Lab 2
THE SUN AND SEASONS

PURPOSE

Without doubt THE most prominent object in the sky is the Sun. You can't help but notice it when you walk outside during the day. You can feel its warmth on your skin and see its effect as it casts shadows behind you as you block its light. I'm sure you are familiar with the saying that "the Sun rises in the East and sets in the West", but it turns out it's not as simple as that. After completing this lab, you should be able to describe the apparent motion of the Sun across the sky, and how it varies throughout the year. We will also tie this information into the duration of daylight hours and altitude of the Sun throughout the year and how this contributes to the seasons.

REQUIRED MATERIALS

This lab requires use of the following programs (see Appendix for program details):

- Stellarium
- Microsoft Excel

IMPORTANT TERMS

In this lab we will be observing the location of the Sun as viewed from Earth at various times of day and throughout the year. As we do so, we will reference a few terms which we learned in last week's lab.

As a reminder, we can note the position of an object on the sky using the azimuth/altitude coordinate system. *Azimuth* is an angular measurement relative to due north, measured eastward around the horizon, while *altitude* measures how high above the horizon an object lies. We also learned in lab 1 (Navigating the Night Sky) that over the course of a year the Sun follows a path across the celestial sphere known as the *ecliptic*. While from our vantage point on Earth it appears that the Sun moves along the ecliptic over time, we know that it is due to Earth's orbit around the Sun, along the ecliptic plane.

Once we gather our data, we will create a few plots to look for trends and correlations within our data, in order to gather evidence for the conclusions we will make. A graphical plot of data usually consists of two variables plotted on an x- and y-axis. The value on the x-axis is typically the *independent variable*. This is the property or value that we can easily set and control. The *dependent variable* is the property or value that we measure once we set the independent variable. Its value depends on what value we choose for the independent variable.

Background Information

In modern times we take for granted that the Sun rises in the East every morning and sets in the West every evening. We pay little attention to the path of the Sun across the sky, nor rely on it to keep track of time. We have watches, calendars, smart phones, and computers that track all of that for us, such that we've lost touch with the significance of certain dates and times and what they mean.

In ancient times, though, live was different. Before the advent of technology, societies depended on tracking the motions of celestial objects to tell them when it was time to plant crops and when to harvest them, when flood season was about to begin, or when migratory animals would be passing nearby and available to hunt. Their very existence relied on charting the motions of celestial objects to notify them of what to do and when to do it.

We still see evidence of the methods they used in lands scattered across the world. The Caracol temple in Mexico, built by the Mayans, used the precise placement of windows within the temple to align with sightings of Venus. Egyptian temples, such as the temple of Amon-Re at Karnak, were also built such that they aligned with the rays of the Sun on specific days, shining down long corridors as sunlight streamed through unimpeded due to proper configurations.

The Big Horn Medicine Wheel in Wyoming contains spokes and other features that align with the rising and setting of the Sun and other stars and is one of over 70 wheels discovered across the United States. But perhaps the most famous structure is Stonehenge, in England, a widely known circular ruin of stones thought to align with the rising and setting of the Sun and Moon on significant days throughout the year. It is also hypothesized that an outer circle of stones which is no longer intact was able to predict eclipses.

While we have little need for structures like these today (other from a historical and cultural perspective), the apparent motion of the Sun across the sky does influence us in one important way. It turns out that the apparent path of the Sun across the sky varies throughout the year, and as we'll discover in today's lab, contributes to the cause of seasons.

In this week's lab, we are going to observe the location of the Sun as viewed from Earth at sunrise, "noon", and sunset throughout the year to see if the evidence we collect reveals any trends in the data and/or correlations between observations, and if the evidence we gather can help explain the cause of the seasons.

Lab Exercise

Part I: Observing the Location of the Sun

For most of the labs, we will be using an online planetarium program called Stellarium. If you haven't yet, go to http://stellarium.org/ and download this program. This program is VERY safe and easy to use. Unfortunately, the web version of this program does not contain all of the information which we require, and so it is necessary to download the program.

After opening the program, click the play/pause button so that the pause icon appears. This stops time from advancing automatically.

