Name______________________________

ASTR 106 **The Active Sun** **due: Monday 6 March 2017**

Sunspots are dark features on the surface of the Sun, lasting from hours to months. Until the invention of the telescope in the first decade of the seventeenth century, the reports that the Sun had such blemishes were not something that could be easily verified. Galileo built one of the first telescopes and used it to clearly view these dark areas on the Sun's visible surface. With a telescope, we can observe spots appear, grow, and gradually disappear, as they move steadily from horizon to horizon across the Sun's surface.

> **NOTE:** Viewing the Sun through a telescope can cause permanent damage to your eyes. It is very uncomfortable, and still dangerous, to view the Sun directly with the naked eye. Galileo learned to be careful to observe the Sun only very close to sunrise or sunset, but still was blind at the end of his life. A way to safely see the features on the Sun is to view its projected image. Instead of looking through the eyepiece of a telescope or binoculars, hold a sheet of white paper behind the eyepiece. The solar image will be projected onto the paper, allowing you to safely observe the Sun.

Galileo was unsure what these dark flat areas spots really were, and suggested they could be clouds. He noticed that the sunspots changed shape as they traversed the Sun's surface. Spots that appeared fairly circular when viewed in the middle of the Sun would be distorted when seen at the edges. He realized the change in shape was due to foreshortened projection of flat areas on the surface of the Sun. A spot will appear different when viewed at the edge of a three-dimensional sphere, compared to how it looks when at the center.

Today we can take advantage of technology not available to Galileo. Our telescopes are larger and constructed with more precision. Such improvements allow us to observe the Sun in more detail. Although Galileo and scientists of his time could see there were dark regions on the Sun, they couldn't see any of the fine structure visible with our modern instruments. Additionally, telescopes today can observe different wavelengths of light, beyond just the optical light our eyes can see. Modern instruments use filters and detectors to measure wavelengths of light beyond the visible colors of the rainbow. Viewing the non-visible light that the Sun emits, such as x-rays, ultraviolet or infrared, provides new tools that allow us to unravel the mysteries of sunspots.

Formulating a Hypothesis:

From centuries of multi-wavelength data, astronomers developed hypotheses to explain the physical nature of sunspots. We have come to understand that a sunspot is a dark region on the sun's surface that is cooler, and thus darker, than its surroundings. In this lab you will investigate the hypothesis that sunspots are cooler because of a strong magnetic field that inhibits the convective transport of heat. The temperature of a sunspot may be as low as 4000 Kelvin (which is still quite hot compared to anything we experience) compared to about 5800 degrees for its surroundings. A small change in temperature creates a big change in brightness. While sunspots are about one third cooler, they are much darker than the surrounding surface of the Sun.

Solar data obtained by instruments on two of NASA's solar telescopes are available to the public at http://sohowww.nascom.nasa.gov/. Go to this website and click on the link titled "The Sun Now." There are 8 different datasets available. Browse this site to get familiar with how to view the images.

The Solar and Heliospheric Observatory (SOHO) Extreme Ultraviolet Imaging Telescope (EIT) is designed to observe extremely hot material (from 1 to 2 million Kelvin) at several wavelengths: 171Å, 195Å, 284Å, and 304Å (the symbol Å is for the unit of an Angstrom, equal to 10^{-10} meters).

The Solar Dynamic Observatory (SDO) Helioseismic and Magnetic Imager (HMI) images are obtained at particular visible wavelengths that can be combined and analyzed to create the magnetogram image that provides information about the strength of the magnetic field on the Sun's surface.

SOHO's Large Angle Spectrometric Coronograph (LASCO) C2 and C3 images produced by wide angle cameras that detect visible light to about 32 solar diameters, from the zone known as the corona.

Procedure:

A. LASCO C2: Click on the "Search and Download Images" link and create a movie of all the LASCO C2 data since the first day January in **2014**. The camera is sensitive to very hot but very diffuse material expelled from the Sun. The LASCO C2 images are colorized in shades of orange, with darker orange representing less light.

1. [1 pt] Why is there a dark orange circular disk in the center of the LASCO C2 image?

2. [1 pt] What is represented by the white outline of a circle drawn onto this dark orange disk?

3. [3 pts] Describe the activity visible in the LASCO C2 images during **2014** January 6 & 7 compared to during **2014** January 18 & 19.

Extra Credit [2 pts] What caused white streaks all over the LASCO C2 images on January 6^{th} & 7^{th}?

B. EIT: Open two browser windows and bring up the "Search and Download Images" request page on each so that both are visible simultaneously. In one window create a movie of all the EIT 171 data since the first day January in 2014; in the other create a movie of all the EIT 284 data since the first day January in 2014.

4. [3 pts] Describe the activity visible in the EIT 171 images compared to that visible in the EIT 284 images.

5. [4 pts] From what you learned about the temperature structure of the Sun and the relationship between temperature of an object and the wavelength at which it emits most of its light, provide an explanation that explains the differences you noted in your response to the above question.

From the "Search and Download Images" request page, request the images for 2014 January 6 & 7 and compare them to the images from 2014 January 17 and 18.

6. [3 pts] Describe the activity visible in the EIT 284 images during 2014 January 6 & 7 compared to during 2014 January 18 & 19.

C. HMI: From the "Search and Download Images" request page, create a movie of all the HMI Magnetogram data since the first day of January in 2014.

Extra Credit [2 pts] Clearly explain what the white and black features represent in these images.

7. [2 pts] Describe the relationship between the black features and white features on the images. Are any there any absolute rules that always seem to exist for what we can observe about the relative brightness or the relative location of the black *vs*. white features?

Open two browser windows and bring up the "Search and Download Images" request page on each so they are simultaneously visible. In one window create a movie of HMI Magnetogram data since the January 1, 2014; in the other window create a movie of HMI Continuum data for the same time period.

8. [2 pts] Are there ever dark features (sunspots) visible in the continuum images that are not reflected in black features or white features in the corresponding magnetogram images?

9. [2 pts] Are there ever black features or white features in the magnetogram images that are not reflected in in the corresponding dark features (sunspots) visible in the continuum images?

10. [3 pts] Describe the relationship between the black features in the magnetogram images and the darkest sunspots in the continuum images. Are any there any absolute rules that always seem to exist regarding the relative location of the sunspots *vs*. black magnetogram features?

11. [2 pts] Describe the activity visible in magnetogram images during 2014 January 6 & 7 compared to during January 18 & 19.

12. [4 pts] Present concise arguments based on the data you analyzed to support a hypothesis that sunspots, magnetic anomalies, ultraviolet flares and coronal mass ejections are related phenomena.