Solar Activity and Multi-wavelength Observations

As we look at the Sun and stars in a variety of wavelengths, we see qualitatively different features, not just quantitative differences. In this exercise, you will be gathering solar data from the Internet and comparing the Sun's appearance in different wavelengths of light.

There are several suggested websites for this activity. You may use any other sites that provide the solar images. Print out the website name on your images. Generally your printer can be set up to print this information automatically. It is not necessary that you use very recent data but don't copy another person's lab and don't use the exact same dates and pictures as another person. If you work with a partner, be sure to use observations from different dates. If you do not find sunspots etc. in recent solar data, use old data.

Some useful sites are:
http://sohowww.nascom.nasa.gov/
This site has archives in many wavelengths and from many sources. The observations are often made more often than once per day. The data called MIDI is "white light". There are several links here that lead to mosaics of data at many wavelengths.

http://www.solar.ifa.hawaii.edu/ Follow the links to the Mees White Light Telescope and go to archives. There you will find monthly synopses of solar observations with a whole month of data together. The bad thing is that they don't observe every day. So you may need to supplement the information with another source. If you look at the link to latest solar observation, you will find data at many wavelengths.

Data from the Yohkoh satellite can be found at
http://solar.physics.montana.edu/YPOP/ or http://www.lmsal.com/YPOP/
(These are mirror sites, so you need to go to only one) The Yohkoh satellite collected x-ray data that shows the structure of the Solar Corona and the coronal holes. Following the links from these sites, you can find EIT (extreme ultraviolet telescope from SOHO) and also CaII or H alpha images.

Another good site is http://bass2000.obspm.fr/. It links to many solar observatories.
www.spaceweather.com tells about solar wind speed and links to movies of solar rotation.

The Mount Wilson Observatory site, http://www.astro.ucla.edu/~obs/intro.html has lots of links. It includes drawings of the Sun's surface where the active group numbers are shown. If you are looking for the identifier for your spot group, this might be the place.

The Big Bear Observatory Site http://www.bbso.njit.edu/ includes maps with multiple wavelengths and numbering for the active regions. Follow the links to Active Regions and go to the archive to get data for the last couple of years, day by day.

The following includes maps of both the Earthside and farside of the Sun.
http://www.raben.com/maps/ (but not an archive of this material).
Flare and other data http://solar.nro.nao.ac.jp/

I Find the Solar Rotation Period
Find a large sunspot group in a white light image. Print out copies of the Sun's image while your sunspot group is in view, following the spot group across the Sun's visible face. Print pictures of the times when the sunspot group crosses the center of the Sun and when it goes off one or both solar limbs (edges). You don't need to get the image every day, but definitely get the EXACT day that the spot(s) cross the center of the image and the EXACT day or days that the spot(s) disappear. There are several sites and sources of white light images of the Sun. The exact time of observation differs from one to the next. You may want to use the in-between time data to pin down the middle and edge of solar disk times.

Print out (or make a file with) your key pictures (the ones at the limbs and middle of the solar disk) and turn them in. They do not need to be in color, but they do need to be legible. They will be returned. Be sure to include the date and source of the picture with each image. You MAY make one page with many pictures if you wish.

I-a What is the range of dates for your observations?

I-b What is the number of your sunspot group There is an official active group number assigned to each sunspot group ?

I-c To find the time for the sunspot to cross the Sun, record at least TWO of the following times

Appeared on East limb ___________

Crossed the center of the Sun__________

Disappeared on West limb_____________

I-d How long did it take for the spot(s) to cross the face of the Sun?

If you find a spot group that is visible for ONLY half way across the Sun's face, double the time to get the time for it to cross. Be sure to find the exact time interval, including hundredths of a day.

I-e Using your value for the time to cross the visible face, find the time will it take for the spot to go all the way around the Sun?

I-f If your sunspot group lives long enough, it may be carried around the Sun and become visible on another solar rotation, either before or after the times of your observations. The length of time that you found in I-d for the spots to cross the entire face of the Sun is the same time that spots spend on the invisible side of the Sun.

Date the spot might reappear on East side of Sun (after the dates you used)
(date it disappeared + time to cross) =

Date the spot might have disappeared on the West side of Sun
(before the dates you used)
(date it appeared – time to cross) =

I-g Look at the images of the Sun on and around the dates you computed in I-f and print them out (or save them to a file). Can you find your spot group?

