Name ______________________

Date ______________________

Lab Partner(s) ______________________

Project Score [ ]

OBSERVATIONS OF THE SUN

PROJECT LEVEL: Introductory
PROJECT GOALS: Students will learn about features on the solar surface through direct observation. Students will also estimate the rotation period of the sun by observing the change in position of sunspots over the period of a week.

1 INTRODUCTION

The Sun is our prototype of a **MAIN SEQUENCE** star, and it is has provided us with much of what we know about stars in general. In addition, the Sun is the dominant object in the sky, and many of its characteristics are among the most interesting phenomena in astronomy. Examples are **SUNSPOTS**, **PROMINENCES** (huge arcs of material suspended above the surface of the Sun by magnetic fields) and **SOLAR FLARES**. Prominences can be seen in absorption on the disk of the Sun as long, dark lines called **FILAMENTS**.

This laboratory is well equipped for observations of the Sun, and it will provide students with a chance to make "real time" observations of the Sun in an observatory setting. The Sun is an interesting object to study in a telescope, because it changes from month to month and day to day. Sometimes it even changes from one minute to the next. Observations this year will be made at about a third of the way from **SOLAR MINIMUM**, when surface features like sunspots are rare. Try and check out the Sun again in 3-4 years, when it has swung around to the maximum state.

Notice!!!

A general rule is to never directly look at the Sun through a telescope. Even looking directly at the Sun with the naked eye can damage the eye. Sunlight intensified through a telescope can cause permanent damage to the eye. The telescopes used in this project are perfectly safe, due to carefully engineered filters employed to reduce solar light to safe levels. If you are interested in solar observations of your own, either use a telescope to project the Sun's image on a screen, or buy a special solar telescope. Make sure to get a good one, such as that used in this exercise.

There are two types of observation which will be made in this week's project.

1 Observations will be made at the eyepiece of a specialized telescope for solar observations called a **PERSONALIZED SOLAR TELESCOPE** made by the Coronado Filters Company. More will be said about this telescope in Section 2. These observations will be made during the regular lab period, although students are certainly welcome and encouraged to return for subsequent observations.

2 Additional observations will be made with solar data from research observatories available online on the internet. Real-time, or near-real-time images of the Sun are available from the **NATIONAL SOLAR OBSERVATORY** at Sunspot, New Mexico (http://www.nso.edu) and the **SOHO** spacecraft approximately a million kilometers out in space in the direction of the Sun (http://sohowww.nascom.nasa.gov).

2 EQUIPMENT AND SOLAR FEATURES

Some solar telescopes show the Sun in **WHITE LIGHT**, meaning that all the light from the Sun is taken, without filtering with respect to color. The telescope used in this exercise employs a **HYDROGEN ALPHA** filter. This transmits only light in a narrow range of wavelengths around the **BALMER ALPHA** line of the hydrogen atom. This line is the bright red emission line that you see in hydrogen spectra. By applying Kirchoff's Laws, we see that the Hydrogen Alpha filter will allow us to see hydrogen gas clouds glowing against the dark background of space, or in absorption against the solar disk.

2.1 THE PERSONAL SOLAR TELESCOPE

The main instrument used in this exercise is the Personal Solar Telescope (PST), manufactured by Coronado Filters Company. A picture of it is shown below. With it you can see the Sun in white light, or the light of hydrogen alpha. Your teaching assistant will show you how to set up this telescope on its special tripod. In addition to manually pointing the telescope to keep up with motion of the Sun across the sky, there are two controls you will need to use.

The focus knob can be rotated clockwise or counterclockwise to sharpen the focus for your eyes. You should adjust the focus so you can see the limb of the Sun as a sharp edge. The filter tuning dial is also very important. The PST only admits a very small range of wavelengths. By rotating the filter tuning dial you can choose which set of wavelengths you are seeing. This operation is completely analogous to turning the dial on your radio to tune in wavelengths of different radio stations. In the case of the PST, tuning the filter will allow you to see different features on the surface of the Sun. Physically what is happening is that different parts of the Sun have different velocities of motion relative to us, and the **DOPPLER EFFECT** causes the different velocities to show up at different wavelengths of light.

