SOLAR SCIENCE

EXPLORING SUNSPOTS, SEASONS, ECLIPSES, AND MORE

Dennis Schatz
Andrew Fraknoi

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Dedication

To Alan J. Friedman, good friend, colleague, and mentor, who inspired everyone he met to remember that science is a way of thinking, not a list of facts.

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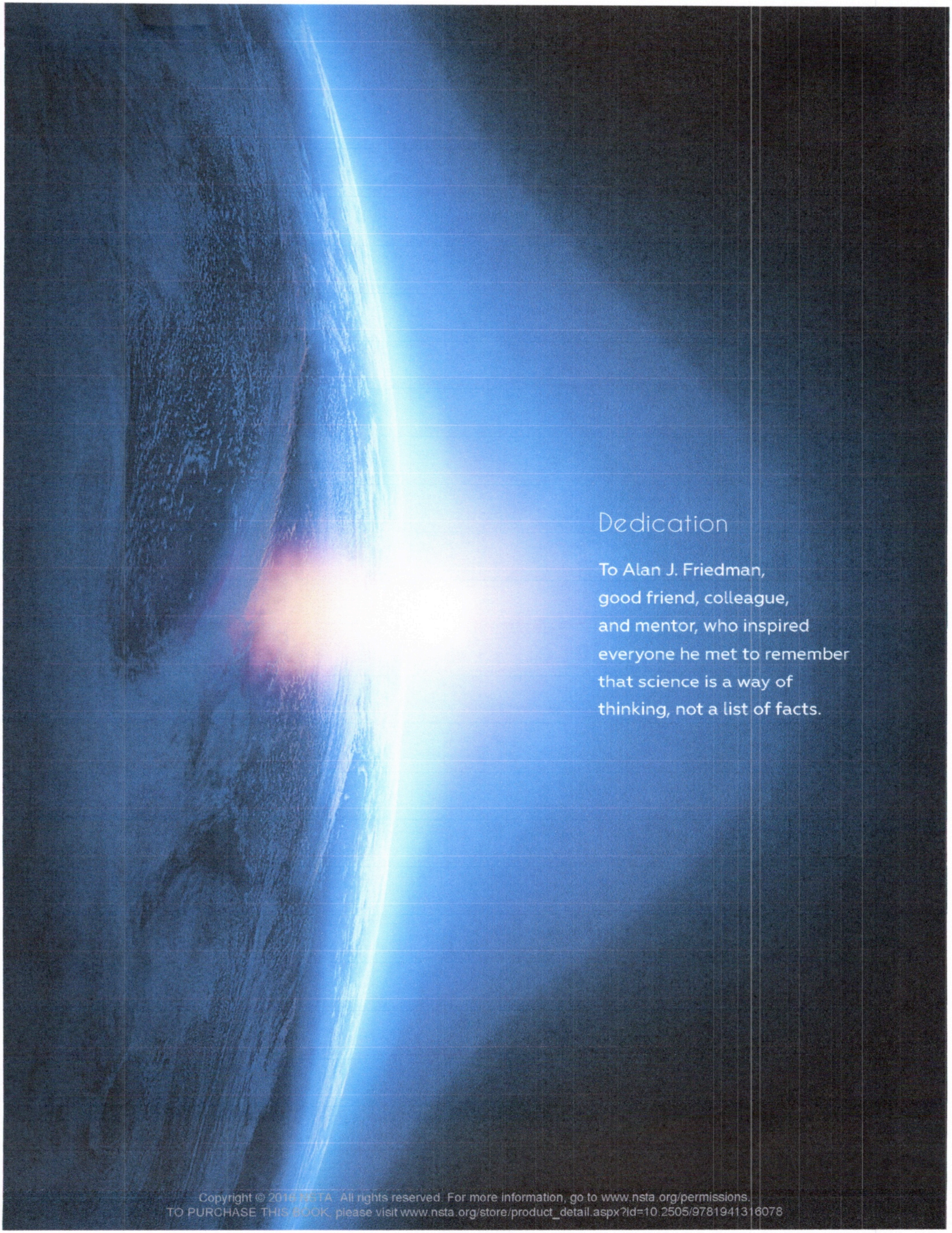

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About the Authors

Dennis Schatz is the author of numerous resources for educators and museum professionals, including *Astro Adventures: An Upper Elementary Curriculum* (Pacific Science Center 2002) and *Astro Adventures II* (Pacific Science Center 2003). He is also the author of 23 science books for children that have all together sold almost 2 million copies worldwide and have been translated into 23 languages. These include *Astronomy Activity Book* (Simon and Schuster 1991) and *Stars and Planets* (SmartLab Toys 2004).

