AST 3018 Project - Investigating the Sun

Due: October 30, 2020

In this project you will investigate some physical properties of the Sun by making your own observations of the Sun and also using data available on the web, obtained from solar observatories.

**REMEMBER: NEVER LOOK AT THE SUN DIRECTLY WITH YOUR EYES OR THROUGH AN UNFILTERED DEVICE SUCH AS A TELESCOPE OR BINOCULARS.**

Practice eye safety. Serious eye injury, including blindness can occur from looking at the Sun.

*“This is more than advice. Why? As a kid, did you ever take a magnifying glass out into the sun and burn leaves? If so, you probably remember that when the focused sunlight coming through the lens was refracted and concentrated to a small spot, the energy available there was truly remarkable. Guess what? You have a lens just like that in your eye. If you look at the sun, your eye-lens will concentrate the sun's light and focus it to a very small spot on the back of your retina. This can cause permanent eye damage or blindness. Additionally, there are no pain sensors back there so you won't even know it's happening!”*

– from How to Observe a Solar Eclipse by Ron Hipschaman

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**I. Build Pinhole Camera to Look at the Sun**

In this part of your project you will design and construct your own pinhole camera.

1. **Research** how pinhole projection/cameras work and how they are used to safely observe the Sun. Some useful websites are listed, but there are many others that you can explore.

http://users.erols.com/njastro/barry/pages/pinhole.htm

http://www2.eng.cam.ac.uk/~hemh/transit.htm

www.youtube.com/watch?v=KUAnKsW93xU

1. **Design** your own pinhole projection or reflected pinhole projection observatory. The goal is to get a large and good enough projected image of the sun and observe and record some sunspots. You have complete freedom in your design, it can be as simple or as sophisticated as you like, the only requirement is that it is works! Be creative and have fun!
2. **Construct, test, and perfect** your pinhole observatory. You may need to change your initial design and experiment to improve your image of the Sun. Once you are satisfied with your observatory set-up, take pictures of the set up to put in your report. **Include a picture of yourself with the set-up.**
3. **Make and record your own observations** of the Sun. Each student should trace their own projected image of the Sun onto a white piece of paper (you will need this for Part II of the project) and mark any features you see such as Sunspots. Each student should include their own tracing to work with and submit. In addition, you can also take pictures of your image with a digital camera or record your projection directly on film.

**Report Part I:**

Your final report should include:

* A brief description of how pinhole projection works and produces an image (Methods/Procedures)
* Diagrams of your initial design
* A description of what you did
* A discussion of any changes you made to your initial design and the outcome of these changes
* Pictures of your final observatory set up, including a picture of yourself with the set up.
* Presentation and description of your resulting observations of the Sun

# **II. Observing the Sun**

For part II, use your pinhole camera to safely observe and document the sun.

1. Use your pinhole observatory to observe a projected image of the Sun. Tape a graph paper to your projection screen (1 mm grid will be better) and trace the bright image of the sun (you can use the images you made earlier).
2. Mark any features you see such as Sunspots in one of the images. You can also take pictures of your image with a digital camera or record your projection directly on film, but this has to be in addition to the hand drawn images.
3. **Take at least 3 measurements** of the diameter of these solar images in the direction (a) going up & down and then (b) going left to right.
4. **Take at least 3 measurements** of the distance from the pinhole to the sheet of paper.
5. Calculate the average diameter of the image and average distance and corresponding errors.
6. Include the date of the observations.

**Report Part II:**

Your final report should include:

* Own tracing of the image (including date of observation)
* All measurements of the diameter of the Sun across both directions
* All measurements of the distance from the pinhole to the projected image
* Average diameter of the image and average distance and corresponding errors.

# **III. Determining the Size and Luminosity of the Sun**

Now that you have recorded an image of the Sun and measured the image’s diameter and distance from pinhole to image, let’s investigate some solar properties.

The physical size of the Sun is a fundamental property and is related to the temperature and luminosity (energy output) of the star. If we assume the distance to the Sun to be 1 A.U. (1.5 x 108 km), then we can use a measurement of the angular diameter of the Sun to determine its physical diameter by simple geometry.

## A. Determining the Size of the Sun Using Ratios

To determine the diameter of the Sun (H) using ratios, the distance to the Sun (D) has to be obtained by some other method. For a pinhole projection, the relationship between the object size, the object distance, and the distance from pinhole to projection is simple:

**Eqn. 1**

where H = size of the object,

D = distance from the pinhole camera aperture to the object

h = diameter of the object’s image in the projection,

d = distance from the pinhole camera aperture to the image projection surface.



**Figure 1**

Using your values for D, average h, and d, calculate the diameter of the Sun. Carefully show the setup and all of your work. Make sure all of your numbers are in meters, and your answer is in scientific notation rounded to two decimal places.

## B. Determine the Sun’s angular size

We can use trigonometry and the very simple geometry shown below to calculate the angular size, A, of the Sun.



**Figure 2**

Using **Figure 2**, calculate the angular size of the Sun on the day of your observations.

Note: Because the orbit of the Earth is not a perfect ellipse, our distance to the Sun changes throughout the year, and, as a result, its angular size will also change. Calculating the angular size of the Sun throughout the year, can let us estimate the Earth’s eccentricity.