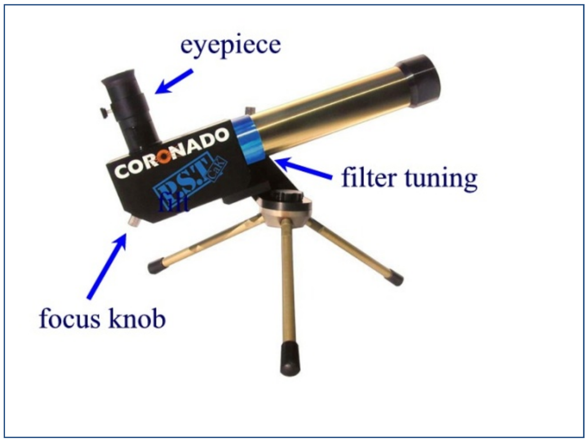


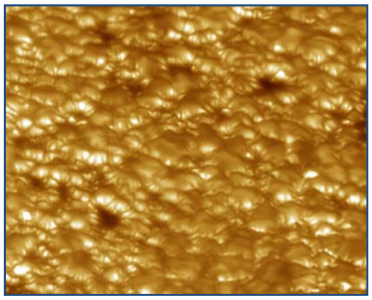
FIGURE 1 - CORONODO PERSONAL SOLAR TELESCOPE

The task for this lab period is to draw the disk of the Sun as accurately as you can (in the light of hydrogen alpha) and see how many of the above phenomena you can see. You should also note what strikes you as noteworthy or interesting. You can then compare your results with the images from the National Solar Observatory or the SOHO spacecraft over the next several days provided by the observatories.

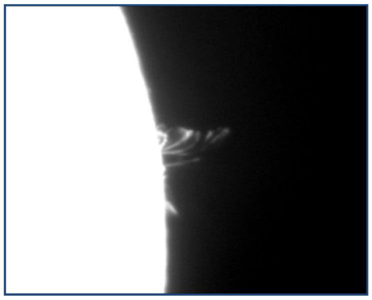
2.2 SOLAR FEATURES

During your observations, you should be looking for the following features/phenomena on the solar disk.

GRANULATION. Granulation is the mottled appearance of the solar disk as seen in hydrogen alpha and is always present. Granulation is an illustration of convection (the process by which heat flows from the interior to the surface) in the Sun. When you are looking at the granules, you are looking at hot blobs of matter that are rising to the surface of the Sun from the even hotter interior, cooling off, then sinking back into the interior again.

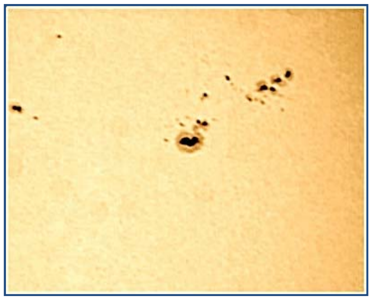


PROMINENCES. Prominences are bright clouds seen at the edge of the Sun against the black of outer space. Often, these appear as bright arches, pushing outward due to magnetic forces. They are bright because they are hot and made of hydrogen, so according to **KIRCHOFF'S SECOND LAW** (A hot gas under low pressure produces a bright spectrum) they glow in the spectral lines of hydrogen.

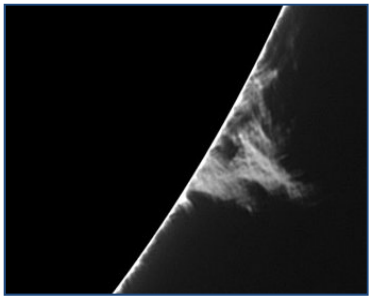


FILAMENTS. Filaments will almost certainly be seen in the observing exercise. They look like long, dark lines on the solar disk. They can only be seen with a hydrogen alpha filter. They represent prominences which are seen in absorption against the light of the Sun, rather than in emission against the dark sky at the solar limb.