Dennis was a member of the five-person design team that developed the Earth and space sciences disciplinary core ideas for the National Research Council that are found in *A Framework for K–12 Science Education*, which was used to develop the *Next Generation Science Standards*.

For many years, Dennis was the senior vice president for strategic programs at the Pacific Science Center in Seattle, Washington. For four years he served as a program director for science education at the National Science Foundation. At the Pacific Science Center, he codirected Washington State LASER (Leadership and Assistance for Science Education Reform), a program to implement a quality K–12 science program in all 295 school districts in Washington State. He was also principal investigator for Portal to the Public, an initiative to develop programs—both on-site and off—that engage scientists in working with diverse audiences to enhance the public's understanding of current science research.

He has received numerous honors, including several from the National Science Teachers Association (NSTA): the 2009 Faraday Science Communicator Award, the 2005 Distinguished Service to Science Education Award, the 1996 Distinguished Informal Science Education Award, and the 1980 Ohaus Honorary Award for Innovations in Science Teaching.

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Andrew Fraknoi is the author of *Disney's Wonderful World of Space* (an astronomy book for grades 5–7) and is the lead author of several successful introductory astronomy textbooks for nonscience majors (such as *Voyages Through the Universe*, 3rd ed., published in 2004 by Brooks-Cole/Cengage). In the 1980s, he also edited two books of science and science fiction for Bantam. He is editor and coauthor of *The Universe at Your Fingertips 2.0*, a collection of astronomy activities and teaching resources published by the Astronomical Society of the Pacific that is in use in formal and informal educational institutions around the world.

He is the chair of the astronomy department at Foothill College, Los Altos Hills, California, and appears regularly on local and national radio explaining astronomical developments in everyday language. Fraknoi was the cofounder and coeditor of *Astronomy Education Review*, the online journal and magazine published by the American Astronomical Society. The International Astronomical Union has named Asteroid 4859 Asteroid Fraknoi to recognize his contributions to astronomy education and outreach (but he wants us to mention that it's a very boring asteroid and no threat to the Earth!).

Andrew is the winner of the 2012 Faraday Science Communicator Award from NSTA, as well as the 2007 Andrew Gemant Award from the American Institute of Physics. Also in 2007, he was selected as the California Professor of the Year by the Carnegie Foundation for the Advancement of Teaching. His other awards include the Annenberg Foundation Award for astronomy education from the American Astronomical Society and the Klumpke-Roberts Award for public outreach in astronomy from the Astronomical Society of the Pacific.

For more about Andrew Fraknoi, see *www.foothill.edu/ast/fraknoi.php.*

EXPERIENCE 4.1

Predicting What the Moon Will Look Like

Overall Concept

Students examine and predict the order of six photographs of the Moon that show different phases. Their predictions are then compared to the actual observations students make over the next 10 to 30 days as part of *explore* Experience 4.3, "Observing the Moon."

Objectives

Students will

1. use photos of the Moon to predict the sequence of the Moon's phases based on their prior knowledge,
2. recognize that the Moon's overall appearance changes on a regular cycle,
3. question how and why the Moon's appearance changes, and
4. identify a number of features on the Moon's surface.

Teacher note: Many students—and teachers—think of the Moon as having eight phases (see, for example, Figure 4.14, p. 297). There is not a specific number of phases, since the Moon goes through a continuous change in phase as it slowly shows more of its lit side after its new phase until we see the full Moon. It then shows less and less of its lit side until it gets back to new phase after 29.5 days. The selection of only six photos for this experience rather than eight is to reinforce the idea that there are not eight specific lunar phases. The photos are also oriented in a random pattern to encourage students to look at the features on the Moon to determine "which way is up" when viewing each image. This provides a reason for the students to learn about craters, maria, and rays. For your reference only at this time, the correct order of the images is in Figure 4.15 (p. 299).

MATERIALS

One per group:

- "Six Lunar Photographs, Set 1" (p. 291)
- Blank sheet of paper
- Scissors
- Tape or glue

One per student:

- Astronomy lab notebook

Advance Preparation

Make a copy of the "Six Lunar Photographs, Set 1" handout for each group.

