Planetary Atmospheres Lab Guide *Experiment A07*

Part A: Greenhouse Gases

If the Earth had no atmosphere, then the only way to warm the planet would be the radiation from the sun being directly absorbed by the planets surface. Some of this radiation could also be reflected back into space. With an atmosphere, this incoming radiation could also be reflected by the atmosphere. However, if this atmosphere contains special gasses, this radiation can be absorbed by these gases and re-emitted in all directions – including back down to the surface. We call these gasses *Greenhouse Gasses* since their effect on warming the planet mimics that of a greenhouse. Of course, one of the most infamous greenhouse gasses is carbon dioxide, CO_2.

In this experiment, you will be simulating two different atmospheres (using two different bottles), with a hot lamb acting as our sun. In one of our bottles (atmospheres), you will be introducing an excess amount of CO_2 by dissolving an Alka Seltzer tablet. Theoretically, the bottle with the excess amount of CO_2 will retain much more of the infrared radiation due to its absorption by the CO_2 molecules, and thus over time you should see this bottle become much hotter than the regular bottle.

NOTE: Due to the nature of the reaction between the tablet and the water, for the first few minutes you may see that the bottle with an excess of CO becomes *cooler*. If done correctly, at the end of the experiment you should see it climb back over the regular (air) bottle. Regardless, you will still record and report your findings.

8.) **(10 points)** Remember, regardless of whether your experiment concluded the regular (air) bottle was cooler, still report your results after 20 minutes here.

9.) **(5 points) NOTE that this problem askes you to include your PLOT from excel.** The best way to do this is to either stake a snapshot of the plot or copy/paste it as an image directly from Excel. Do NOT submit your Excel shet as a separate submission, and make sure to only include your plot – NOT the data. Include this either right alongside this question or at the end of your report. The written portion of this question just asks you about what your plots look like.

10.) **(5 points)** Just like we discussed in lab 5, *light* can come in all different kinds of wavelengths – not just those pertaining to the colors of the rainbow. The light that is being absorbed here is the infrared portion, and as we said in the introduction, the greenhouse gasses are special because it can absorb this particular wavelength of light.

11.) **(10 points)** What happens if we were to unnaturally pump more greenhouse gasses into the atmosphere?

12.) **(10 points)** Greenhouse gasses are not all bad; we actually require them in order for the surface temperature to be at a livable level. If greenhouse gasses were no longer in our atmosphere, then the atmosphere would become *too cold* to sustain life!

Part B: Atmospheric Distortion

Do you remember what we discussed in the earlier spectroscopy lab (lab 5)? We said that the speed of light (a wave) actually changes depending on the medium it is propagating through. In that lab we saw that this change in speed caused light rays to bend at the boundary of two different media. Light could also experience this bending effect in a single medium like air when it moves from one area with certain properties (like a certain temperature) to another with different properties (i.e., there are a lot of factors that determine the index of refraction of a specific medium). This happens a lot in our atmosphere - air is always moving due to uneven heating and cooling. This creates little pockets of air with different properties than the surrounding air. When the light passes through these pockets it *bends*; these pockets of air act like little lenses! Due to the chaotic behavior and constant motion of these pockets of air at every point in time in our atmosphere, the light that was originally traveling through space (an unchanging medium) is now bent in unpredictable ways.