SUNSPOTS. Sunspots are somewhat more obvious in white light, but if there are some on the solar disk at the time of the observations, we should see them with the PST. They probably will be surrounded by bright regions called **PLAGES**. The number of sunspots increases and decreases with solar cycle, so you may see many, or none at all depending on the year.



SOLAR FLARES. One of the most exciting phenomena to see is a solar flare. Flares are huge explosions on the surface of the Sun and their occurrence can sometimes be detected at Earth (one astronomical unit away). If you see a flare, it will appear like a flame on the solar edge, or like a bright point on the solar disk, almost always in the vicinity of a sunspot. Flares are short lived, increasing to maximum brightness and fading away in a matter of minutes.



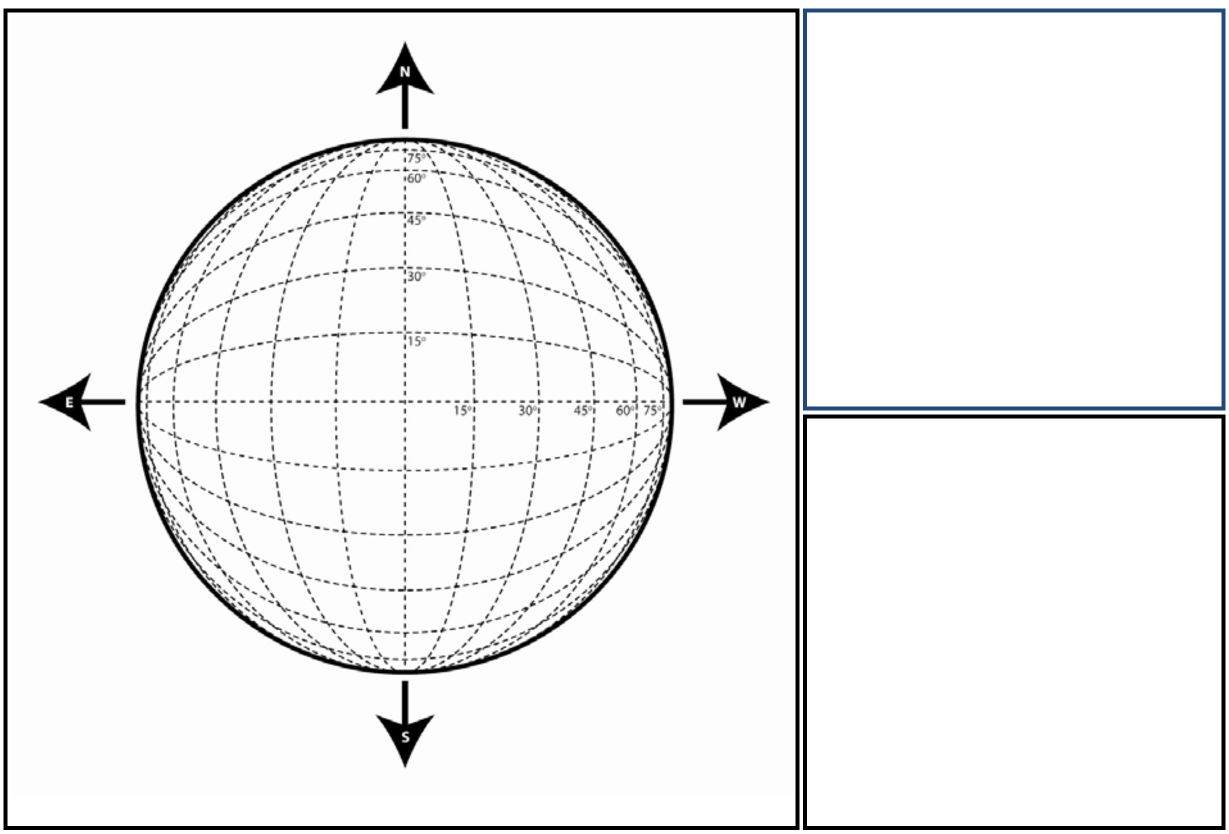
3 OBSERVATIONS

3.1 OBSERVATIONS WITH THE PERSONAL SOLAR TELESCOPE

Work in pairs with your lab partner and set up the PST. Ask your lab instructor for assistance if needed. You can find the Sun by looking for the bright dot in the viewfinder screen near the eyepiece. When you have the Sun in the viewfinder, look in the eyepiece and you will see the Sun in the light of hydrogen alpha. When looking at the Sun you should first determine the directions, and orientation of the solar disk. This may be done by simply watching the Sun drift out of the field of view. The Sun drifts westward due to the Earth's rotation, so the west limb will leave the field of view first. You can determine north and south by moving the telescope north (upwards) or south (downwards). The Sun will then move out to the south or north, respectively. Do this determination first. This will let you accurately draw the location of features you observe.