Procedure

1. Tell the students that a teacher colleague of yours (identify by name if desired) had a set of lunar photographs sent to him or her by an amateur astronomer friend. Unfortunately, your colleague dropped the photos on the floor and no longer knows the order or orientation of the photographs. The friend asked for help from you and your class to get them in the correct order. You have made copies of the photos so the students can help with this challenge.
2. Distribute copies of the "Six Lunar Photographs, Set 1" handout, scissors, tape or glue, and a blank sheet of paper to each work group. It is important to use a photocopy machine that will preserve the detail in the photos. The students' goal is to place the photographs on the sheet of paper in the order in which they think they would see the shape of the Moon if they made observations for several weeks. Allow 10 to 15 minutes for discussion and decision making in each group.
3. Once each group is satisfied with the order, students should tape or glue the photos to the blank sheet of paper. Have them number the pictures from 1 to 6 in the order each would be seen. Be sure they indicate which way is up. They should also put their names on the paper to show who made the prediction.
4. When all of the groups have completed their photo sequences, have them move around the room to see the predictions of other groups. Ask the work groups, one by one, to explain their reasoning for choosing the sequence they came up with. These reasons should not yet be judged for appropriateness since the students are only presenting their best guess.
5. Use this discussion as a transition to Experience 4.3, "Observing the Moon," by pointing out that the best way to know the correct order is to observe the Moon over a number of days. The students' predictions should be posted on a wall of the room for ongoing reference during Experience 4.3. Alternatively, one

member of each work group can keep the team's photo sheet in his or her astronomy lab notebook for later reference.

Teacher note: Students will want to be immediately be told the "right" answer for the order of the Moon photographs. It is important not to share the right answer at this point but to use Experience 4.3 as a way for students to discover the correct order for themselves.

6. The discussion in step 4 is also an effective transition to the next *engage* experience, whichlets students think about and express what they already know about lunar phases and eclipses.

Six Lunar Photographs, Set 1

Source:
Fred Espenak,
www.astropixels.com

4.3

EXPLORE

EXPERIENCE 4.3

Observing the Moon

Overall Concept

A major outcome of Experience 4.1, "Predicting How the Moon Will Look," is that students want to know who has the right sequence for the phases of the Moon, so they are motivated to go outside to observe the Moon, which is the focus of this experience. To completely identify the appropriate sequence—and orientation—of the photos, the students need to be able to identify a number of features on the lunar surface, so this activity also allows for a study of lunar craters and maria. (Just a reminder that the word maria means "seas" in Latin and is plural; the singular is mare.)

Objectives

Students will

1. make a daily record of their Moon observations;
2. identify features (e.g., craters, maria) that they see on the lunar surface; and
3. use their observations to develop an understanding of the sequence of lunar phases and the location of a select number of lunar features.

Advance Preparation

Experience 4.1, "Predicting How the Moon Will Look," provides an excellent introduction to this experience, so we suggest you

MATERIALS

For the class:

- A large poster or projection of the "Lunar Map" (p. 300)
- A large poster of the "Lunar Observing Record Chart" (p. 301)

One per group:

- "Six Lunar Photographs, Set 1" (from Experience 4.1, p. 291)
- Predictions of the order of the lunar phases from Experience 4.1, if you did that experience

One per student:

- "Lunar Map" (p. 300)

begin this experience at its conclusion. This experience is ideally started a few days before the Moon is at first quarter. The Moon will be in the western sky in the afternoon and evening, which will allow you to take students outside near the end of the school day to make the first observation together. Some students may not realize that the Moon is often visible in the daytime as well as at night, so you may want to have the students think about the different times of the day they have seen the Moon. This first daytime observation allows you to review with the students what each lunar observation consists of and gets them into the routine of making daily observations either when the entire class can observe together or on their own. With your assistance, students will then be able to use their skills to make nighttime observations in the coming weeks when the Moon is not visible in the daytime sky.

You may also find it useful to provide the students with a chart (see Table 4.5) that tells them when the Moon will be above the horizon for some of the key phases.

If you have multiple classes or cannot take students out near the end of the day to make the observations, you can ask them to do their first Moon observation as homework on the way home or shortly after they get home.

You can easily find when the Moon is near first quarter by looking on a calendar or searching the internet for "phases of the Moon." You can start the experience at any time, but certain phases work better for

TABLE 4.5

Rising and setting times of the Moon during key phases

Moon phase		Approximate rise time	Approximate set time
New Moon	●	Sunrise	Sunset
First quarter	◐	Noon	Midnight
Full Moon	○	Sunset	Sunrise
Third quarter	◑	Midnight	Noon

MATERIALS *(continued)*

- "Lunar Observing Record Chart" (p. 301); you may provide two charts per student if you want them to make observations over a longer period of time
- Pencil
- Clipboard or other firm writing surface
- Astronomy lab notebook
- (*Optional*) Binoculars—some schools may have extra binoculars to lend to students overnight on a rotating basis

making observations during times when students are outside or awake. You should also check the weather reports to help identify a day around first quarter when it is likely to be clear in the afternoon.

We highly recommend that you do this experience yourself a month or two in advance of doing it with the class so that you will be prepared for some of the challenges that students will encounter—primarily bad weather, trying to observe from a location where buildings or trees block the view of the Moon, or looking at the wrong time of day.

