

Lab 7: The Sun, Earth and Zodiac

Part I: Precession and the Zodiac

Motions of the Earth

The Earth is constantly in motion. It **spins** on its axis, it **orbits** the Sun at an average distance of about 150 million kilometers (93 million miles), and the Earth **precesses**. This third motion, called precession, is less widely known. The Earth bulges slightly at its equator as a result of its rotation (the Earth is not a perfect sphere). The Sun and Moon's gravitational pull on the Earth's equatorial bulge causes the Earth to wobble like a top, or 'precess'.

Let's compare the timescales for which each of these motions occur. The first two you should already know.

1. What is the time it takes Earth to complete one rotation (spin)?
2. What is the time it takes Earth to complete one revolution about the Sun (orbit)?
3. What is the time it takes Earth to complete one precession cycle (spin axis traces out a complete circle from the wobble)?

26,000 years

Below is a short video demonstrating how precession works:

<https://youtu.be/0qHjtp4cdCA>

4. Recall from previous labs, we learned that the Earth's axis currently points to a particular star. What special star is this?
5. Where is this special star located on your star wheel?

6. Consider the precession demonstration video. Do you think that the Earth's axis will always point at this special star? Why or why not? Explain your reasoning.

It's important to realize that the **Earth precesses very slowly**. Over a human lifetime, the effect from precession is generally quite negligible. Thus we can use the same 'pole star' for our entire lifetimes, and teach it to our children who can teach it to their children. But as we'll see later in the lab, precession must be considered when comparing current observations of the sky to observations made thousands of years ago, or if we wish to predict what others will see thousands of years in the future.

In this lab, we will explore the effect of Earth's motions on observations that we make of the Sun and the stars over the course of days and months. Precession will not come into play because it happens so slowly. However, we will take note of the effect precession does have on what we see today versus what people saw some 2000 years ago.

Constellations of the Zodiac

Some of the most famous and ancient constellations are the constellations of the **zodiac**. As the Earth orbits the Sun, the Sun appears to move against the background stars (this isn't obvious since you can't see the stars during the day!). **The path that the Sun takes through the zodiacal constellations is known as the ecliptic**, which is the plane defined by the Earth's orbit.

For thousands of years, people all over the world have paid attention to the Sun's path through the stars. Because the Sun is a significant part of our lives, many cultures also attached an equivalent significance to the constellations that make up the zodiac.

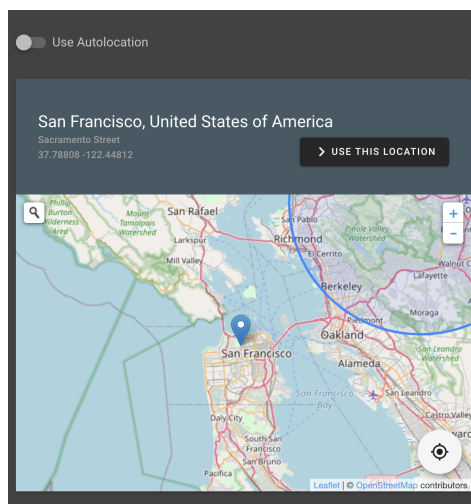
7. Do you know your astrological (zodiacal) sign? If so, what is it? If not, look it up and write it down here.

Your astrological sign is, in principle, the constellation that the Sun was 'in' on the day you were born. It is common to say that the Sun (or planet) is 'in' a certain constellation. However, it's important to understand that the Sun (or planet) is really in between the constellation and Earth. The Sun is much, much closer to the Earth than any other star!

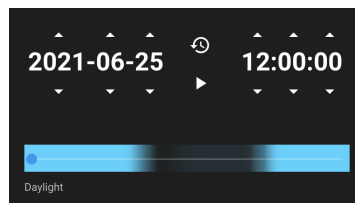
Astrological signs are believed to have been defined roughly 2000 years ago. At that time, there were 12 zodiacal constellations, each covering about 1/12th of the ecliptic, so that the Sun was ‘in’ each constellation for about a month. **Since then, the Earth’s precession has caused a shift in the position of the Sun on different dates creating a 13th zodiacal constellation.** As a result, most people’s zodiacal sign is no longer what it would have been 2000 years ago. We’ll see which constellation the Sun was actually ‘in’ on your birthday in a minute.

Let’s find the ecliptic in Stellarium (<https://stellarium-web.org/>). The directions below will help you make Stellarium useful for this particular lab.