We want to answer two research questions: **"How does the direction that the Sun rises and sets change over the course of a year?"** and **"How does the noon-time Sun's position above the southern horizon change over the course of a year?"** While this is something we could actually do by observing the Sun from our current location, to gather the amount of data we want would take a year. To speed things up, we will use an online planetarium program which will allow us to observe the location of the Sun at any time of day on any day of the year.

You have been provided with an Excel spreadsheet to record your data. We will also be using Excel for most of our labs. To help you familiarize yourself with some of its functions, a spreadsheet has been provided which will do the calculations and plotting of graphs for you. In future labs, though, you will be expected to do this for yourself. You are welcome to use this lab's worksheet as an example or refer to the directions in the Appendix to learn more.

- Open Stellarium and click on the "Sky & Viewing Options Window" icon. Click on the "Markings" tab and then click on the three boxes next to "Meridian". This will display the meridian on the sky.

- Click on the "Date/Time Window" icon to open the Date/Time Window. Move it to the upper-right of the screen. You'll want to keep this open.

You will be measuring the location of the Sun on the 21st of every month for a year, starting with December 21 of last year. Set the date for this day. Either by scanning the sky or using the search tool, find the Sun and click on it.

Within Stellarium, when you click on an object, a wealth of information is provided. We are only interested in a few values:

Rise – the time of sunrise

Transit – the time when the Sun crosses the meridian

Note that this is ALSO when the Sun reaches its highest altitude in the sky on that day AND when it is located due South (at an azimuth of 180°)

Set – the time of sunset

Daytime – the duration (or length) of daylight hours (from sunrise to sunset)

Record these values into the Excel spreadsheet, making sure to record the hours and minutes in the appropriate columns.

Set the time to sunrise. Record the azimuth of the Sun in degrees (you can ignore the arcminutes and arcseconds).

1. When you look at the Sun on the horizon, is it rising exactly due east? (Notice the "E" on the horizon).

   If not, does it rise to the north (left) of east, or to the south (right) of east?

Next, ADVANCE the time to the transit time (ostensibly "noon", but not quite) and watch how the Sun moves across the sky. Record the altitude of the Sun in degrees (again, ignoring the arcminutes and arcseconds).

2. When you look at the Sun at its highest point during the day, is it at the zenith?

   If not, how far away is it?

Advance the time to sunset, again, watching how the Sun moves. Record the azimuth of the Sun in degrees.

3. When you look at the Sun on the horizon, is it setting exactly due west?

   If not, does it set to the north (left) of west, or to the south (right) of west?
   How does this compare to its location at sunrise?

Once you have made these measurements for the first date, repeat for the remaining dates, filling out the spreadsheet as you go along. (You may notice that for the months of March through October, the Sun transits after 1pm instead of noon. This is due to Daylight Saving Time being in effect.)

Part II: Looking For Trends in the Data

Once you finish filling out the table, click on the "Graphs" tab in the Excel spreadsheet. You will find four graphs already plotted for you:

- Location of Sunrise
- "Noon" Transit Height
- Location of Sunset
- Number of Daylight Hours

Each plot measures the day of the year along the x-axis. This is our **independent variable**. This is the value that we easily controlled and set to measure the other values. The y-axis displays the values of the **dependent variables**. In each graph, the dependent variable is one of the values we measured using Stellarium.

4. Does the Sun rise in the same location every day of the year?
   If so, where?
   If not, describe how the location changes over the course of the year?

5. Is there a date when the sun rises <u>precisely</u> due East?
   If so, around what date?

6. Is the Sun ever directly overhead (at zenith) at noon?
   If so, on what date(s)?
   If not, describe how the altitude of the Sun changes over the course of the year?

7. Is the duration of daylight the same every day of the year?
   If so, how long?
   If not, describe how the duration of daylight changes over the course of the year?

PART III: LOOKING FOR CORRELATIONS IN THE DATA

8. When the Sun rises the farthest North of East (smallest azimuth) where does it set?

   When it rises the farthest South of East where does it set?

9. Do the dates when these occur correlate with any particular occurrence related to the altitude of the Sun at noon?

   How about with the duration of daylight?

10. Complete the following sentences:

    When the Sun rises its farthest North of East, it transits due South at its (highest/lowest) altitude before setting its farthest _________ of West, resulting in the (longest/shortest) day of the year.

    When the Sun rises its farthest South of East, it transits due South at its (highest/lowest) altitude before setting its farthest _________ of West, resulting in the (longest/shortest) day of the year.