Procedure

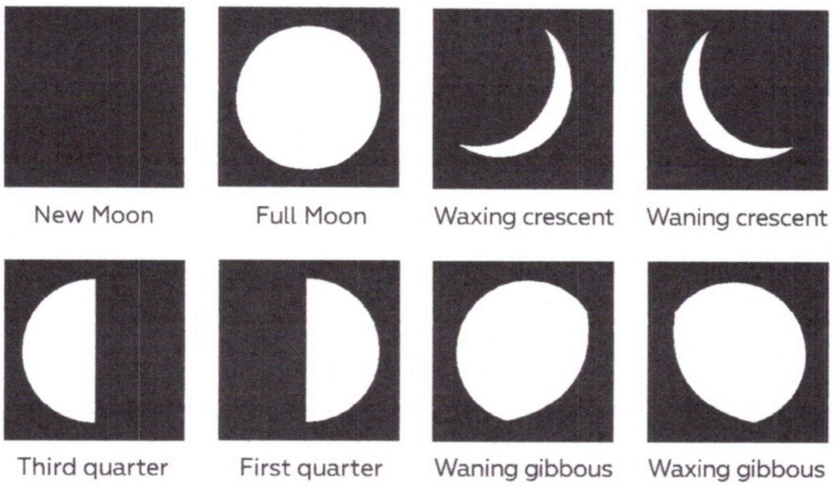
1. Distribute the "Lunar Map" handouts and have students use the maps to identify some key features they should look for when out observing the Moon. These features should be large or noticeable for another reason (e.g., different in coloring), so students can see them with no equipment except their eyes. Ask the students to find the features on the photographs they sequenced in Experience 4.1. This is also a good time to provide more information about craters, maria, rays, and what caused them. See the Content Background section on the surface features of the Moon (pp. 277–279) for more information about these features.

2. Distribute copies of the "Lunar Observing Record Chart." Tell the students they will now have an opportunity to observe the Moon themselves to determine the correct order for the lunar photographs. They will also be able to explore some of the ideas they raised in Experience 4.2, "What Do We Think We Know?" (if you did that experience). This is also a good time to introduce the astronomical vocabulary regarding what we call each phase of the Moon (Figure 4.14).

   Teacher note: Ideally, the students will make observations over an entire month. If time constraints or the weather do not allow the students to observe the Moon for that long, they should be able to begin determining the pattern of the phases after about 10 observations. Observations are not required every day, so some days without observations should be fine. When the weather becomes a problem (clouds for more than two or three days in a row), students can use internet resources to complete their observation charts.

FIGURE 4.14

Names of the phases of the Moon



Websites for finding the current lunar phase include the following:

- Calculator Cat: *www.calculatorcat.com/moon_phases/phasenow.php*
- Calendars Through the Ages: *www.webexhibits.org/calendars/moon.html*
- Moonpage.com: *www.moonpage.com*

3. Explain how the "Lunar Observing Record Chart" is used. This is best done by going outside with the class to locate and make the first observation of the Moon together. Bring a pair of binoculars with you if you have one so that students can get a better look at some of the surface features, which are often difficult to see in the daytime. Record the date, the time of the observation, the Moon's location in the sky, and its shape. Add small drawings that show the shape and location of lunar features that can be identified from the lunar map.

   Teacher note: When the Moon is in a crescent or quarter phase, it can often be difficult to be sure which feature is being seen. Tell the students to make their best guess and then follow the feature during the coming days as they make observations.

The key features will become obvious as the Moon approaches full Moon.

4. Have students go out every clear day or night to repeat their observations. Encourage them to use binoculars if they have access to a pair to help identify various lunar surface features. After the first observation, make a class activity of predicting what phase the Moon will be in before the next observation.

   Teacher note: In some urban areas, parents may not be comfortable with students going outside at night to find the Moon. You may want to send a sheet about this experience home with students and get a sense of how parents feel and whether they would be comfortable going out with their students to help. If not, then students could use internet resources to fill in the phases for days when the Moon is only visible at night. Also, binoculars may not be available to students at home. If the school has binoculars in quantity, you might want to arrange for a loan program, or you may want to make the identification of features at home a less important part of this experience.

   It is helpful to summarize daily observations on a classroom copy of the "Lunar Observing Record Chart" that can be posted on a wall. An alternative to this is to have one student draw a picture each day on construction paper of the class's observations for the previous day. These could be posted daily in consecutive order to allow the students to see the pattern of the phases emerge throughout the activity. After a number of days, students should be encouraged to compare their daily observations to the predictions they made in Experience 4.1. Some students will want to start making changes to their predictions. Tell them that they will have plenty of opportunity to compare their observations to their predictions, but for now they need to leave their predictions unaltered.

