29:50 Lab Project
Stars, Galaxies, and the Universe
Fall 2007

Observations of the Sun

Name……………………………….
Date………………………………..

I. 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 the time of "solar minimum", when surface features like sunspots are rare. Try and check out the Sun again in about 5 years, when it has swung around to the maximum state.

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 below. 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. Realtime, or near-realtime images of the Sun are available from the National Solar Observatory at Sunspot, New Mexico (http://www.sunspot.noao.edu) and the SOHO spacecraft approximately a million kilometers out in space in the direction of the Sun (http://sohowww.nascom.nasa.gov) .

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, because carefully engineered filters are 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.*

II. Types of Solar Telescopes

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.

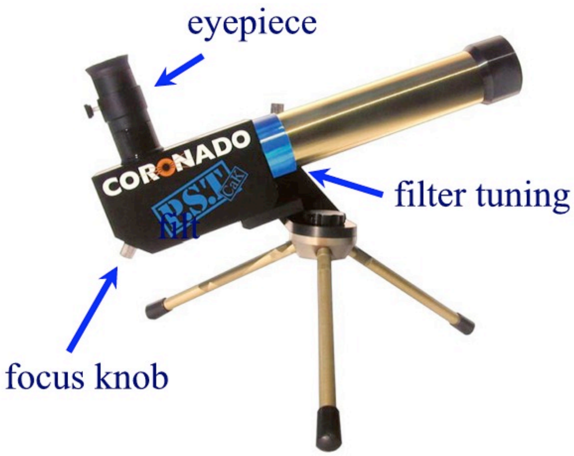
III. The Personal Solar Telescope

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 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.

The PST can also be used as a white light telescope by tuning the wavelength away from the Hydrogen alpha line. Your teaching assistant will provide further details.



IV. Solar Features to Look For

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

(1) *Granulation.* Granulation is the mottled appearance of the solar disk as seen in hydrogen alpha. It will appear as bright patches separated by darker boundaries. Granulation is an illustration of convection in the Sun, the process by which heat flows from the interior to the surface of 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. Since granulation is the process by which heat flows from the center of the Sun to its exterior, it is present even at solar minimum.

(2) *Prominences.* Prominences are bright clouds seen at the edge of the Sun against the black of outer space. Often, these appear as bright arches. They are bright because they are hot and made of hydrogen, so according to Kirchoff's Second Law, they glow in the spectral lines of hydrogen. An amazing thing about prominences is that they are held up against the strong gravitational force of the Sun by magnetic forces.

(3) *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.

(4) *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. Since this project is being carried out at solar minimum, there will probably only be small sunspots, or none at all.

(5) *Solar Flares.* One of the most exciting phenomena to see is a solar flare. Flares are huge explosions on the surface of the Sun. The effects of these explosions can sometimes be detected at Earth, one astronomical unit away. If you see a flare, it

will appear as a starlike bright point on the Sun, almost always in the vicinity of a sunspot. It will increase to maximum brightness and fade away in a matter of a few minutes. The tremendous energy associated with solar flares comes from the energy stored in solar magnetic fields.

The task in the lab period will be 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 National Solar Observatory or the SOHO spacecraft over the next several days provided by the observatories.

V. Observations

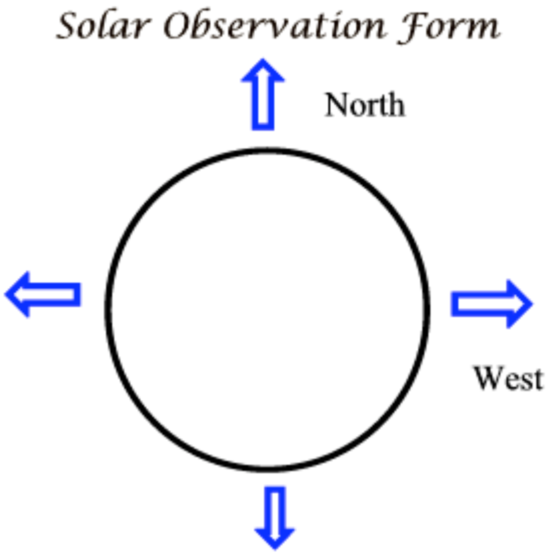
(1) Observations with the Personal Solar Telescope
Work in pairs with your lab partner. Your teaching assistant will show you how to set up the PST. You can find the Sun by looking for the bright dot in the viewfinder screen near the eyepiece. When you have the Sun in the viewfinder, look in the eyepiece 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.