QUESTION 1:

Draw the features you see in the space provided and record their locations as accurately as possible. You can also sketch other interesting features you see off to the side, such as prominences, or filaments.



Features may be drawn in more detail on the right side of the form, or in any blank space on this document. Below, make a list of the solar features which you observed. Also specifically state what phenomena were not present at the time of your observations. ***Be sure to note the time of your observations.*** This information will be needed later.

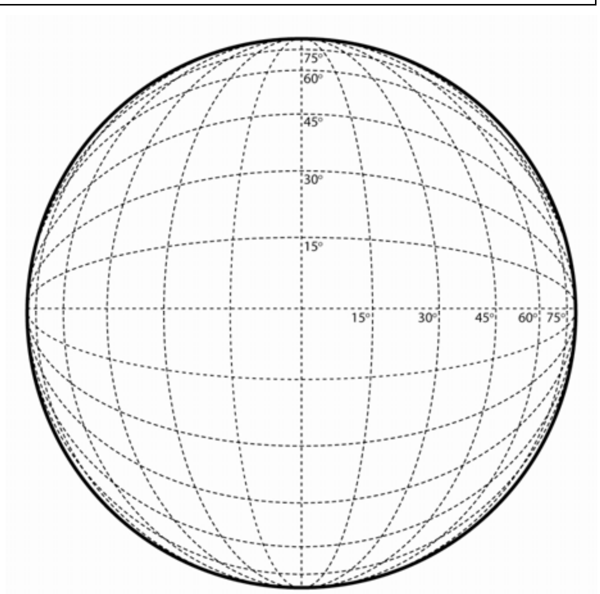
QUESTION 2:

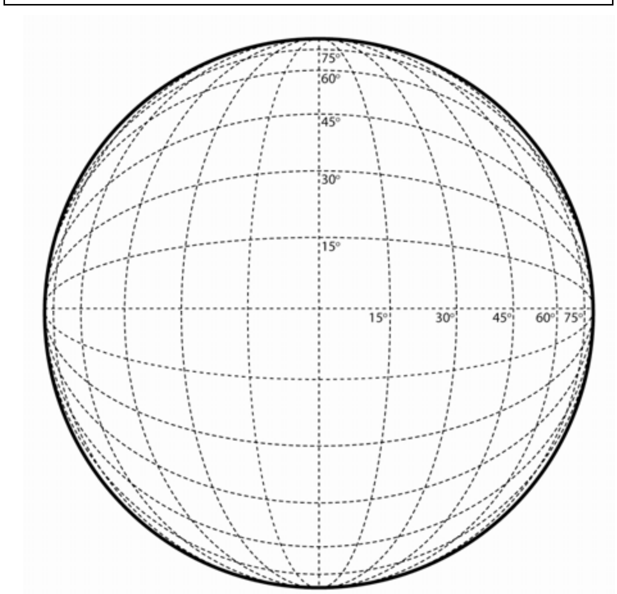
Locate a feature (preferably near the east limb; you can determine this once you have established directions) that you will be able to recognize when asked to make a second observation. Describe the feature below, indicating its approximate position (latitude, longitude), size, and color. Also record the time of your observation.

