This week we learn about the behemoth of the solar system, the Sun: its gaseous content and how it generates the energy by which it shines. We then explore the many types of stars that exist, and what can be learned by studying their spectra.

- **Voyages Through the Universe**, Chapter 15 sections 15.1, 15.2, 15.3.1, 15.3.2, 15.3.3, 15.4.2

Having completed our whirlwind tour of the Solar System, we skip ahead several chapters and commence with our study of stars, beginning with the Sun. The first three sections of Chapter 15 present a fair amount of detail about how the Sun generates its energy, laying out all three steps of the proton-proton chain. The most important thing to keep your eye on from all of this is the end result: hydrogen nuclei are fused into helium nuclei, releasing energy (photons) and neutrinos; positrons, a form of anti-matter, are also given off in the reaction (but they quickly annihilate with electrons to produce additional photons). Here’s the overall reaction:

\[
4 \ ^1\text{H} \rightarrow \ ^4\text{He} + 2\gamma + 2\nu + 2e^+ 
\]

where \(\gamma\) represents a photon (energy), \(\nu\) represents a neutrino (very light particles), and \(e^+\) represents a positron. Know also that energy is given off through fusion due to the conversion of mass to energy via \(E = mc^2\); in this case, about 0.7% of the original hydrogen atoms is converted into energy through the fusion process. Section 15.3.2 introduces a key concept: hydrostatic equilibrium: the idea that the pressures exerted outward in the sun exactly balance the gravitational pressure inward, to create a stable equilibrium (i.e., the star is neither expanding nor contracting). Since much of the outward pressure is produced by the photons that are generated through the hydrogen fusion, we’ll have to keep a close eye on this situation when the hydrogen fuel supply becomes exhausted. The reading concludes for this chapter with §15.4.2, which discusses the detection of neutrinos from the Sun (those of you who watched the PBS NOVA program last week learned all about the exciting history behind this achievement). Remember, these enigmatic particles stream freely from the sun’s core, making it to Earth in about 8 minutes (i.e., the light travel time from Sun to Earth), whereas the photons produced in the core take about a million years to get out of the sun. The neutrinos thus permit the only direct look at what is happening in the Sun’s core RIGHT NOW.

- **Voyages Through the Universe**, Chapter 16 sections 16.1, 16.2, 16.3

We now begin to investigate other stars, and begin with a discussion of their brightnesses and the arcane manner by which (optical) astronomers measure them. In terms of the brightness of astronomical objects, the most important concepts to understand are:

- **Apparent brightness**: How bright an object appears in the sky. A measure of the observed light received from a star or other object at the Earth.
- **Luminosity**: The total energy radiated into space each second by a star or other object.
- **Standard Candle**: An astronomical object of known luminosity.

A key idea is that one can use standard candles as distance indicators: Since they are of known luminosity, measuring their apparent brightness will yield their distance when proper account is taken for the “inverse square” diminution of light with distance (recall Fig. 4.4 on p. 89). Note that the **color** of a star is independent of its distance but, rather, is intimately linked to its temperature through Wien’s Law.

Section 16.3 discusses the formation of stellar spectra, and includes details of the seven principal spectral classes (OBAFGKM) in addition to the newer L and T categories. While you do **not** need to memorize all of the spectral features present in each of these classes (i.e., Table 16.1), you should know the rough temperature range spanned by the sequence (∼ 700 K → ∼ 28,000 K, as you proceed from Type T through Type O), and the fact that the Sun is a G star.
● On-Line Material: Chapter 15 – Look at the Active Figure called “Gravity vs. Pressure”, and page through it. It may help your understanding of hydrostatic equilibrium. When finished with the chapter, take the Post-Test; you may skip questions 1 and 2 (I thought these were a bit too picky on facts), as well as numbers 14, 15, and 17 (they cover information that we skipped in the chapter).

● On-Line Material: Chapter 16 – I found the Active Figure called “Apparent Brightness I” and the Astronomy Exercises called “Apparent Brightness II”, “Blackbody and Wien’s Law”, “Stefan-Boltzmann, Wien’s Law, and Blackbody Radiation”, and “Stellar Atomic Absorption Lines” to be quite helpful.

Writing Assignment for Tuesday, March 7

Please answer the following question in the form of a short essay. Take the approach in your response that you are explaining this to another student who has not had the benefit of Astronomy 101.

1. Explain in your own words and with as much detail as possible the role that Einstein’s famous equation $E = mc^2$ plays in our present understanding of how the Sun generates the energy by which it shines.

(Uncle Albert ponders the Universe.)