EXPLORING THE SUN

What will you learn in this Lab?

You will learn the difference between synodic and sidereal rotation periods on the Sun. You will also examine the differential rotation of the Sun and examine coronal mass ejections.

What do I need to bring to the Class with me to do this Lab?

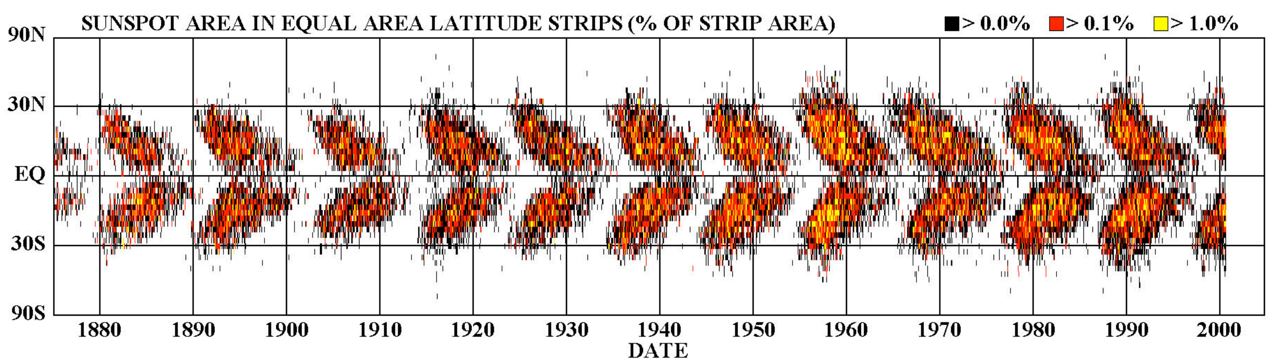
For this lab you will need:

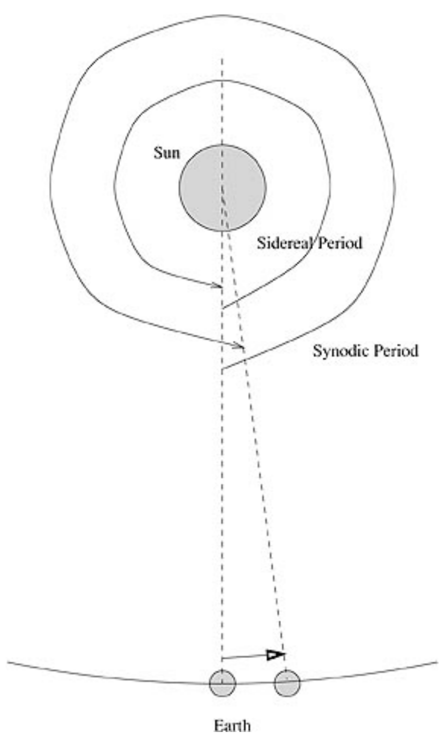
- A copy of this lab script
- A pencil (a colored pencil will be provided)
- A scientific calculator
- Compasses will also be provided by the instructor
- Your two solar observations

Introduction:

The purpose of this exercise is to observe the Sun and some of its visible features. You will determine both the synodic and sidereal rotation periods of the Sun. You will also look at the Sun's differential rotation.

The most noticeable solar surface features are sunspots. They were discovered telescopically by Galileo in 1611 and there are earlier references to them in Chinese records. We will observe them in a safe manner by projecting the image of the Sun. Individual sunspots can last 1 to 100 days and typical large sunspot groups are visible for a month. The sunspots go through an 11-year cycle. This cycle has two aspects. First the number of sunspots changes. Early in the cycle there are few or no sunspots. As the cycle gets closer to 11 years of age there are more and more sunspots. Second, at the beginning of the cycle, sunspots appear at middle latitudes and as the cycle ages toward solar maximum the sunspots move closer to the equator (see butterfly diagram in most astronomy text books).





The Sun does not rotate as a solid body. It undergoes what is called **differential rotation**. It rotates at a different rate near the center than at higher latitudes. This is simply due to the Sun lacking a solid surface. For reference, the **synodic period** of the Sun is defined as being the length of time it takes for the same feature to rotate all the way around the Sun, and return to the same place on the disk of the Sun as seen from the Earth. The **sidereal rotation period** of the Sun is defined as being the time it takes the Sun to rotate once on its axis relative to the stars (i.e. 360º). The two times are **not** the same since the Earth moves on in its orbit during a solar rotation, so our point of view changes.