1) **Set the location.** We are all going to use San Francisco as our location so that we can all see the same constellations. At the bottom of the webpage you should see a button that tells you where you’re observing from. It’ll say “near (location),” click that button. Once the map pops up, drag the location pin to San Francisco and click “> use this location” above the map. Also make sure that the toggle for “Use Autolocation” is turned off.



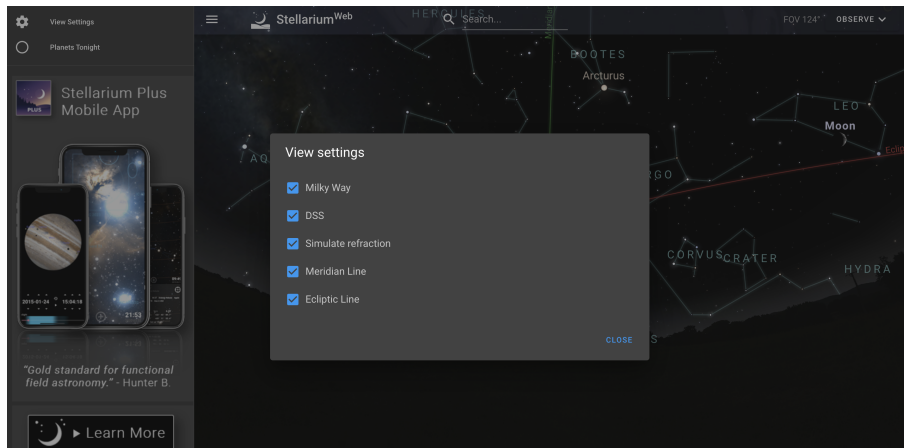
2) **Set the time.** At the bottom right of the screen you should see another button with the time and date. Click that button. Once the window pops up you should see something that looks like the image below. Set up the date and time to match the image below. Set it for June 25th 2020 at 12:00pm (12:00 hours). Also be sure to “pause” time. You’ll see the pause button in the middle of the popup.



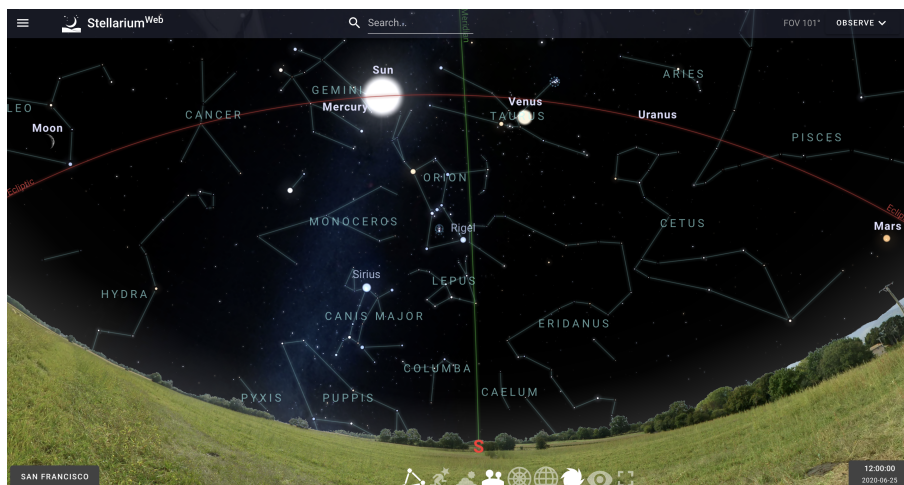
3) **Turn on/off icon features.** At the bottom, you'll also see a bunch of symbols which will turn on and off certain features of the night sky. Turn on the “Constellations” and **turn off the “Atmosphere”** symbol as shown below. If this isn't done, you won't be able to see the stars!



4) **Turn on the Meridian and Ecliptic.** Click the three horizontal line icon in the top left of the screen and look for “View Settings”. Open the settings and check the box that says “Meridian Line” **and also check the box that says “Ecliptic Line”**. Once done, you can close out of the settings menu.



Now that all the settings are setup, turn your view and look towards the South. You should see the ecliptic in Red, the Meridian in Green and the Sun high up in the sky **ON** the ecliptic as shown below.



