ASTR-1010: Astronomy I
Course Notes
Section V

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Abstract

These class notes are designed for use of the instructor and students of the course ASTR-1010: Astronomy I taught by Dr. Donald G. Luttermoser at East Tennessee State University.

V. The Solar Atmosphere

A. General Characteristics

1. The Sun is a star $\Longrightarrow$ **our star**, the planets are essentially the children of the Sun.

2. Physical data:

Distance from Earth:	Mean: 1 AU = 1.49598 x 10^8 km
	Max: 1.52100 x 10^8 km
	Min: 1.47096 x 10^8 km
Mean angular diameter:	32.0 arcmin
Radius:	6.9599 x 10^5 km = 109 $R_\oplus$
Mass:	1.9891 x 10^{30} kg = 3.33 x 10^5 $M_\oplus$
Composition (by number):	90.8% hydrogen
	9.1% helium
	0.1% other elements
Mean Temperature:	Surface: 5780 K
	Center: 1.5513 x 10^7 K
Luminosity:	3.8268 x 10^{26} W

3. The Sun is gaseous throughout its interior. The light which we see radiating from the Sun is emitted from the outermost layers of gas $\Longrightarrow$ the **solar atmosphere**. The solar atmosphere is composed of 3 distinct layers: the **photosphere**, **chromosphere**, and **corona**.

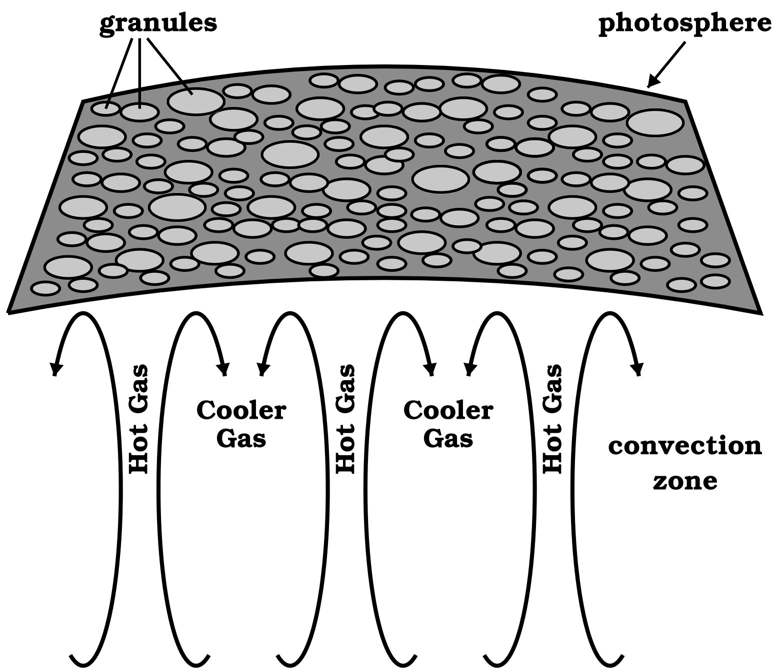
B. The Photosphere

1. The bright disk we see in the sky is the **photosphere** (*i.e.*, *sphere of light*).

2. It is 400 km thick and ranges in temperature from 10,000 K at it deepest layers to 4500 K at its uppermost layers. The median temperature, called the **effective temperature**, is 5780 K.

3. The continuum of the Sun's spectrum comes from the deeper depths of the photosphere and most of the absorption lines arise from the upper layers of the photosphere.

4. Close inspection of the photosphere shows a fine **granulation** — each **granule** is about 1000 km across $\Longrightarrow$ these are the tops of convection cells from that rise up from the interior of the Sun.



5. The photosphere appears darker as you look off towards the limb $\Longrightarrow$ **limb darkening**:

C. The Chromosphere

1. The middle layer (2000 km in thickness) of the Sun's atmosphere is the **chromosphere** (*i.e.*, *color sphere*) $\Longrightarrow$ seen as a red ring around the Moon during a solar eclipse.

