# Exploring the Sun's Shape with SunSketcher

## HIGH SCHOOL LESSON PLAN

### High School NGSS (Next Generation Science Standards)

HS-ESS1-3: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

### TARGET LEARNING OBJECTIVES

I can articulate the significance of precise recording of Baily's Beads timings and GPS locations as part of scientific observations, demonstrating an understanding of how this data contributes to the mathematical predictions of the Sun's shape and internal dynamics.

### OBJECTIVES

1. Understand the scientific significance of studying the shape of the Sun.
2. Introduce the SunSketcher project and its goal of involving the public in solar science.
3. Familiarize students with the Baily's Beads phenomenon and its connection to solar astrometry.
4. Encourage participation in the SunSketcher project to contribute observations for scientific research.

### MATERIALS

1. Projector or whiteboard for presentations.
2. Handouts with relevant information.
3. SunSketcher website access: sunsketcher.org
4. SunSketcher app download instructions: sunsketcher.org/download.php
5. Diagrams or visuals of Baily's Beads and solar eclipse.
6. Shapes printed and cut out from the template sheet (see next page). Each student will need the template.
7. Worksheets printed/provided for each student.

# Exploring the Sun's Shape with SunSketcher

## TEMPLATE SHEET

**Oblate Sun**

**Circular Sun**

**Moon**

**Moon**

*Cut the two Moon circles out and set them on top of each other. Hold them together with a couple of paper clips. Then use scissors around the edges to make a matching set of Moons, each with the same set of "mountains" and "valleys."*

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## ABOUT THIS LESSON PLAN

Most eclipse resources will tell you that when an eclipse happens, the disk of the Moon passes in front of the Sun, progressively "eating away" at the disk of sunlight. The eclipse starts as a small "bite" out of the Sun and then advances across the disk of the Sun until only a crescent of sunlight remains, before even that disappears behind the Moon.

If the Moon were a perfect sphere, this would all be exactly true. But the Moon is not perfectly round. It has high mountains and deep valleys, so that what happens just before the Sun is totally obscured by the Moon is more accurately described as follows:

1. Only a thin crescent of sunlight remains;
2. The highest mountains at the lunar limb penetrate the crescent, creating dark gaps in the bright crescent of sunlight;
3. As more and more of the lunar mountains obscure the Sun, the dark gaps in the crescent get bigger, until all that is left is a series of bright dots, where the sunlight is passing through the lowest valleys in between the mountains. These bright dots of sunlight are called "Baily's Beads," after Francis Baily, who discovered them during an eclipse in 1836. They typically last only a few seconds
4. When the bottom of the deepest valley finally makes it to the edge of the Sun, the last Baily's Bead creates a "diamond ring" effect, and then the eclipse enters its totality phase.

In this hands-on exercise, your students will use a model of the lunar disk, complete with mountains and valleys, to show how studying the pattern and timing of the Baily's Beads can reveal the exact shape of the Sun.

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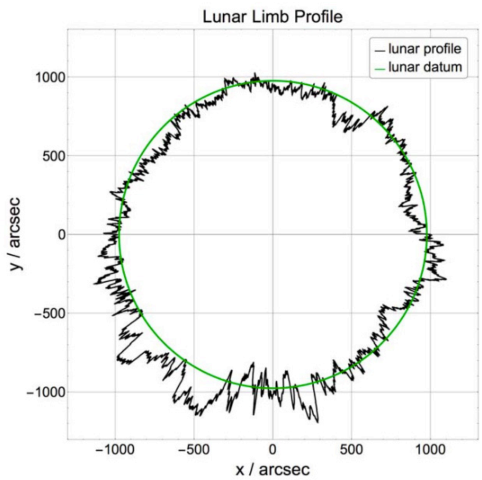
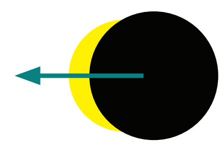
## CLASS DIRECTIONS

1. Create a "lunar landscape" by making small cutouts around the edge of the black disk. These cutouts should range in depth from a millimeter to a few millimeters. They can be sharp nicks (a valley surrounded by steep mountains) or more gradually tapered (an extended shallow valley). They can even mimic crater walls and valleys; be creative. (You can have the students do the actual cutting, or you can use pre-prepared "lunar topographies" that you make in advance).

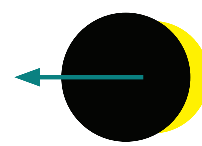



The diagram (Lunar Limb Profile, left) shows an example of the actual topography of the lunar limb (which varies with time and position of the observer); the attached sheet shows an example of a lunar limb profile during an earlier solar eclipse on 16 February, 1999. In these figures the sizes of the mountains and valleys are greatly exaggerated relative to those on the actual Moon, of course, but they are an excellent guide to how to prepare your own "lunar landscape" using the black disk on the template.