8. What constellation is the Sun currently in for the date and time we set in Stellarium?

Important!: *If you are unsure if the ecliptic goes through a certain constellation, click on the name of the constellation. The borders of that constellation will pop up as dashed lines and you should be able to tell if the red ecliptic line is within the borders of that particular constellation.*

9. Now let's name all of the constellations of the Zodiac. Starting from the constellation, Pisces, and moving to the right along the ecliptic, list all 13 constellations of the zodiac, in order. *To scroll through the entire ecliptic (to the right), you will need to move time backward by pressing the down hour arrow on the time panel on the bottom right of the screen.*

Sometime during the last 2,000 years since the Zodiac was defined, the constellation, Ophiuchus, has joined in. If you weren't able to find the 13th zodiac constellation before, now try to find Ophiuchus in Stellarium and confirm that the ecliptic actually does go through its borders.

Note: Do not close Stellarium, we will return to it later in the lab.

Where was the Sun on your Birthday

Humans long ago defined an astrological sign to be the constellation that the Sun was in on the day of your birth. Your answer to question 7 above is based on what constellation the Sun was in 2,000 years ago on the day of your birth. Let's modernize it and find what constellation the Sun was actually in on the day of your birth now that Ophiuchus is in the mix.

Below is a diagram of the Earth, Sun and Zodiac constellations and how they would be aligned for someone with the astrological sign of Virgo. Notice that from the Earth, the Sun appears to be “in” the constellation of Virgo.

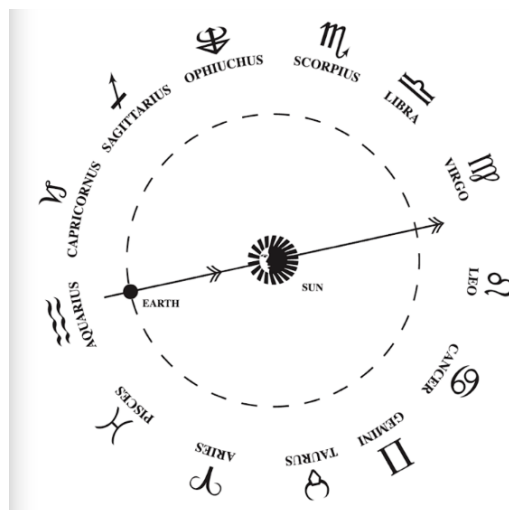


Figure 1: Image: nasa.tumblr.com

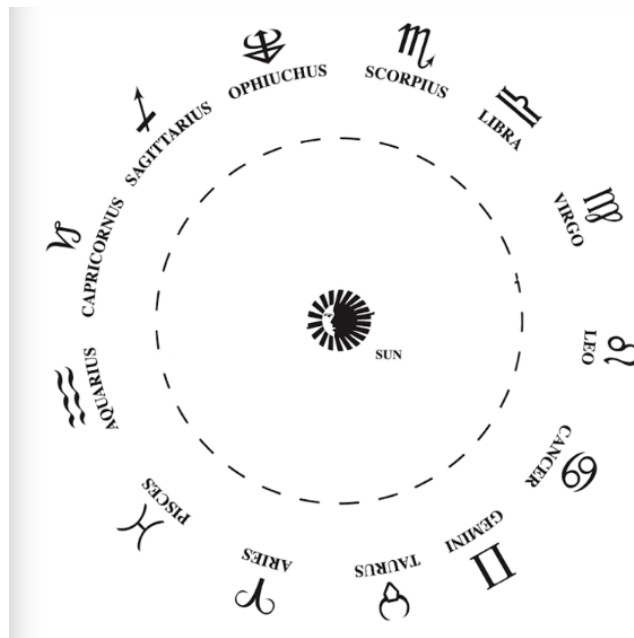
The chart below shows how the dates have changed in 2,000 years, due to precession. Using the example above, we know that the person with the astrological sign, Virgo, should be born sometime between Sept. 16 and Oct. 30.

SIGN	OLD DATES		NEW DATES	
Aries	March 20	to April 20	April 18	to May 13
Taurus	April 20	to May 21	May 13	to June 21
Gemini	May 21	to June 21	June 21	to July 20
Cancer	June 21	to July 23	July 20	to August 10
Leo	July 23	to August 23	August 10	to September 16
Virgo	August 23	to September 23	September 16	to October 30
Libra	September 23	to October 23	October 30	to November 23
Scorpio	October 23	to November 22	November 23	to November 29
Ophiuchus	N/A	to N/A	November 29	to December 17
Sagittarius	November 22	to December 23	December 17	to January 20
Capricorn	December 22	to January 20	January 20	to February 16
Aquarius	January 20	to February 19	February 16	to March 11
Pisces	February 19	to March 20	March 11	to April 18

Figure 2: Source: <https://astrology.wonderhowto.com/how-to/discover-your-new-zodiac-astrological-sign-thanks-ophiuchus-0123964/>

1. Use the chart on the last page to find what constellation the Sun was in on your birthday. You can do this by finding your birthday in the column titled “New Dates”. What constellation was the Sun in? (We’ll call this your sign for the rest of the lab).

