Chapter 6. Atoms, Light, and Telescopes

- Atoms are the tiniest indivisible unit of an *element*. Atoms are made of protons, neutrons, and electrons. Protons and neutrons form the nucleus of an atom. The number of protons in an atom is called the *atomic number*, which defines the chemical element. The number of protons and neutrons in an atom is called the *atomic weight*.

- Atoms have equal numbers of electrons and protons, so the total electric charge is zero. When an atom loses (or gains) one or more electrons, it becomes positively (or negatively) charged. Charged atoms are called *ions*. Atoms can also combine to form *molecules*.

- Light can be considered as "waves" or "particles" – the dual nature of light.

- Light, as waves, has a velocity $c = \lambda\nu$, where λ is the wavelength and ν is the frequency. There is a wide range of wavelengths in the spectrum of light. Ordered in decreasing wavelength (or increasing energy):
  Radio → Infrared (IR) → Visual → Ultraviolet (UV) → X-rays → γ-rays.

- The particle of light is *photon*. Each photon is a packet of energy, and the amount of energy depends on its frequency. The energy of a photon $E = h\nu$.

- The energy in each photon is very small. For example, the energy carried by a photon of the yellow light at 5,500 Å is 10^{-12} times the kinetic energy of a mosquito. Another example, a 100-watt light bulb produces $\sim 10^{20}$ photons per second!

- A *blackbody* is a perfect absorber (no reflection). It emits continuous radiation, and the emitted energy balances the absorbed energy exactly. The spectrum is described by Planck's law, and depends on only the temperature of the blackbody.

- Temperature is a measure of kinetic energies of particles (atoms, molecules, etc) moving or vibrating in solid/liquid/gas. *Absolute zero* is when all particles stop moving. This occurs at 0 K, or -273° C.

- Stefan-Boltzmann's law: flux = $5.7\times10^{-8}T^4$ watts/m^2.

- Wien's law: $\lambda_{max} = 2.9\times10^7/T$ Å. We can use this law to calculate the blackbody temperature from λ_{max}, the wavelength at which the spectrum peaks. The Sun has a λ_{max} of $\sim$ 5,500 Å, hence its temperature is $\sim$ 5,270 K.

- Spectra may have continuous radiation (*continuum*) and discrete features (*spectral lines*). Spectral lines may occur in absorption or emission. Spectral lines produced by different elements have different sets of wavelengths and strength. The association of spectral lines to atoms/ions/molecules is like the association of finger prints to people.

- Kirchhoff's laws of spectral analysis:
  (1) An incandescent solid or high-density gas produces a continuous spectrum.
  (2) A hot low-density gas produces an emission-line spectrum.
  (3) A source of continuous radiation viewed through a cool, low-density gas shows absorption-line spectrum.

- Using Kirchhoff's laws, it is possible to explain the spectra of stars. Stars emit continuous radiation, because they are made of hot, high-density gas. The atmosphere of a star is cooler and less dense, so produces absorption lines. If the atmosphere of a star is extended, then the regions not projected against the stellar disk would produce emission lines.

- Niels Bohr proposed in 1913 that the electron's orbits in a hydrogen atom are quantized. The different orbits of an electron have different energies. The energy diagram describes the energy levels associated with the orbits. $n = 1$ is the ground state, larger n for higher energy, and when n goes to infinity the electron becomes free (ionization limit).

- Only photons with energies equal to the differences between two energy levels can be absorbed or emitted. An electron can absorb a photon to reach a higher energy level, or emit a photon to reach a lower energy level.

- For hydrogen atoms, the transitions to a common lower energy level produce a series of lines. The Balmer series (transitions to $n = 2$) are in the visible wavelength range, hence most frequently used to study astronomy. The designation of the Balmer series is "H". The Hα line at 6563 Å corresponds to the transition from n=3 to n=2.

- Astronomical observations are made with tools:
  (1) **telescopes** to collect light
  (2) **instruments** to make images or to disperse light into spectra
  (3) **detectors** to record data (images or spectra)

- The light-gathering power of a telescope is proportional to the area of the lens or mirror.

- The diffraction pattern of the telescope's lens or mirror produces a bright central circular spot, called *diffraction disk*. The diameter of the diffraction disk is $1.22\lambda/D$, where λ is the wavelength and D is the diameter of the telescope aperture.