5. After observing the Moon for 10 to 30 days (which are required to see the pattern for the lunar phase cycle), it is time to summarize what the students learned from their observations. Use the think-pair-share process to have students write and discuss what their observations revealed about the phases of the Moon. The following are key ideas that should emerge, assuming you are observing from typical Northern latitudes in the continental United States:

a. The phases started with a crescent Moon that had sunlight on the right side (assuming you started a few days before first quarter).

b. More and more of the Moon facing the Earth became lit by the Sun over the next week or two until it was all in sunlight (full Moon).

c. After the full Moon, less and less of the Moon facing the Earth was lit by the Sun, and the lit part was on the left side.

d. If students observed for a full month, then they should be able to conclude that the time to go from a given phase back to that phase is approximately a month (actually, it's 29.5 days).

e. Although the amount of light on the Moon's surface facing toward the Earth changes throughout the month, the features on the Moon appear to stay in the same location on the side of the Moon we can see.

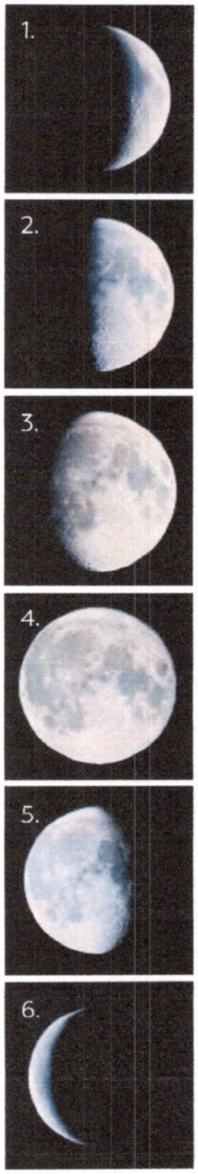
This is a good time to talk about the relationship between the lunar phase cycle and why we divide the year into months. You might also discuss that many cultures had calendars based on the lunar cycle rather than the cycle of the Earth's orbit around the Sun.

6. Conclude the experience by giving each group another copy of the "Six Lunar Photographs, Set 1" handout and asking them to redo the ordering process. This new order should be attached to the original paper just below their initial predictions. Once they have done this, you can confirm the appropriate order for the photographs (see Figure 4.15) and also review the different phases the Moon goes through. Finally, you can reinforce that the Moon takes 29.5 days to go through a full set of phases.

7. If you need to assess individual student understanding of lunar phases, this is an appropriate time do the first *evaluate* experience (Experience 4.10, "Lunar Phases Revisited").