2. Now place the Earth in its orbit on the day of your birthday, so that we see the Sun “in” your constellation on that day. Then draw an arrow that starts from the Earth, goes through the Sun and points to your new constellation. Use the blank diagram below.



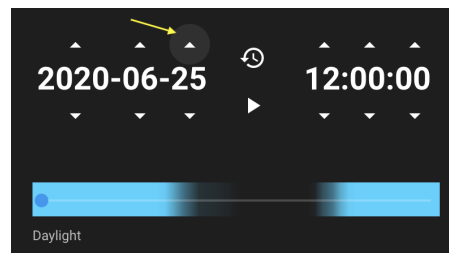
3. How does this compare with your old astrological sign? If it has shifted, indicate by how many constellations.

4. Considering how slowly the Earth precesses, how long do you think it might be until your sign would change again?

Part II: Changes in the Night Sky over a Year

Let's go back to Stellarium to learn about the **annual motion** of the Sun. While the **diurnal motion** or “day” motion, of the Sun is what we see from day to day (rising in the East and setting in the West), annual motion is what we observe the Sun to do throughout the year.

Set the Stellarium date and time back to the original values from the beginning of the lab. Make sure that you can see the Sun on the ecliptic up in the sky. We're going to observe the Sun as we change the date. Move time forward by clicking the up arrow to change the days as shown in the image below.



1. Click the up arrow enough times so that you can see which way the Sun appears to move against the background of the constellations. Does it appear to move to the left or to the right?
2. Which compass direction does the Sun appear to move against the background of the constellations: east or west?
3. Does the Sun actually move?

The change in perspective resulting from Earth's orbit causes an apparent motion of the Sun against the background of constellations (stars). The apparent motion caused by the Earth's orbit (neglecting rotation) is known as **annual motion**.

4. Considering how long it takes the Earth to complete one revolution around the Sun, can you estimate how many degrees the Sun appears to move each day? (*Hint: there are 365 days to a year and in a year the Earth traces out a circle of 360°*)

The Sun's apparent motion also affects which constellations are visible at different times of the year. **Notice** as you click through the days, moving time forward, the Sun moves into different constellations!

Now let's set the date in Stellarium to your birthday. Keep the year 2020 and keep the time 12:00, but change the month and day to your birthday. You should also be looking South.

5. What constellation is the Sun in on your birthday?

6. Is it possible to see your constellation on your birthday? Why or why not? Explain.

Let's figure out when it is the best time to see your sign in the sky. Change the time in Stellarium to, 19:00 (7:00pm PDT), the Sun should be near the western horizon simulating sunset. *If your birthday is in the Summer the Sun will be slightly above the horizon and if it's in the Winter it'll be below the horizon, this is okay.*

7. We know, from previous labs, that the best time to view something at night is when it is on the meridian. With the time set to simulate sunset and the date set on your birthday, fill in the first row of the table below. You only have to list 2 or 3 of the **zodiac** constellations that are closest to the meridian (highest in the sky).

8. Fill in the rest of the table by moving the up month arrow key in the time panel by the amount indicated in the table below. Again, only list the 2 or 3 closest constellations to the meridian (constellations that are highest in the sky).

	date	constellations visible after sunset
Birthday		
3 Months after B-day		
6 Months after B-day		
9 Months after B-day		

9. Are there any dates on which you can see ‘your’ constellation after sunset? If so, when?

10. Imagine that you were living in Tokyo, Japan at 35°N and 139°E , or perhaps in Athens, Greece at 37°N and 23°E , instead of San Francisco. On a given date, would you see the same constellations right after sunset that you see from San Francisco, or would they be completely different? Explain.

One additional motion of the Earth has been left out of our model above. The Sun orbits the center of the Milky Way galaxy carrying Earth and all the other objects in the Solar System with it. The Sun is about 25,000 light years from the center of the galaxy, and it takes the Sun about 200 million years to complete a single orbit around the center. So far, the Sun has done this about 20 times in its life.

11. Why do you think it was okay to ignore this motion in the exercise above?

12. In 100 million years from now, would you expect the constellations of the zodiac to still be the same? Why or why not?