PART IV: THE TILT OF EARTH'S AXIS AND SEASONS

The reason behind the fact that the apparent path of the Sun changes throughout the year is because Earth's axis is tilted relative to its orbital path around the Sun. As Earth orbits (or revolves) around the Sun, it also rotates about its axis. This axis, though, is not pointed "straight up" (i.e., perpendicular to the ecliptic plane, or the orbital plane along which Earth revolves). Earth's rotational axis is tilted 23.5 degrees relative to the ecliptic. As a result, throughout its orbit, there are times when Earth is tilted toward the Sun, and times when it is tilted away from the Sun.

Seasonal temperature variations occur due to changes in the amount and intensity of energy we receive from the Sun. We receive more sunlight when it is above the horizon for longer periods of time, heating the ground more. When days are shorter, the Sun has less time to heat the ground. When the Sun is higher in the sky, it heats the ground more directly, and the Sun's rays are more concentrated, heating the ground more. When the Sun is lower in the sky, it heats the ground less directly, and the Sun's energy is more spread out, heating the ground less.

Earth's northern hemisphere is tilted the most toward the Sun on or around June 21, the summer solstice. On the celestial sphere, this places the Sun at its most northerly declination of +23.5 degrees (or 23.5 degrees north).

11. What evidence did you gather regarding the altitude of the Sun that suggests that when the northern hemisphere is tilted toward the Sun we experience warmer weather during the summer? Explain your reasoning.

12. What evidence did you gather regarding the duration of daylight that suggests that when the northern hemisphere is tilted toward the Sun we experience warmer weather during the summer? Explain your reasoning.

Earth's northern hemisphere is tilted the most away from the Sun on or around December 21, the winter solstice. On the celestial sphere, this places the Sun at its most southerly declination of -23.5 degrees (or 23.5 degrees south).

13. What evidence did you gather regarding the altitude of the Sun that suggests that when the northern hemisphere is tilted away from the Sun we experience cooler weather during the winter? Explain your reasoning.

14. What evidence did you gather regarding the duration of daylight that suggests that when the northern hemisphere is tilted away from the Sun we experience cooler weather during the winter? Explain your reasoning.

Part V: Further Investigations

In today's lab you investigated the apparent motion of the Sun across the sky throughout the year. You collected data and looked for correlations among the data, ultimately using it to provide evidence to support the cause of seasons in the northern hemisphere.

Following the procedures you conducted in the lab you performed today, you could investigate the apparent motion of the Sun from other locations on Earth, such as the southern hemisphere, the Equator, or even the North Pole.

- What do you think you would find out if you did?

- What is one research question related to the apparent path of the Sun throughout the year that you might want to investigate using Stellarium?

What Do I Turn In?

In addition to the Lab Exercise pages which contain your answers, please upload the following:

- Your completed Excel spreadsheet, along with the plots that were created
- Your lab report (see below)

Lab Report

For this week's lab report, create a word document. Write your name, course, and section at the top as shown below. Create a title for your lab report, similar to the example from last week. Instead of writing a full report as we will for later labs, answer the questions below. **Unlike last week's lab, the questions are more general, but your lab report should contain the same level of detail as the one you wrote last week.**

YOU SHOULD ANSWER IN COMPLETE SENTENCES, RESTATING THE QUESTION AS PART OF YOUR ANSWER.

<u>A person should know what you are talking about without having to re-read the question for reference.</u>

Name:

Course and Section:

Lab 2: ______________________________

Introduction:

1. What is the topic of this lab?
2. What is the purpose of this lab?
3. What are some key terms related to this lab, and how are they defined?
4. Why is it important to understand the concepts being addressed in this lab?

Procedure:

5. What steps did you take in this lab to investigate the concept(s) being studied?
6. Why did you take those steps? How did they help you investigate the concept(s)?
7. What was/were the ultimate goal(s) you were hoping to accomplish?

Conclusion:

8. What are some of the results that you discovered in this lab?
9. What are some of the astronomical relationships (either stated qualitatively, or if possible, as formulae) that you derived in this lab?
10. What do these relationships tell you about the concept being investigated?
11. What can you conclude, as it relates to the purpose stated above?
12. In conclusion, summarize in one or two sentences the main idea/concept and how it relates to the big picture of astronomy