I-h The Earth orbits in the same direction that the Sun spins. So the time that you found for the Sun to spin is not exactly the time that an outside observer would see. The Earth orbits the Sun in the same direction at a rate of 360^o every 365.24 days or 0.9856 degrees per day.

So how many degrees does the Earth move during the number of days that it took for the sunspot group to go all the way around the Sun?____________

I-i Correct for motion of the Earth to get the Sun's sidereal rotation period

The "correct" time for the Sun to rotate, the **sidereal period**, would be the time for the Sun to go 360 degrees compared to the stars or another fixed reference. The time that you have is for the Sun to go 360^o compared to the Earth. Since the Earth is moving, the Sun has gone 360^o plus the angle that the Earth has gone, the value from I-h.

So in the time that you found, how many degrees did the Sun go compared to the stars? (once around plus the angle from I-h).

Will the sidereal period be longer or shorter than the time that you found??

Now you can find the sidereal period of the Sun's rotation. To find this value, make the ratio

$$\left(\frac{\textbf{Sidereal Period}}{\textbf{Period You Found}}\right) = \left(\frac{\textbf{360deg}}{\textbf{360deg + motion of Earth over time for Sun to spin}}\right)$$

You know everything except the sidereal period, so solve for the sidereal period. It will be in the same units as the period you found.

Sidereal Period _______

I-k Look up the Sun's sidereal rotation period. It will be in your text book and on the internet. What do you find (hint, it isn't one simple number)?

I-l What are some assumptions that we made in computing the Sun's rotation period?

II Evolution of Sunspots and Active Groups

II-a Consider one large sunspot group. It can be the one you used for the first part. Be sure you have at least 5 or 6 pictures of the same group. Describe how it changed appearance over the time interval of your images (include the reappearance if you found one)

II-b What date did the group appear to be the largest?

What date did the group appear to have the most distinct spots?

II-c Estimate the lifetime of your spot group. If your spot appeared or disappeared while it was on the side of the Sun that we observe, you can get an idea of the time that your spot group lasted. Did your group last for more or less than the time for it to cross the face of the Sun? __________

If the spot group lasted longer than it took to cross the face of the Sun, but was not visible either half a spin before or after, you will just need to estimate how long the group was present while invisible.

What is your estimate for the life of your spot group? ___________

II-d Now look at the Magnetograms and Ca II or Hydrogen alpha (Halpha) images of the Sun for some of the dates when your sunspot group is present.

Print out at least one magnetogram and one CaII or Halpha image. Get a print out of the white light image for the same time (or as close as the data allows). Turn in these pictures.

II-e Identify the location of the sunspot group on the magnetogram and on the CaII image and label it on each picture.

How does your sunspot group look on the magnetogram and on the CaII or Halpha pictures?

II-f) Which type of image makes the spot group the most obvious?
Are there features on the CaII or Halpha image or on the magnetogram that you cannot find on the white light picture?

If you see more features, what do they look like?

III Features of Other Sunspot Groups
III-a) Find two other sunspot groups. They do not need to be on the same pictures that you already have. You should have three spot group images **all from the same instrument (same spacecraft and same wavelength)**. This is so that the sensitivity of the telescope is the same. So you will be comparing the sunspots, not the capabilities of the telescope.

III-b) Print out (or save electronically) at least one picture of each of your other sunspot groups.

III-c) Compare them to your first group, using the table below to organize your work

Spot Group Number	Date First Visible	Date Last Visible	Comparative lifetime (longest, shortest or middle)	Comparative Size (largest, smallest or middle)

III-d Do larger spot groups last a longer or shorter time than small spot groups?

What is YOUR evidence for the answer to the question above?

Describe the evolution of one of your sunspot groups. Probably the largest spot group will be the most interesting.

IV Multiwavelength Astronomy

Compare the appearance of the sun in several different wavelengths. It would probably be easiest to look at the same dates you used for finding the Sun's rotation.

IV-a Go to a site like the SOHO site **http://sohowww.nascom.nasa.gov/** or the Big Bear Site http://www.bbso.njit.edu/. You will find views of the Sun using at least 5 different types of signal. Most of the data is light of various wavelengths. Other data available is magnetic data, where the direction and field strength is shown.

Print out views of a spot group using the different views. Try to get them all within 24 hours. You will not necessarily be able to get the exact same moment.

Which view makes the Sun look the most uniform?

Which one makes it appear least uniform?