FIGURE 4.15

Correct order for the lunar photographs in set 1



Waxing crescent

First quarter

Waxing gibbous

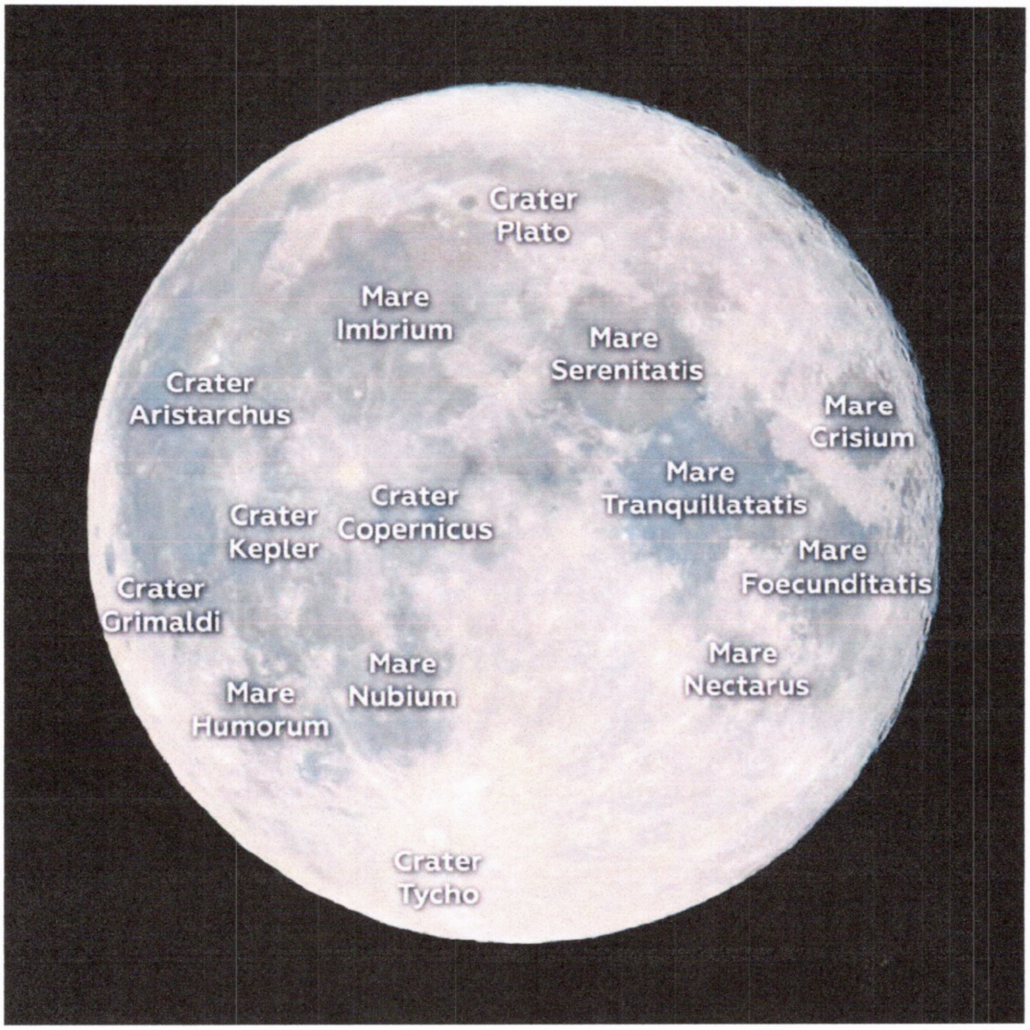
Full Moon

Waning gibbous

Waning crescent

Source: Fred Espenak, *www.astropixels.com*

Lunar Map



Source:
Fred Espenak,
www.astropixels.com

Lunar Observing Record Chart

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:
Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:	Date______ Time______ Location:

EXPERIENCE 4.4

Modeling the Moon

Overall Concept

Now that students understand the order of the lunar phases and the length of the cycle, the typical question they bring up is, "What causes the phases?" This experience allows students to understand the cause by building on the modeling activity from Chapter 1 in which the students' heads were the Earth and a lightbulb at the front of the room was the Sun. The Moon is now added to the model—in the form of a small Styrofoam ball attached to a pencil. This allows the students to explore the relationships among the Earth, Moon, and Sun to understand what causes lunar phases.

Objectives

Students will

1. be able to identify the order of the Moon's phases from one full Moon to the next; and
2. demonstrate how the Moon's position around the Earth (relative to the Sun) creates the phases.

Advance Preparation

Be sure there is plenty of space for students to stand with a hand stretched out and to spin around as they work through this experience. Check that the lamp or lightbulb for the model Sun works properly and can be placed high in the front of the room for everyone to see it. The room you use

MATERIALS

For the class:

- Lightbulb on a stand or clamp (or a lamp with its shade removed); a 60 W bulb is best for this experience
- Extension cord
- A room that can be made completely dark

One per student:

- Smoothfoam or Styrofoam ball or light-colored sphere for each student (as a model Moon)

  Teacher note: Smoothfoam balls have a denser, smoother surface that works better for this activity, but they are often harder to find than Styrofoam balls. Either will work. Places on the web that sell Smoothfoam or Styrofoam balls include Michaels (*www.michaels.com*) or Smoothfoam.com (*www.smoothfoam.com/category/balls.html*). Staples and other similar companies also carry them online.
- Pencil
- "Moon Phase Activity Sheet" (p. 310)
- Astronomy lab notebook

for this experience needs to be completely dark, which often means you have to switch rooms or spend time putting up black plastic sheets, dark tablecloths, or poster boards to cover light leaks in your classroom.