The Sun does not just give light out into the solar system, but particles are constantly emitted. Sometimes the particle emissions occur in a violent fashion called a Coronal Mass Ejection. It is these events that cause the most spectacular aurorae, which occasionally knock out power and disrupt satellites and communication here at Earth.

PART I: Visual Observations

Observations:

The first part of this lab involves two observations to be taken during the day with the ASU “solar” telescope. One of the 8 in telescopes will have a solar projection screen located 40cm behind the eyepiece. This will enlarge the image and provide an opportunity to view the solar image in an INDIRECT manner. Using ONLY this special equipment, you will make a drawing of sunspots on two different days, 4 days apart.

To make your first observation:

a) Mount your solar drawing paper (page **6**) with paperclips on the inside of the projection screen. Focus the telescope so that the solar image (primarily the edge of the Sun) appears sharp. Mark N and E on your drawing so that you can determine the orientation of the drawing for your second observation as well as the direction of sunspot motion. A TA will be there to help you with any questions you have.

b) Draw the outline of the Sun and ALL visible sunspots. Look especially carefully at the limb of the Sun for sunspots that have just rotated into view.

c) Record both the time and date and have the TA initial your observation.

4 days later:

d) Make a second observation using the same observing sheet – use a <u>different</u> colored pencil.

Now that you have two observation of the position of sunspots you can determine the synodic period of the Sun and the direction of solar rotation. You will use a graphical method to determine the angle through which the sunspots moved across the Sun during your observations

a) Mark all sunspot groups and determine which groups were observed on both days.

b) Choose your best sunspot group that appeared on both days of your observations. Draw a line connecting the two sunspot groups. This line will be a line of constant solar latitude. Using this line, you will determine the true orientation of the solar latitude and longitude (i.e. where true solar N, S, E and W are).

c) You will now bisect the chord you have drawn connecting your sunspots – i.e. bisect the line that passes through your sunspots where it crosses the solar limbs. This bisecting line is the N/S line of the Sun.

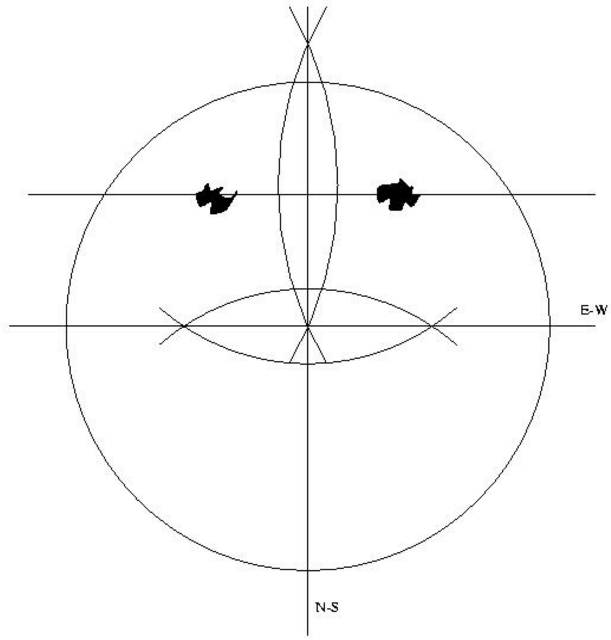


Figure 1 – How to determine the N-S and E-W lines from your observations

d) Bisecting, again, the N/S line will show you the solar equator's location.

e) You will use Figure 2 to find the angular distance each sunspot has moved between the two observations. Overlay this equatorial projection of the Sun by aligning it with your determination of the longitude and latitude system. Determine the latitude and longitude of each of the sunspot groups you saw, and the change in longitude between the two observations. From the longitude change what is the synodic period of the Sun? Why have we determined the synodic and not the sidereal period?

FYI the known synodic period of the Sun ranges from 26.87 days at the equator to 29.65 days at a latitude of 40º.

