level
  - n=1 (Ground state) E = -13.6 eV

Energy levels:
- $n=5$, $E=-0.5$ eV
- $n=4$, $E=-0.85$ eV
- $n=3$, $E=-1.5$ eV
- $n=2$, $E=-3.4$ eV
- $n=1$ (Ground state) $E=-13.6$ eV