3.2 COMPARISON WITH DAILY OBSERVATORY IMAGES

During the next week, download an image of the Sun in hydrogen alpha from the National Solar Observatory or an ultraviolet image of the Sun from the SOHO spacecraft. Examine these images and compare them with those you made on the rooftop. You can also examine white light images from the NSO or Big Bear, or the SOHO spacecraft. Accurately sketch any important features and give each an appropriate label. Make sure to record the date and time of your observations, as you will need this information for the final section of this lab. ***You will be required to do this 4 times over the next week. If you use Images from different sources, make sure you have properly rotated each image so your sources match orientations.***

DATE, TIME AND SOURCE:	DATE, TIME AND SOURCE:





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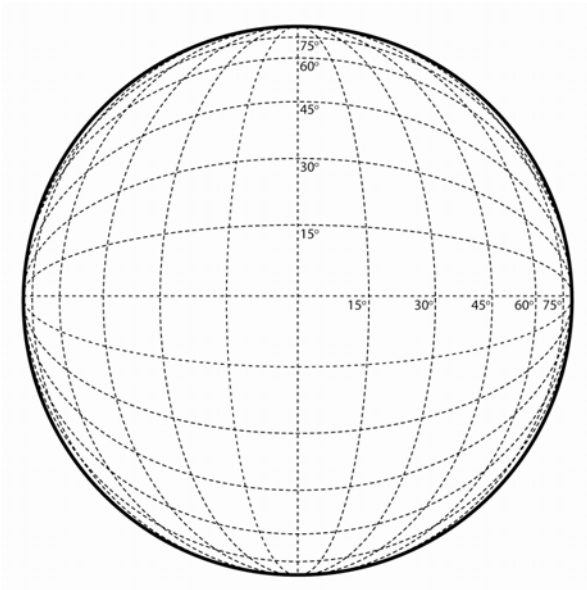
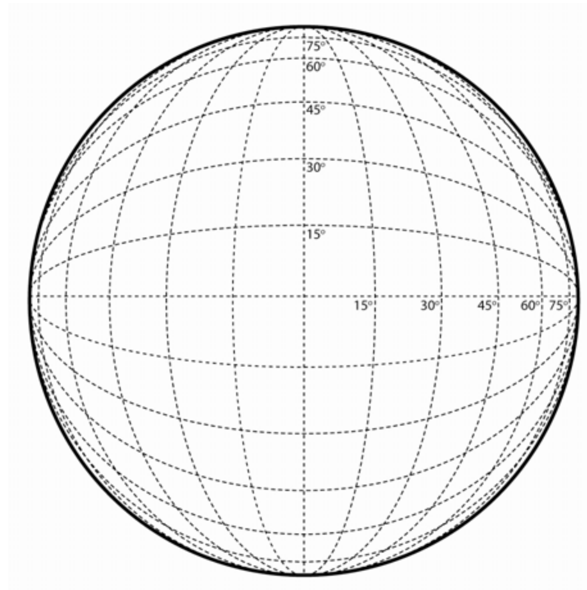




3.3 MEASURING SOLAR ROTATION

If you pick a feature on the solar surface, and watch it over a period of several days, you will see it move across the solar disk from east to west. By measuring the rate of change of the feature with respect to time, you can determine the angular speed of rotation of the Sun, and thus its period. The steps are as follows.

1. For each day, note the location of a solar feature that was visible for a majority of your observations. This feature should follow a constant line of **LATITUDE** on your images.
2. Convert your date and times to **DECIMAL DATE**, i.e. the days since your first observation plus the fraction of that day the time represents. For example, if your first observation is on Tuesday at 12:30PM, your Decimal Date for that observation is 0.52 (Try this). If your second observation is on Wednesday at 4:15PM, your second decimal date is 1.59 (Try this as well. If this step is confusing, please ask your lab instructor for help).
3. Scale all of your Decimal Dates by the time of the first measurement. Do this by subtracting each date by the Decimal Date of your first observation.
4. Record **LONGITUDE** of the feature for each observation day. Use negative numbers for θ if the feature is to the left (east) of the center and positive values of θ if it is to the right (west). For many of your measurements you will need to estimate the position between grid spaces.
5. ***To account for the earth's motion between your observations, add the scaled date to your longitude measurements before you plot them. This corrects for the ~1 degree per day motion of the earth around the sun.***
6. Make a graph in which you plot Longitude vs. Scaled Date for your observations. When you have plotted all of your data points, draw the line through them. The slope of this line will be the angular rotation speed of the Sun, and will have units of degrees/day. This final value for the rotational speed of the Sun can be denoted by the variable **W**, and has units of degrees/day. Do all of your calculations in the space provided.
7. Finally, the rotational period **T** of the Sun is given by $\mathrm{T} = 360\ \mathrm{deg/W}$

If there are several features on the surface of the Sun, see if you get the same value for W and T for features at different solar latitudes.