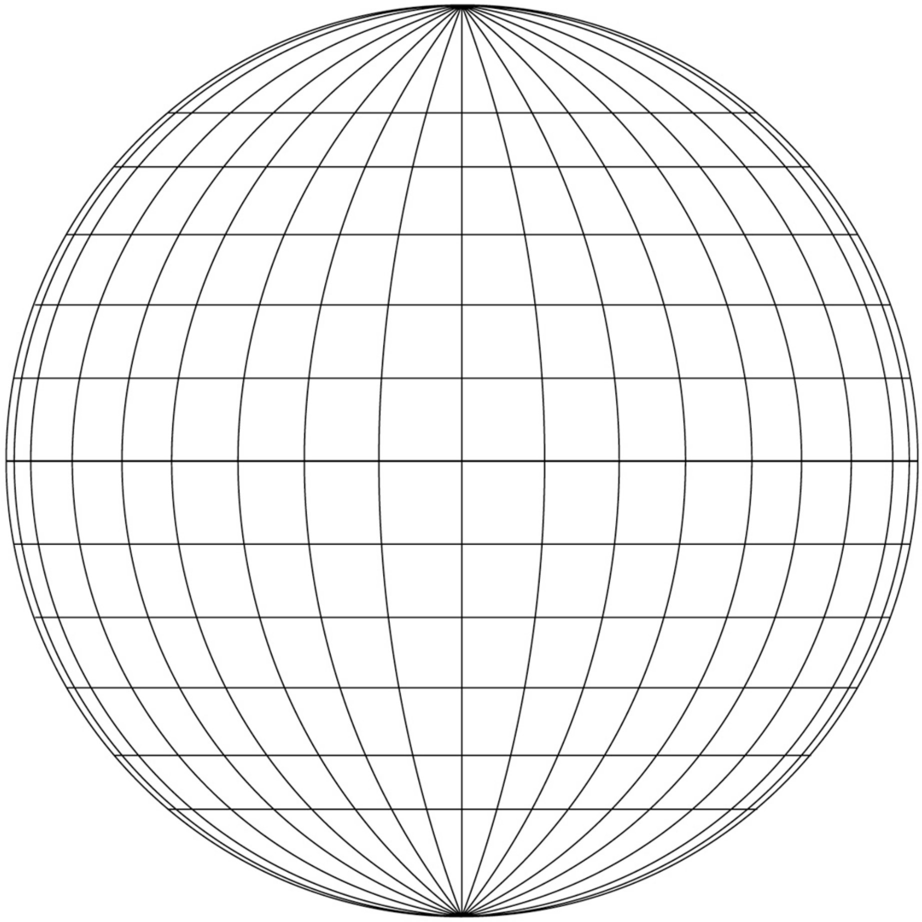


Figure 2 – latitude and longitude grid to use for your observations. Each line is 10º apart from its neighbor

f) How would you determine the sidereal period of the Sun? Determine the sidereal period of the Sun. How far from the known sidereal period at that latitude is your answer?

The sidereal period of the Sun ranges from 24.97 days at the equator to 27.75 days at a latitude of 40º.

Observations of Sunspot Positions

Name: ____________________

Date: Obs #1 ____________________

Time: Obs #1 ____________________

Date: Obs #2 ____________________

Time: Obs #2 ____________________

Outline the image of the Sun
Draw all of the sunspots you see
Indicate North and East on your drawing
Use a different color pencil for the 2nd observation

TA verification: Obs #1 ____________________ Obs #2 ____________________

PART II. Sunspot structure and limb darkening

In this part of the lab exercise you will be looking at 2 regions of the Sun with to telescopes that have been fitted with a Mylar solar filter. It is safe to look through the eyepiece when such a filter is in use. Using a pencil draw what you see in the field of view on the circles below. (Note: the circle you see represent the entire field of view. If you think an area of the Sun is darker then use your pencil to shade the darker area.)

Sunspot drawing

Limb drawing

Questions:
These questions should be addressed in your lab report for this lab.

1. How much did the sunspots move?

2. Did the sunspots change shape or orientation?

3. Did they move parallel to each other? If so, why would you expect this?

4. What are the sidereal and synodic periods of the Sun?

5. How is sunspot latitude related to rotation period of the Sun?

6. Measure the size of a sunspot (in cm) with a ruler (using the drawing on page 6). The diameter of the Sun is 1,391,000 km and the scale of you drawing is 114,959 km/cm. How big are sunspots?

7. How big are sunspots compared to Earth? The diameter of Earth is 12,756.2 km.

CONCLUSION:

INDOOR ALTERNATIVE (in case of cloudy weather).