Record your observations on the form below. Draw the features you see, and record their locations as accurately as possible. You can also sketch other other features you may see in more detail off to the side, such as prominences, granulation, and filaments.

Solar H-Alpha Light Image

Observer……………………………..   Date……………………………………



Features which may be drawn in more detail can sketched on the right side of the form, or in any blank space on this document. On the facing page, or on a separate sheet of paper, you should make a list of the solar features which you observed. Also specifically state what phenomena were *not* present at the time of your observations.

(2) Comparison with Daily Observatory Images

Every day for 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. Comment on the changes you see in the space below.
Do it! …………………………………………………………………………………….
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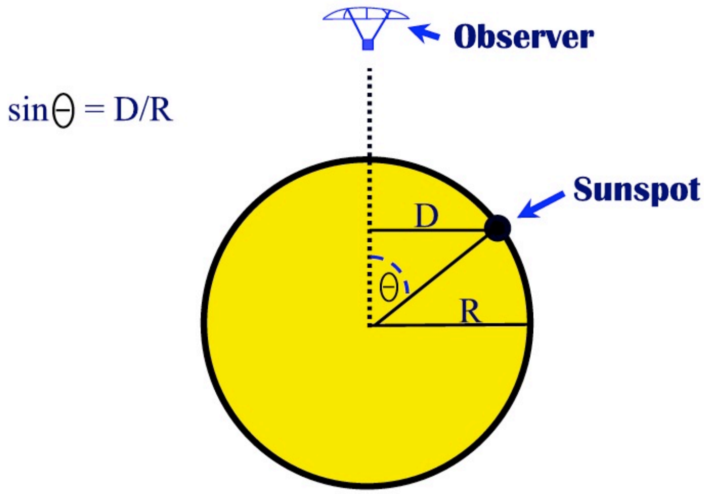
VI. Measuring Solar Rotation

Observations of the sort described above should be continued for the week between the lab period and and the next lab class. These observations can be most conveniently made via the internet, but a student who wishes to make them with the PST is encouraged to make arrangements with the instructors.

If you pick a feature on the solar surface, such as a sunspot or filament, and watch it over a period of several days, you will see it move across the solar disk from east to west. From these observations, you can determine the angle theta defined by the Earth-Center of Sun-Sunspot (see figure below). By measuring the rate of change of theta with time, you can determine the angular speed of rotation of the Sun, and thus its period.



Solar Rotation Measurement

The steps involved in measuring the angular speed of the Sun are as follows.

- For each day, draw a line across your image of the Sun at the solar equator. Note that this will require that you determine the east and west directions on your image.
- For each feature you are tracking, draw a line on the solar disk parallel to the solar equator, which goes through the feature being measured. We'll call this line the chord.
- Determine the center of the chord.
- Use a transparent ruler to measure the distance (in centimeters or millimeters) from the center of the chord to the feature. This distance is D in the above diagram. Record your data in the table below. Use negative numbers for D if the feature is to the left (east) of the center of the chord, and positive values of D if it is to the right (west).
- Next measure the distance from the center of the chord to the limb of the Sun. This is the distance R in the figure above.
- The angle theta is given by the formula in the above figure, sin(theta)=D/R.
- Make a graph in which you plot theta as a function of time in days from the start of your observation. Each observation will be separated by 1.00 days if you make your observations at the same time each day. If you make observations at different times (i.e. at 2PM one day and 9 AM) the next, correct your data appropriately.
- 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 value should be corrected by adding 1 degree per day to correct for the orbital motion of the Earth. We want effectively the sidereal rotation period of the Sun. 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 on the facing page, or a separate sheet of paper which you hand in with this form.

- Finally, the rotational period of the Sun is given by $T=360/w$.

Include your graph and calculations with w and T with this form and turn it in to your TA in the next lab period.

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.

Date	**time of day**	**D (units)**	**R (units)**	**Theta(degrees)**