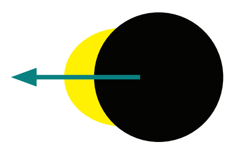
2. Tape the circular "Sun" on a flat surface, and then slowly slide the black disk across it to simulate a total eclipse. Observed the pattern of yellow cardboard (Baily's Beads) at the leading edge of the black disk just before the "Sun" is completely covered by the "Moon."



3. Continue moving the black disk across the yellow one until yellow "flashes" appear at the *trailing* edge of the black disk, signifying the end of the totality phase. Observe as these beads gradually coalesce into a crescent of yellow "sunlight."



4. Then rotate the black disk (so that different parts of the disk form the leading and trailing edges) and repeat the experiment. Notice how the pattern of "beads" is different, reflecting the different lunar topography that penetrates the crescent of sunlight. Try this for a variety of orientations of the lunar disk.
5. Now repeat the experiment using the "oblate" yellow disk to represent the Sun. Notice how the crescent shape and (more importantly) the pattern and duration of the various beads is a lot different than for the circular "Sun."



Discuss with your students how the location and timing of the "beads," together with knowledge of the shape of the lunar valleys and mountains, would allow you to determine the exact shape of the Sun.

This is the way that the SunSketcher app works: it will use precise timing of the Baily's Bead flashes, measured by ordinary smartphones located all along the April 8, 2024 eclipse path to determine the precise shape of the Sun. This shape provides a probe into the nature of the flows of gas within the solar interior.

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## STUDENT WORKSHEET

### INSTRUCTIONS

Place the Moon disks so that their leading edges are just touching the edge of their respective Suns. Do you see any Baily's Beads? How many for each case (Circular vs. Oblate Sun)? Keep sliding the two Moons over their respective Suns and complete several entries in the following table, one for each position of the Moon. Count the number of distinct beads in each case and also measure the size of the largest bead showing (example entries have been filled in for you).

| | CIRCULAR SUN | OBLATE SUN |
|---|---|---|
| *EXAMPLE ENTRY* | | |
| Number of Baily's Beads Visible | 8 | 5 |
| Largest Bead Visible (mm) | 3 | 1 |
| | MOON POSITION 1 | |
| Number of Baily's Beads Visible | | |
| Largest Bead Visible (mm) | | |
| | MOON POSITION 2 | |
| Number of Baily's Beads Visible | | |
| Largest Bead Visible (mm) | | |
| | MOON POSITION 3 | |
| Number of Baily's Beads Visible | | |
| Largest Bead Visible (mm) | | |
| | MOON POSITION 4 | |
| Number of Baily's Beads Visible | | |
| Largest Bead Visible (mm) | | |
| | MOON POSITION 5 | |
| Number of Baily's Beads Visible | | |
| Largest Bead Visible (mm) | | |

# Exploring the Sun's Shape with SunSketcher

## STUDENT WORKSHEET

### REFLECTION

How does the table help you understand how SunSketcher data will help scientists determine the shape of the Sun?

### HOMEWORK ASSIGNMENT

1. Download the SunSketcher app; available for free on both iOS and Android: sunsketcher.org/download.php
2. Familiarize yourself with the app and its feature. Take a screenshot of the app.
3. Create a plan for using the app during the eclipse. Encourage your friends and family to use the app as well, and explain to people why these efforts are valuable to science.
4. Share your results with the class!

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## LESSON CONCLUSION

### Q&A AND CLARIFICATIONS

Address any questions or concerns from the students regarding the SunSketcher project, solar astrometry, citizen science or the upcoming eclipse.

### CONCLUSION AND CALL TO ACTION

Summarize the key points discussed during the lesson.

Emphasize the importance of citizen involvement in scientific projects like SunSketcher.

Encourage students to participate actively in the SunSketcher project during the upcoming solar eclipse.

### ASSESSMENT

1. Participation in class discussion.
2. Understanding demonstrated during the hands-on activity.
3. Submission of worksheet.
4. Completion of the homework assignment.