Provided Observations

This part should only be done in the event of bad weather or a lack of daytime observations.

Introduction:

In this part of the lab exercise you will use a photograph to determine the synodic and sidereal period of Sun. You will also determine how the rotation period of the Sun changes with latitude. Finally you will measure the motion of a coronal mass ejection. The data provided is from the SOHO (Solar and Heliospheric Observatory) satellite that has been imaging the Sun daily since 1995.

Sunspot Measurements.

a) Using the two images of the Sun and the solar grid provided determine the latitude and longitude of each of the group of spots on the Sun in a method similar to that used in Part I.

b) Calculate the synodic and sidereal periods of the Sun for each of the sunspot groups.

c) Plot the sidereal period of the Sun as a function of latitude. Is there a correlation? Does the Sun appear to rotate differentially?

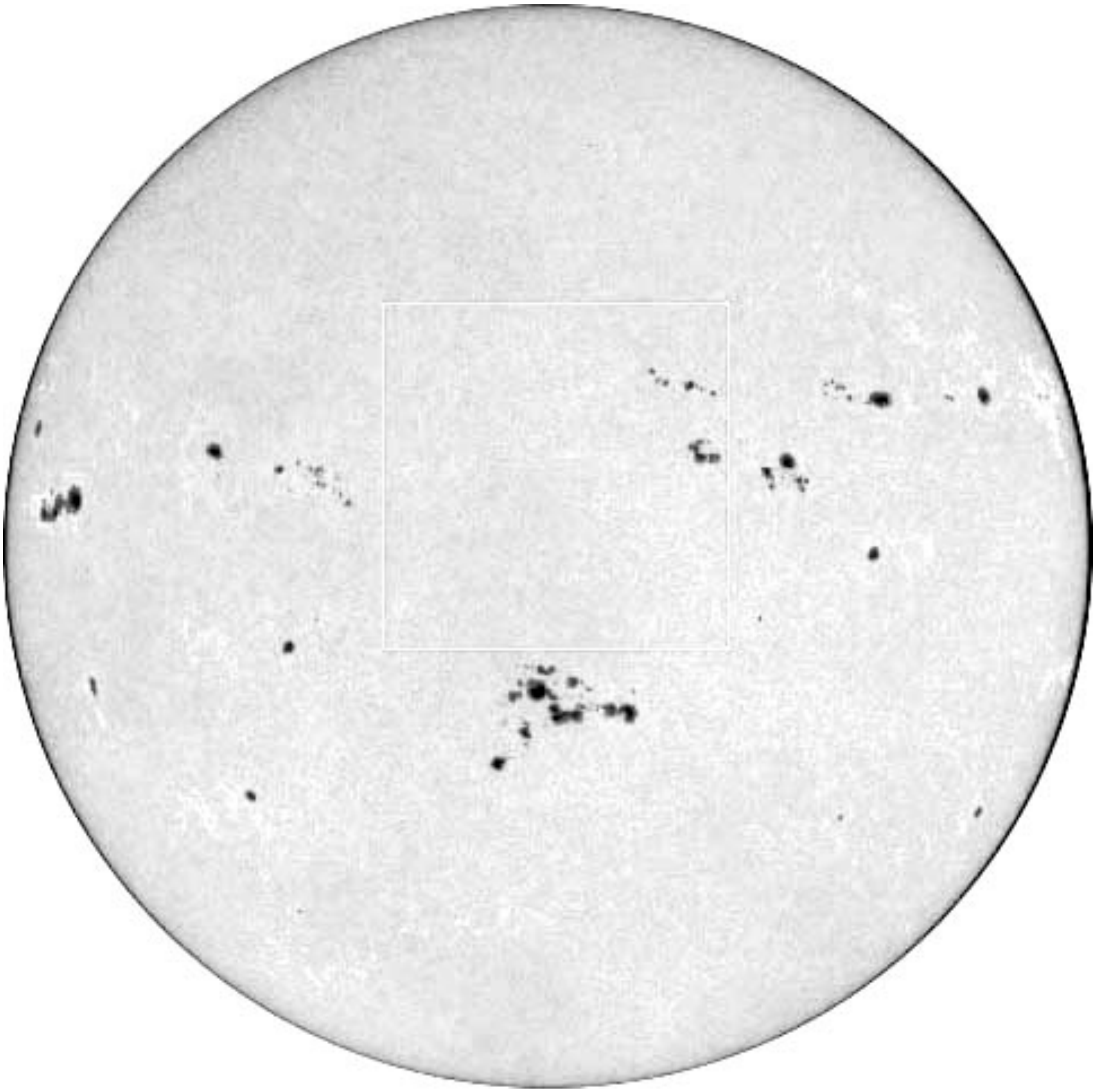


Figure 3 – First SOHO observation – made July 20, 2000 at 1:36 UT

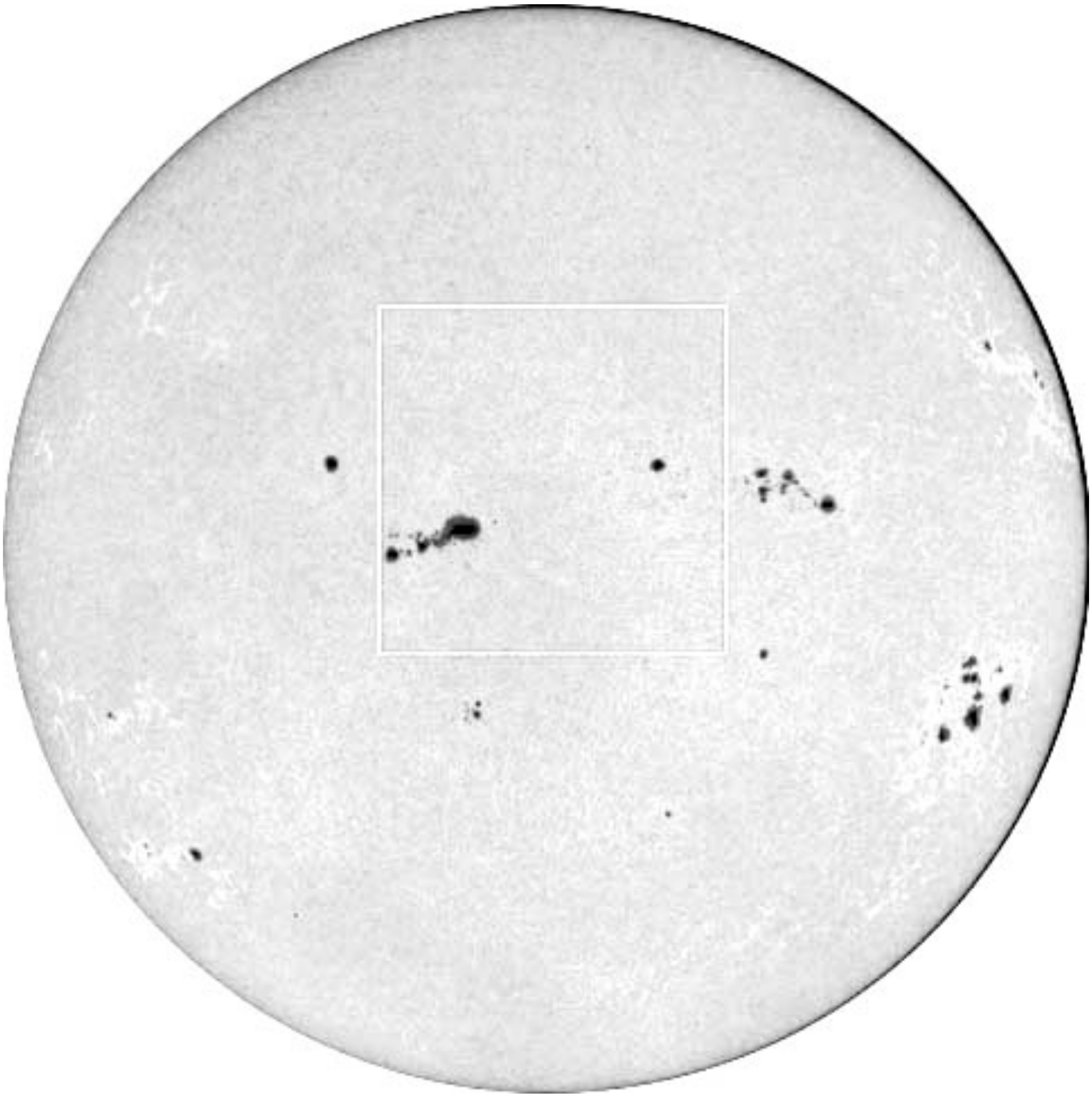


Figure 4 – second SOHO observation – made July 24, 2000 at 0:00 UT

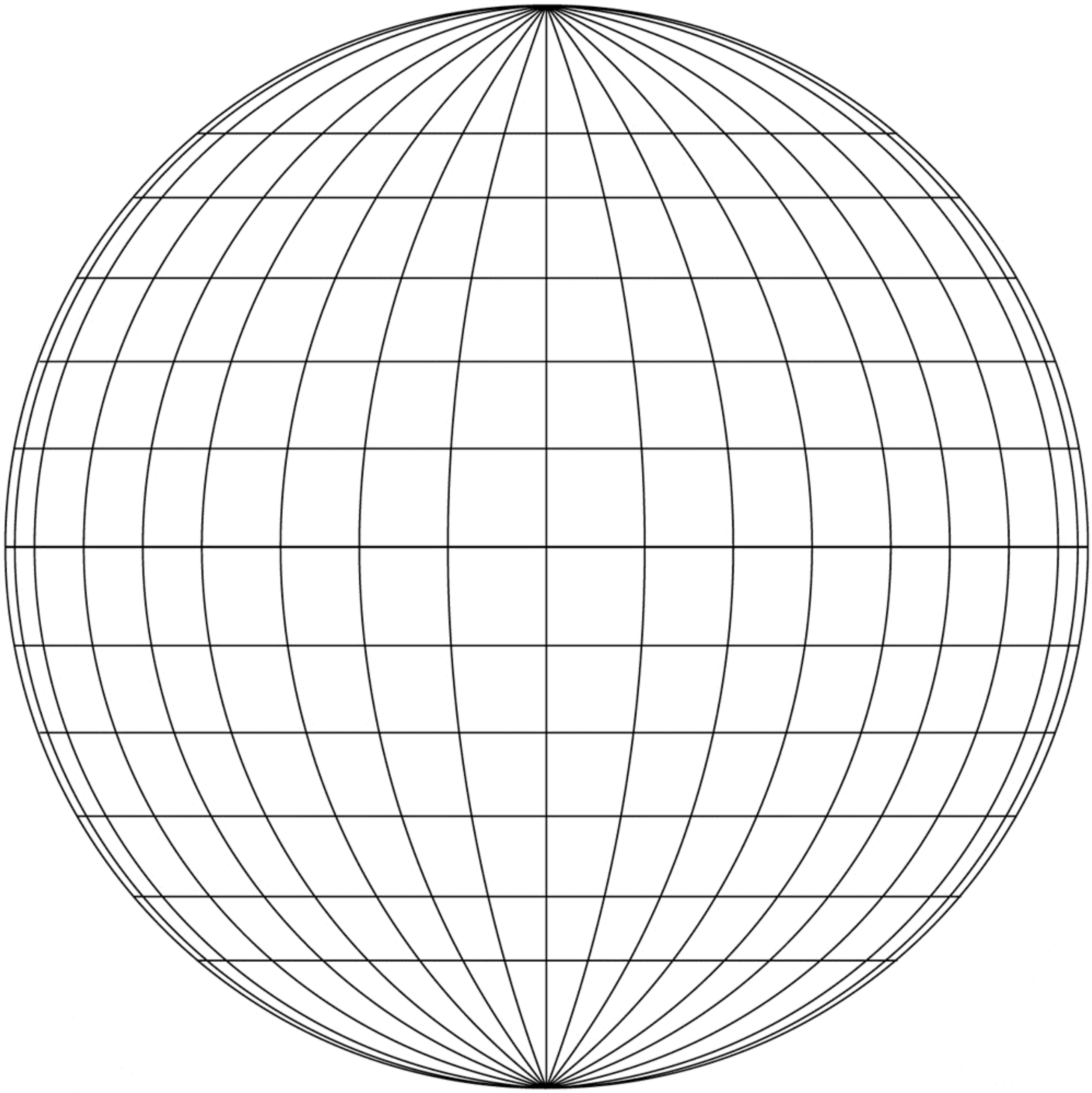


Figure 5 – latitude/longitude grid for use with SOHO data