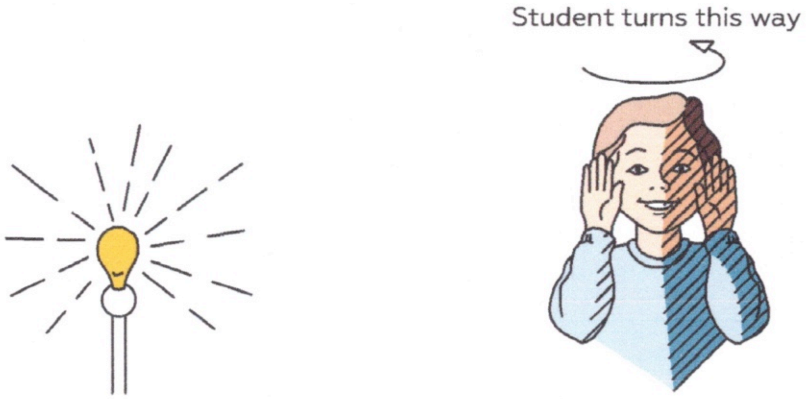
Procedure

1. Review the results of Experience 4.3, "Observing the Moon," which showed that the Moon goes through a sequence of phases. Work with the students to review the order of the phases from one full Moon to the next. Discuss some of the students' predictions about what causes the lunar phases, if this was explored in earlier discussions.
2. Tell the students that since we cannot go to outer space to observe the Moon orbiting Earth and the change in phase, we will use a model to learn what causes the Moon phases. Make the room completely dark and place the lamp at the front. Remind students of safety near the hot lightbulb and electrical cord. Have students stand facing the lamp. Make sure they are spread out enough that light from the lamp reaches each student. If you did Experience 1.5, you can remind students that this activity will be an extension of their model Sun–Earth system. The lamp still represents the Sun and their heads still represent Earth, with their noses being the students' hometown.
3. Review what they learned from the model of the Earth and Sun developed in Chapter 1. Ask students to stand so it is noon in their hometown (noses-at-noon). If disagreement occurs as to what position this would be, have students discuss until it is agreed that noon is when their nose is pointed toward the model Sun. Next, ask them to stand so it is midnight at their noses. They should turn so that they face away from the Sun.
4. Students should recall which way Earth rotates on its axis from the experiences in Chapter 1. If students did not do those experiences or do not remember them, you will need to review a few things. Determine which way north, south, east, and west are for their model Earths (their heads). If their hometown (nose) is in the Northern Hemisphere, north is the top of their heads, south is their chins, east is to their left, and west is to their right. From prior knowledge and their Moon observations, they should know

that the Sun rises in the east. Have the students place their open hands on the sides of their heads, acting as horizon blinders. Have them determine which way Earth rotates so that the Sun rises over their left (eastern) hand. After some trial and error, they will be able to determine that the Earth rotates from right to left in their model, with their right shoulder moving forward (Figure 4.16).

FIGURE 4.16

Diagram showing how the students should stand in the model



5. Ask students to stand so it is sunrise and then so it is sunset. Practice the ideas of sunrise, noon, midnight, and sunset until you feel that the students have a good understanding of these relative positions. This is a good review of what they learned in Chapter 1, and it gives them some practice with the model before introducing the Moon.
6. Distribute one "Moon ball" to each student. Have them stick a pencil into the ball to make it easier to hold and observe the phases of the Moon in the model. If there is already a hole in the ball from previous use, tell them to use that one and not make a new one. Have students hold the model Moon at arm's length. Allow time for students to explore how the Sun's light reflects off the model as they place their Moons in different positions around the Earth. This is a good time to tell students that the Moon orbits the Earth in a counterclockwise direction when

looking down on the Earth and Moon from above the North Pole. As they explore the different lunar phases, remind them to always have the Moon move in the correct direction.

One question that usually comes up and must be addressed is how high the model Moon should be held. If it is held at head height, there will be an eclipse (instead of a full Moon) during each orbit of the Moon around the student's head. Help the students develop the idea that they did not observe a lunar eclipse during Experience 4.3, and generally people make a big deal about eclipses. Therefore, they probably do not occur every month. Students should then conclude that they have to hold the Moon balls up high so the balls are exposed to the Sun's light throughout their orbit around Earth. The topic of eclipses is covered in Experience 4.5, "Modeling Eclipses," and in Experience 4.6, "How Often Do Eclipses Occur?" In Experience 4.6, they will learn that the Moon's orbit is not aligned with the Earth's orbit around the Sun (or relative to the circle that the Sun appears to make among the constellations in the course of a year, which is how we on Earth perceive our motion around the Sun). As a result, the Moon is usually either above or below the Sun in the sky. But if you plan to do Experience 4.6, you may not want to give away the answer while you help them with the current activity.

7. Help students find a few of the phases of the Moon with which they are already familiar, such as a full Moon, a new Moon, and the first and third quarters. A new Moon occurs when the Earth, Moon, and Sun are aligned, and the Moon is between Earth and the Sun. A full Moon occurs when the three bodies are aligned, and the Earth is between the Moon and the Sun (Figure 4.17, p. 308).

Teacher note: Students will have many questions as they explore. Try not to answer directly. Encourage them to explore their questions using the model before providing an answer.