**Note:** Adjust the timings as needed based on the specific needs of your class.

# Annular Solar Eclipse of 1999 Feb 16

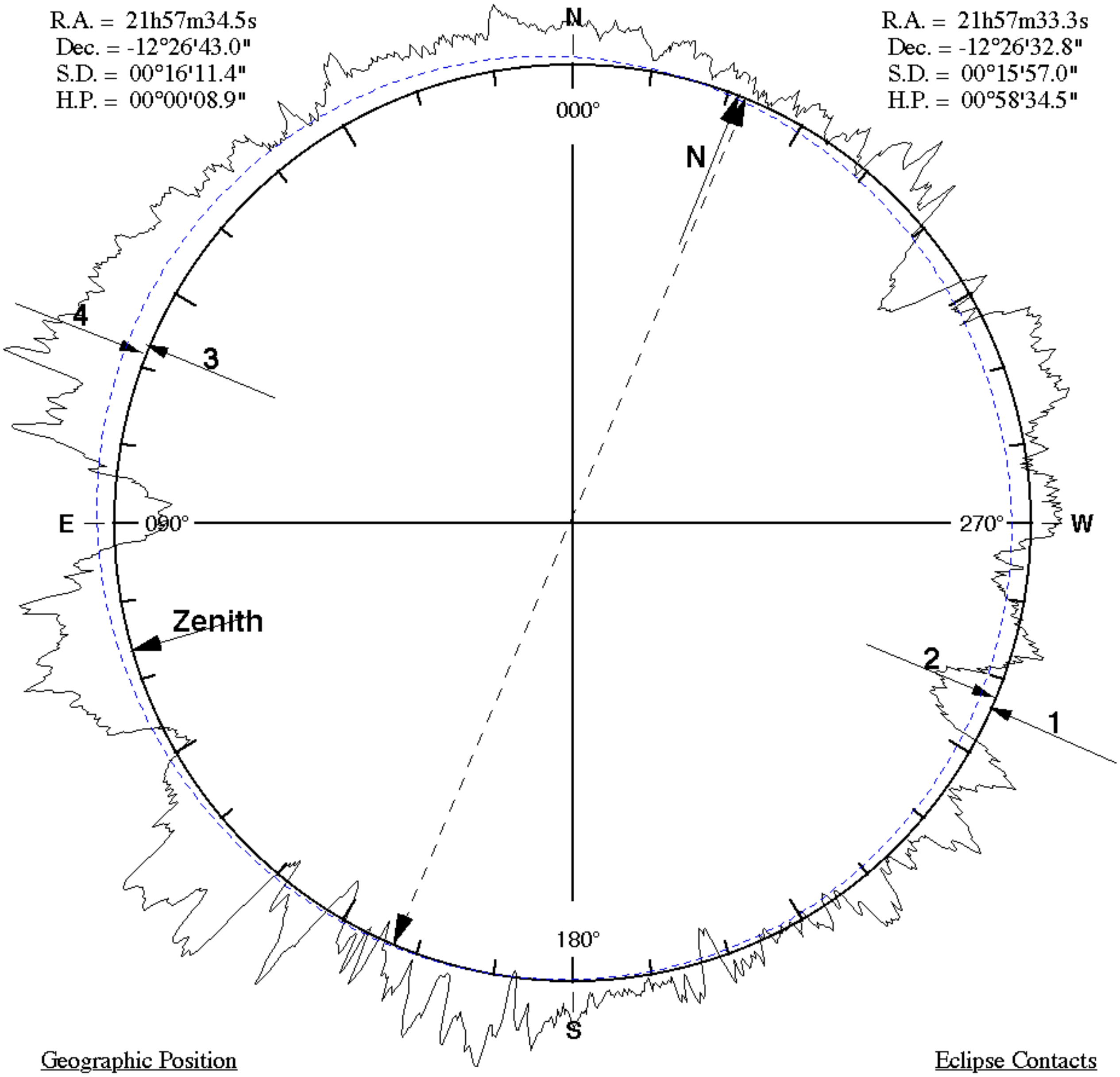
Maximum Eclipse = 08:00:00.0 UT

**Sun at Maximum Eclipse**
(Topocentric Coordinates)

R.A. = 21h57m34.5s
Dec. = -12°26'43.0"
S.D. = 00°16'11.4"
H.P. = 00°00'08.9"

**Moon at Maximum Eclipse**
(Topocentric Coordinates)

R.A. = 21h57m33.3s
Dec. = -12°26'32.8"
S.D. = 00°15'57.0"
H.P. = 00°58'34.5"




**Geographic Position**

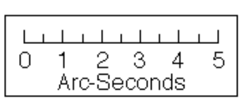
Name = Center Line at 08:00:00.
Lat. = 19°57'39.6"S
Long. = 133°26'27.3"E
Elev. = 0.0 m

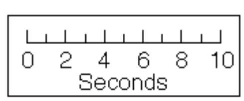
**Ephemeris & Constants**

Eph. = DE200/LE200
ΔT = 63.5 s
k1 = 0.2725076
k2 = 0.2722810
Δb = 0.00" Δl = 0.00"
Δb´ = -0.06" Δl´ = 0.55"

**Local Circumstances at Maximum Eclipse**

Sun Alt. = 22.9° Path Width = 64.4 km
Sun Azm. = 264.5° Duration = 01m01.0s
PA(N.Limit) = 157.4° A.Vel. (M:S) = 0.472"/s




*F. Espenak, NASA/GSFC - 1999, Jan 20,*

**Eclipse Contacts**

C1 = 06:46:53.0 UT
C2 = 07:59:29.5 UT
C3 = 08:00:30.6 UT
C4 = 09:04:06.5 UT
ΔC2 = 3.3s ΔC3 = -8.4s

**Topocentric Libration**
(Optical + Physical)

l = -5.68°
b = 0.10°
c = -21.55°

cor.C2 = 07:59:32.8 UT ( 3.3s) cor.C3 = 08:00:22.1 UT ( -8.4s)