## C. Calculate the Luminosity of the Sun

Determine the Luminosity of the Sun using the Stefan-Boltzman Law assuming an effective temperature for the Sun of 5780 K. Include errors on your estimate.

**Report Part III**

Your final report should include:

* Calculation of the solar diameter (show all your work, including any diagrams you used)
* Calculation of the angular size of the Sun (show all your work). Include the day of your observation.
* Calculation of solar luminosity. Including errors

# **IV. Determine Rotation Period of the Sun**

The Sun rotates about its own axis as does the Earth and most astronomical objects. Unlike the Earth, the Sun is not a solid object. Therefore, the Sun exhibits differential rotation – different parts of the Sun rotate at different rates. This differential rotation plays an important role in the generation of magnetic fields and sunspots.

We can trace the differential rotation by observing the motion of sunspots located at different latitudes. For this part of the project, you estimate the rotation rate of the Sun for at least two different latitudes and compare them. You can obtain your own observations from your pinhole observatory (however, this year, the sun is close to a minimum of activity and sunspots are rarely seen) or you can obtain archival images of the Sun and its sunspots from either the Soho or Solar Dynamic Observatory online.

1. What you need:
   1. Observations of the sun and sunspots, over a 10 to 20 day period, either taken by you or obtained from one of the following websites:
      1. Solar Dynamic Observatory: https://sdo.gsfc.nasa.gov/data/ - use one of the HMI Intensitygram images (browse data)
      2. SOHO:
         1. [https://soho.nascom.nasa.gov/sunspots/](about:blank)
         2. [https://sohowww.nascom.nasa.gov/data/synoptic/sunspots\_earth/](about:blank)

Note: The SOHO site above is nice because they label the sunspots, making them easier to track. The times the observations were taken are not listed however. You can assume that they were taken at the same time each day.

* 1. Appropriate Solar, Stonyhurst grid – found at:
     1. [http://solar-center.stanford.edu/solar-images/latlong.html](about:blank)

1. Analysis
   1. Find at least two (if possible) prominent (large) sunspots, preferably at differing latitudes. The sunspots should be close to the left edge of the image, so you can track them as they move across the Sun. You should follow these spots over a 10 to 20 day period, getting observations at least every other day.
   2. For each spot, estimate the location (longitude and latitude) of the spots on the sun by using the solar grid, scaled to match the size of the sun on your image. Don’t forget to also record the date and time of each solar observation.
   3. For each individual sunspot, construct a plot of longitude (y-axis from -90 to 90) versus increasing time (in units of days –i.e. first observation at 11:30 would be 11.5/24 or .48 days and the next day’s observation at 12 would be 1.5 days). Note: if measurements are good, the data points should trace close to a straight line.
   4. Measure the slope of the line for each spot.
   5. Estimate the rotation period from the slopes.
   6. Compare rotation periods for the individual spots.
   7. Compare what you found to what is known in the literature about the rotation of the Sun.

**Report Part IV**

Your final report should include:

* A figure of the images or observations used. Make sure you identify the sunspots you used for your measurements in the images.
* A table of all your measurements.
* Graphs of longitude versus time for each spot used.
* Your calculations.
* A Results table with slopes and resulting rotation period for each latitude.
* A discussion of your uncertainties and errors.
* Comparison of your results for the different latitudes and brief discussion of what this means. Is this what you expected?
* Discuss how your results compare to what is known about the Sun and if your results are different from what was expected, discuss why that may be.

**Grading Rubric**

This project should be formatted more or less like a proper report. For sections 2 and 3, you won’t need to include a lot of text, but for sections 1 and 4, the discussions and descriptions should be presented in full sentences and paragraphs. Putting measurements (for example, those in section 2) into tables is generally the simplest way to present a set of values. If you have further questions on formatting, contact your TA.

Part I. Build a pinhole camera [*20 points*]

* A brief description of how pinhole projection works and produces an image
* Diagram of your initial design, and a description of the construction process
* A discussion of any changes you made to your initial design, and the outcome of these changes; if you did not need to make any modifications, comment on what you think made your design successful
* Picture(s) of your final observatory set up, including one of yourself with your set up
* Presentation and description of your resulting observations of the Sun

Part II. Observe the Sun [*25 points*]

* Tracing of the projected image (including date of observation)
* All measurements of the diameter of the Sun across both directions (3 vertical, 3 horizontal measurements; 6 total)
* All measurements of the distance from the pinhole to the projected image (3 measurements)
* Average diameter of the image (combine vertical and horizontal for a single average value), average distance, and corresponding errors

Part III. Determine the radius and luminosity of the Sun [*25 points*]

* Calculation of the solar diameter (show all your work, including any diagrams you used)
* Calculation of the angular size of the Sun (show all your work). Include the day of your observation.
* Calculation of solar luminosity, including errors

Part IV. Determine the rotation period of the Sun [*30 points*]

* A figure of the images or observations used. Make sure you identify the sunspots you used for your measurements in the images.
* A table of all your measurements.
* Graphs of longitude versus time for each spot used.
* Your calculations.
* A **Results** table with slopes and resulting rotation period for each latitude.
* A discussion of your uncertainties and errors.
* Comparison of your results for the different latitudes and brief discussion of what this means. Is this what you expected?
* Discuss how your results compare to what is known about the Sun and if your results are different from what was expected, discuss why that may be.