2. Whereas the temperature decreases as one goes outward in the photosphere, the temperature reverses and begins to increase with height in the chromosphere — 4500 K to 10,000 K.

   a) Some form of mechanical energy source must be heating the chromosphere.

   b) Sound waves from the rising convection cells is thought to heat the lower chromosphere and magnetic waves (**Alfv́en waves**) heat the upper chromosphere.

3. The core of strong absorption lines form in this layer and the Hα line at 6563 Å arise from this layer $\Longrightarrow$ this red hydrogen line give the chromosphere its color during a solar eclipse.

4. Flame-like structures called **spicules** are seen in the chromosphere and they outline **supergranules** (see Fig. 18.8 in text).

D. The Corona

1. The outermost layer of the solar atmosphere is the **corona**. The word *corona* means "crown" $\Longrightarrow$ the corona looks like a crown around the Moon during a solar eclipse.

2. The temperature rises very fast from the top of the chromosphere to the base of the corona $\Longrightarrow$ 10,000 K to over 10^6 K over a few 100 km! This sharp rise is called the **transition region**.

3. The temperature of the corona is 1-2 x 10^6 K which can extend out to 2 solar radii above the photosphere.

4. The solar corona is very inhomogeneous — it exist in loop structures called **solar coronal loops**. Regions in between these loops are called **coronal holes** (see Figure 18.10 in text).

5. Lines from highly ionized metals arise from this layer (*i.e.*, Fe XIV, etc.)

6. Magnetic and electrical mechanical energy sources heat this layer — the solar coronal loops are associated with strong magnetic field regions.

E. Solar Activity

1. Every so often on the solar disk, dark spots appear $\Longrightarrow$ **sunspots**.

   a) Darker because these regions are about 1000 K cooler than the surrounding photosphere.

   b) These regions are associated with strong magnetic fields (B-fields) as deduced through the **Zeeman effect** of spectral lines $\Longrightarrow$ some absorption lines split into two (or more) components if the gas that gives rise to the absorption lines is embedded in a strong B-field — the more intense the B-field, the bigger the splitting.

   c) The inner part of a sunspot is darker and is called the **umbra** and the lighter outer part is called the **penumbra** (see Figure 13.18 in the text).

2. The number of sunspots vary with an 11-year period $\Longrightarrow$ the **sunspot cycle**.

3. Sunspots always appear in pairs $\Longrightarrow$ **active regions**. The *leading* spot is either of **north** or **south** B-field. This orientation will last throughout the cycle and then will flip in the next cycle $\Longrightarrow$ a 22-year magnetic cycle.

4. **Solar flares** are violent eruptions (*i.e.*, last a few minutes) that occur in active regions. They probably result from B-field collisions and recombinations.

5. **Prominences** are gradual eruptions (*i.e.*, last a few hours to days) of B-fields over active regions.

F. The Solar Wind

1. Once mankind developed space technology, probes sent into space recorded a stream of charged particles originating from the Sun traveling at velocities from 300 to 400 km/s $\Longrightarrow$ the **solar wind**.

2. The Skylab mission in the 1970s determined that the solar wind (at least the high speed component of it) originates in the coronal holes.

3. Close to the Sun, the solar wind travels at a relatively slow speed, but quickly accelerates to a terminal velocity of 300-400 km/s (that is, by the time it gets to the Earth's orbit, it is flowing at its terminal speed).

4. As the solar wind travels outward, its density decreases. Once the density decreases to the value of the local interstellar medium (the dust and gas that exist between the stars), the wind abruptly stops $\Longrightarrow$ this is called the **heliopause**.

5. Models predict that the heliopause exists somewhere between

50 to 100 AU from the Sun. Four "extrasolar" spacecraft have been launch by humanity: *Pioneer 10*, *Pioneer 11*, *Voyager 1*, and *Voyager 2*. Each spacecraft is monitoring their immediate environment in the hope of detecting this heliopause.