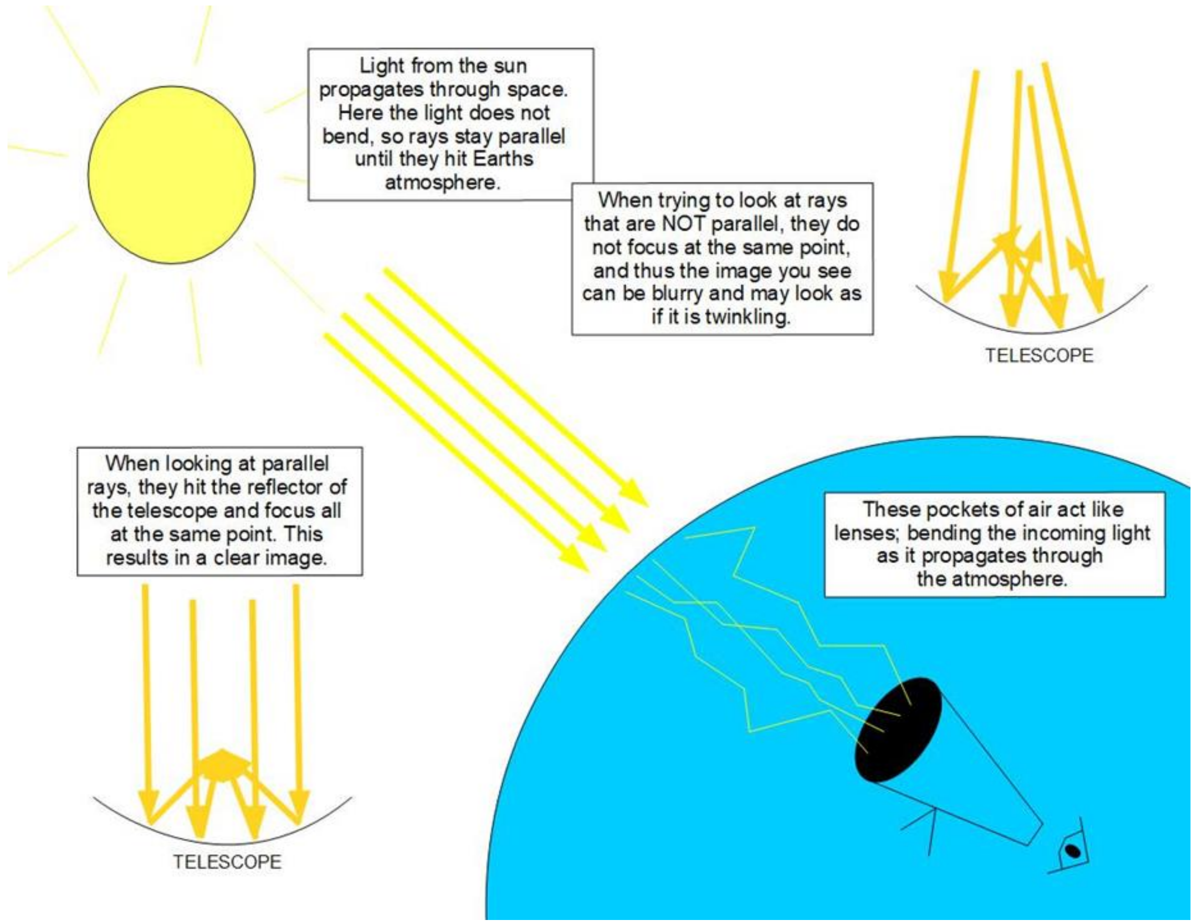

Figure 1: Atmospheric distortion of incoming light rays form the sun

Now think back again to lab 5 where we looked at how parallel laser beams reflected off of a concave mirror. We saw that all the reflected beams *focused* on a single point. This is very similar to how *reflecting telescopes* work – the incoming parallel light is focused into the eyepiece so that you can see a crisp image. If the light is perfectly parallel, then the beams are reflected back to the same exact point, and the image is not blurred. However, if the light is NOT perfectly parallel (even in the slightest bit), then they are all not reflected to the same exact point and the resulting image can look blurry (i.e., it is not *focused*). The pockets of air in the atmosphere (the little lenses) cause the incoming light from the sun to not be parallel once they reach the surface, where you and I have our telescopes positioned. Thus, it is difficult to perfectly focus this incoming light and our pictures look blurry! The image above is another illustration of this idea, the other being in your lab manual.

2.) **(6 points)** You are simulating these pockets of air in the atmosphere with steam (water vapor – a gas). First off, this water vapor is a different medium than general air all together so we know the index of refraction will be different. Thus, as the laser beam passes through pockets of this water vapor (acting as little lenses), it will bend in unpredictable ways. Knowing this, you should be able to predict what will happen to the laser beam on the wall that has passed through the steam. Do you see this beam twinkling or vibrating on the wall?

4.) **(6 points)** This is to essentially prove to you that its not the laser that is doing the twinkling – it is the very fact that it is passing through the water vapor that is casing the light to continuously be bent in different directions.

5.) **(6 points)** We have pretty much answered this question in our discussion here.

6.) **(6 points)** If you are higher up in the atmosphere, then you have *less* of the atmosphere for the incoming light to have to pass through before it hits your telescope. If it has to pass through less of these pockets of air (i.e., its passing through less of these little lenses), what do you think should (or shouldn't) happen to the light rays? Why would this be ideal for multi-billion-dollar telescopes looking for the best images possible?

7.) **(6 points)** You should watch this video to truly get an understanding of this technology. The key idea here is the word *adaptive*; the telescope (more specifically its mirror) *adapts* to the distorted incoming light. The distortion of the light is measured, and then the mirror in the telescope changes its shape so that all of the incoming light rays focus on the same point as if there were no distortion of the atmosphere. Since the incoming light is continuously distorted due to the constant motion of the little lenses in the atmosphere, this mirror armed with this technology is constantly changing its shape - multiple times per second!

