General Astronomy (29:61)
Fall 2012
Lecture 30 Notes, November 12, 2012

1 Layers of the Earth's Atmosphere

There are a number of layers of the Earth's atmosphere. The distinctions between these are quite meaningful. See the discussion on pp 216 and 217 of the book.

- Troposphere: this is the level of the atmosphere in which we live, and to which the above calculation is relevant. It is a region in which heat transport from the surface of the Earth to the cold upper atmosphere is carried by convection.
- Stratosphere: this is the layer immediately above the troposphere. Convection is not typical there, so the atmosphere is stably stratified. We also speak of it as "convectively stable". Jet airliners fly in the upper troposphere or close to the troposphere-stratosphere boundary.
- Higher layers such as the mesosphere, thermosphere, and exosphere. A **very important distinction** comes at altitudes greater than 100 kilometers. At such altitudes, we are above so much of the atmosphere that there is not effective absorption of the ultraviolet light from the Sun. This UV radiation ionizes the nitrogen and oxygen atoms, so the gas is partially ionized. This produces the **ionosphere**. $\longrightarrow$ see diagram in online notes showing the density of ionized atoms as a function of altitude. The ionosphere is our nearest, naturally-occurring example of a form of matter called a *plasma*, which is the most common form of matter in the universe.

1.1 The Temperature Profile in the Earth's Atmosphere

Figure 9.5 of the textbook shows the measured temperature profile in the Earth's atmosphere. $\longrightarrow$ See also plot in online notes.

We can see some interesting features in this plot. First of all is the fall in the temperature with increasing height in the troposphere. In the stratosphere this trend reverses, and the temperature increases to a maximum at around 50 km. This stratospheric increase has an interesting explanation. It is due to ozone molecules absorbing solar ultraviolet light. Some of this energy goes into heating the stratospheric gas. This stratospheric temperature increase is a consequence of the same process that is protecting us from harmful UV light.

1.2 Auroras

Another important phenomenon related to the upper atmosphere is auroras. Auroras are glowing lights that are seen in the northern sky. $\longrightarrow$ see pictures in online notes and diagrams. They are rare here in Iowa, but occur almost nightly in the north (like central Alaska). They occur at the lower levels of the ionosphere, say 100 - 140 km above the surface of the Earth. They are caused when energetic electrons from far out in space are beamed down into the Earth's atmosphere. These electrons ionize and excite atoms in the atmosphere (oxygen and nitrogen), causing the air to glow. They are a hint that there are interesting things happening out in space beyond the Earth's atmosphere.

2 Charged Particles in Magnetic Fields

We have just seen that in the upper atmosphere, plasmas are important. They are also important throughout the rest of astronomy. In a plasma, at least some of the particles that make up the gas are charged. Electrons are charged negatively, ions are positively charged.

One of the most basic laws of physics is that a charged particle moving with respect to a magnetic field feels a force. We call this the *Lorentz Force*. It is given by

$$\vec{F} = q\vec{v} \times \vec{B} \tag{1}$$

The SI unit for magnetic field is the Tesla. A Tesla is a whopping large magnetic field.

This is a vector cross product. Remember our rules of vector algebra that govern the cross product. Let's see what this force does to a charged particle moving perpendicular to a magnetic field $\longrightarrow$ drawing on blackboard.

The Lorentz force makes the charged particle move on a circular path. Let's see what the characteristics of this path are. Since the force produces a *centripetal acceleration*, we have

$$\frac{mv^2}{r} = qvB \tag{2}$$

$$r = \frac{mv^2}{qvB} \tag{3}$$

$$r = \frac{mv}{qB} \tag{4}$$

This radius is called the *Larmor radius.*

What the Lorentz force tells us is that charged particles cannot move across a magnetic field. They will be bent on to circular paths. Charged particles can move *along* magnetic fields, since then $\vec{v} \times \vec{B} = 0$. This then means that magnetic fields act like force fields to deflect beams of charged particles.