IV-b The Sun's surface is at a temperature of about 5880K and puts out the peak of its Planck curve at about 5000Å. The Corona is a temperature of 1,000,000 –2,000,000K. What is the wavelength at the peak of the corona's Planck curve if you assume that the temperature is 1,500,000K? (Hint, the formula is Wien's law and is in the textbook,)

IV-c The EIT, Extreme Ultraviolet Imaging Telescope images the Sun in several wavebands. These are identified by the type of element, the number of electrons lost from that element due to temperature and the wavelength of light that is detected.

For example **Fe XII 195 means** Iron (abbreviated Fe, like ferrous metal) that is eleven times ionized. The Roman numeral XII, twelve, indicates the number of electrons that have been lost. The numeral is ONE MORE than the number of lost electrons. Fe I is iron with NO lost electrons. The number **195** is the wavelength in Ångstrom units.

Does a wavelength with a smaller number of Ångstrom units indicate a higher or lower energy for each photon?

IV-d Look at images of the Sun in various wavelength images on the same day. Can you find any feature on the EIT images that corresponds with your group?

IV-e Find some “loops” where the magnetic field has caused gas to condense. They arch above the Sun’s surface, like an archway of balloons.

Find and label at least two loops (i.e. indicate with an arrow that they are loops). They can be on two different pictures.

Which of the EIT wavelength images of light shows the most loops?

IV-f The EIT images look very different from the white light pictures and magnetograms because the EIT wavelengths are coming from the Sun’s corona.

The corona is divided into sections by the Sun’s magnetic field. The material in the corona tries to stream out, escaping from the Sun at hundreds of kilometers per second. Where the magnetic field is strongest, the gas is held in loops and the corona appears bright. Where the field is weaker, the gas in the corona streams out rapidly. The Sun appears dark and the solar wind streams out quickly.

The sites,
http://solar.physics.montana.edu/YPOP/ or http://www.lmsal.com/YPOP/

take you to a brief movie of the Sun rotating**.** The images were taken in x rays, which are even more energetic than the far ultraviolet of the EIT. The coronal structure is clearly shown in the images. Unfortunately, the Yohkoh satellite that collected the X ray images is not operating any more. So you probably will not be able to get X ray data for the same date

Mark the boundary of a bright and a dark sector on one of the EIT images of the Sun and label it.

Where is your spot group compared with the boundaries? Is it in a coronal hole?

IV-g Look for very dark areas on the EIT images. Typically they might be about 1/10 of the diameter of the Sun in each direction. They are called coronal holes. Can you find any such very dark areas on your EIT image of the Sun? If so, label the area (draw around the boundary with a crayon). If not, report that fact here.

Coronal holes are places where the Sun's magnetic field is not very strong. There is little x-ray light coming from these areas, but there is LOTS of Solar Wind.

EXTRA CREDIT

V The Solar Wind

The solar corona doesn't have a fixed edge. The coronal material speeds up and flies away from the Sun at speeds of hundreds of kilometers per second. This material is called the Solar Wind. It isn't any special type of material, just the same hydrogen and helium as the rest of the Sun. One of the ongoing problems in understanding the Sun is that the source of energy to accelerate the solar wind is not well understood.

The solar wind was first discovered as we went outside Earth's atmosphere and it is being measured from space. There are several "Space Weather" websites where you can check what is happening today. Look up the space weather and find

V –a Today's Space Weather

Date______

Solar Wind Speed______

Solar Wind Density_______

On the space weather web page, there is a link labeled "more data". It shows plots of density and solar wind speed.

When the wind speed goes up, what happens to the wind density?

V-b When we detect the solar wind with a spacecraft in Earth orbit, we get a sample of the wind near the Sun's equator. To find out the three dimensional structure of the wind, we need to sample it at all solar latitudes. There is a satellite named Ulysses measuring this. Ulysses loops around Jupiter and back over the Sun's north and south poles. Ulysses samples the solar wind and detects the speed and density of the wind. It doesn't publish daily or weekly data because it takes years for the spacecraft to complete its orbit.

Go to the Ulysses website and find out

When was Ulysses launched?

Does the solar wind change speed depending on what part of the Sun it is above?

What part of the Sun has the fastest solar wind?

What happens to the solar wind and the corona as the sunspot cycle changes?

Where is Ulysses today?

Be sure to turn in you Objective, Conclusion, printouts of your spot group as it passes the visible face of the Sun, your printouts comparing views of the Sun in various wavelengths and the answers to all the questions.