Part C: Atmosphere Retention

Why do planets have atmospheres? There are several answers to this question, but we will be talking about how a planets *gravity* allows it to hold onto an atmosphere. An atmosphere can be made up of all different types of gasses (for example, Earths atmosphere is primarily nitrogen and oxygen), and these gases are basically a collection of *molecules*. Each of these molecules have a mass, and so are affected by the force of gravity in the same way you and I are. This force is of course:

$$F_{Gravity} = G\frac{m_{smaller\ body}M_{larger\ body}}{r^2}$$

Where r is the distance between the center of the smaller body to the center of the larger body. Notice that the higher up you are above the Earth (i.e., higher in its atmosphere), the *smaller* the force of gravity becomes due to r^2 in the denominator.

In our experience, if we throw something up in the air, it does not keep on going into outer space; it falls back to the ground. HOWEVER, if we kept throwing it and each time throwing it faster and faster, eventually the object WILL be fast enough to escape the clutches of Earth's gravity – this velocity is called the *escape velocity* and this particular value is determined by the planets total mass. As humans, we need very powerful rockets to reach this speed because as the object we're throwing gets heavier (i.e., another person or a large rocket), it takes more energy in order to accelerate it. We are also limited to starting from the surface of the planet.

However, lets now think of molecules in the upper atmosphere – these molecules are so high up that the force of gravity on them is not as strong as it would be on the surface (see how the force of gravity above is inversely proportional to r^2!). What this means is that it would require *less* energy to accelerate them up to the planets escape velocity! Thus, if a particularly fast molecule collides with another molecule in such a way, it would be possible that this molecule will attain a velocity equal-to or greater-than the planets escape velocity and permanently leave the atmosphere. Do this enough times and you can theoretically LOOSE an entire atmosphere!

What is another factor of an atmosphere that can attribute to the planet loosing or keeping it? Well, from lab 4 we can remember what we said about temperature; temperature is just some measure of the average *kinetic energy* of the measured particles. We know kinetic energy is associated with the *speed* of the particles. If a planet has a higher atmospheric *temperature*, then the molecules in the atmosphere will (on average) be moving very fast. In this case it would be much easier to accelerate these particles past the escape velocity compared to a cooler atmosphere.

In the **Atmospheric Retention** simulator in **NAAP Labs**, we will be investigating the necessary conditions for a planet to retain an atmosphere. We will see how a planets mass and temperature effects this retention, and also consider how the differences in atmospheric makeup affect it as well – we know if we have multiple molecules making up an atmosphere (which we always do), it will be harder for the heavier ones to escape.

2.) **(2 points)** You should be thinking of the box on the left of the simulation as some 2D container. Once you start the program you should see that each of the blue dots (representing oxygen) moves around and bounce off the sides of the container.

3.) **(2 points)** What do you notice about the *speeds* of the particles as compared to before?

4.) **(2 points)** It's obvious that the red dots (representing hydrogen) are moving a lot faster than the blue dots, but why is this? The are at the same temperature? Well just like we discussed in the intro, the particles *mass* is also a contributing factor to its speed – hydrogen is much lighter than oxygen and is thus much easier to accelerate to higher velocities.

5.) **(4 points)** Now that you clicked the box for "allow escape from chamber," you can think of this 2D container as a kind of boundary of the atmosphere – if a particle hits it and it is going *faster* than the escape velocity, it leaves and never returns. Because of hydrogens low mass, it is easier for these particles to attain high velocities that could allow them to reach the escape velocity.

6.) In order to change the "escape speed" the "allow escape from chamber" box must be checked.

7.) **(5 points)** Increasing the escape speed is the same as increasing the *mass* of the planet – larger planets will require larger velocities in order to escape their gravitational pull. On top of this, you are also *decreasing* the temperature of the particles, meaning that they will have (on average) slower speeds to begin with. Running the simulation, you can see that we still loose hydrogen, but at a much slower rate than we did in the previous run. Again, even though the particles start off on average slower (due to the temperature) and require larger speeds to escape (due to the larger mass of the planet), the weight of an individual hydrogen atom is so light that it is still fairly easy to accelerate them to this new escape speed.

8.) **(5 points)** Now we are on a small (low mass/low escape velocity), hot (high temperature) planet. Putting together the ideas we've established so far, it is pretty easy to predict what would happen here.

9.) **(5 points)** In our solar system, what is the first planet that comes to mind when you think of SMALL and HOT? Does this simulation explain to you why this planet does not have much of an atmosphere?

11.) **(5 points)** Again, with all the ideas we've used so far this should be easy – we need to RETAIN an atmosphere which means we don't want particles to reach these high velocities. How can we *slow* the particles down, and how can we *increase* the speed necessary to escape the planet (its escape velocity)?