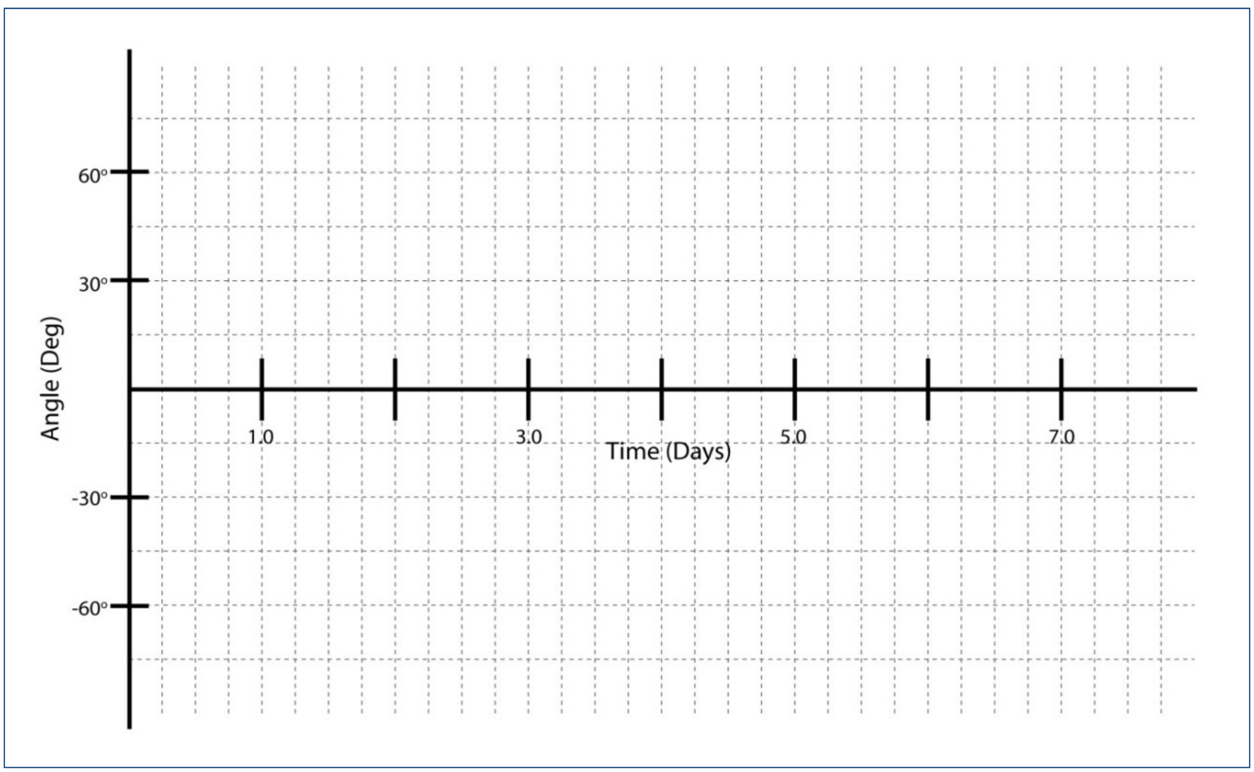
QUESTION 3:

Record your observations in the table below.

Date and Time of Observation	Decimal Date	Scaled Date	Theta(degrees)	Corrected theta

QUESTION 4:

Make a plot of Longitude Angle (deg) with respect to the Scaled Date.



Question 5:

Draw a line through the points in your plot and estimate the slope of the line (change in angle divided by the change in time). Use this slope to calculate the rotational period of the sun at your feature's latitude.

Slope	
Period (T)	