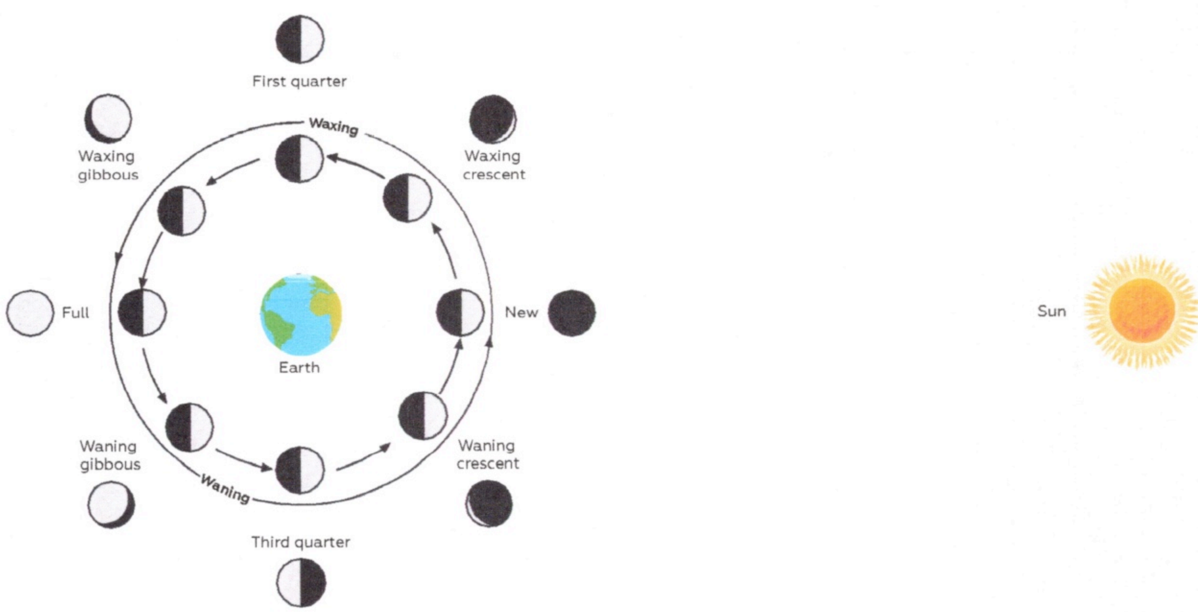
There is a common misconception that Earth's shadow causes the phases, and some of your students may try to involve the shadow of their heads in the modeling. If students are trying to produce the different phases by hiding parts of the Moon with shadows of their heads, you will need to address this. Students should also come to recognize, possibly with some assistance, that they cannot generate the shape of the different phases by using the shadow of Earth.

8. After students explore finding the phases, choose one lunar phase and ask the students to determine what position in the Moon's orbit they must place their Moon to achieve that particular phase. Full Moon is a good phase to start with. Encourage students to compare their positions and discuss differences. Ask a student who has the correct position to explain why it is correct. By walking around the classroom, you can check for understanding by seeing if all the students are holding their Moons in the same position.

9. Have students model other phases, for example, first quarter, third quarter, and new Moon. Use the terminology introduced in Experience 4.3 when requesting a particular phase, such as waning gibbous and third quarter.

FIGURE 4.17

A diagram of the Moon phases in relation to the Sun and Earth



The inner sequence shows the Moon's relative position to the Earth and the Sun as viewed from outer space, above the solar system. Students are asked to produce a portion of this diagram on the "Moon Phase Activity Sheet." The outer sequence shows the Moon as seen from Earth. For example, you would see the waning crescent (lower right) as a small slice of the Moon illuminated on the left side. A waxing crescent, upper right, would have the right side of the Moon illuminated.

10. Allow time for students to experiment with the movement of the Moon—always moving it in a counterclockwise direction around the Earth. They can observe their own model as well as other students' models. This activity is very powerful and can answer many questions that the students generate about the motion of the Moon and its appearance in the sky.

    Teacher note: Students may find it helpful to change the model slightly to answer certain questions. If one student holds the Moon ball and another student is Earth, they can more easily see Earth spinning on its axis while the Moon is barely moving in its orbit. How much of a circle does the Moon travel each 24 hours? (*About 1/29th or 1/30th of a circle.*) So everyone on Earth basically sees the same phase on the same night.

11. Now have students work together in small groups as they each complete the "Moon Phases Activity Sheet." The goal is for them to produce a diagram similar to the one in Figure 4.17. These drawings should be kept in their astronomy lab notebooks.

12. After completing the diagrams, ask students to write down in their astronomy lab notebook the causes of the changing Moon phases. (*The movement of the Moon around Earth and the relative positions of the Sun, Earth, and Moon cause the phases. The spinning Earth—the student's head—makes the Moon rise and set each day, but this does not affect the phase of the Moon.*) Encourage them to use diagrams in their explanations.

13. Check student diagrams and explanations for the causes of phases. Ask students if they are sure that their observations and the model support their diagrams and statements. If discrepancies arise, have students go back to the model to further clarify the concepts.

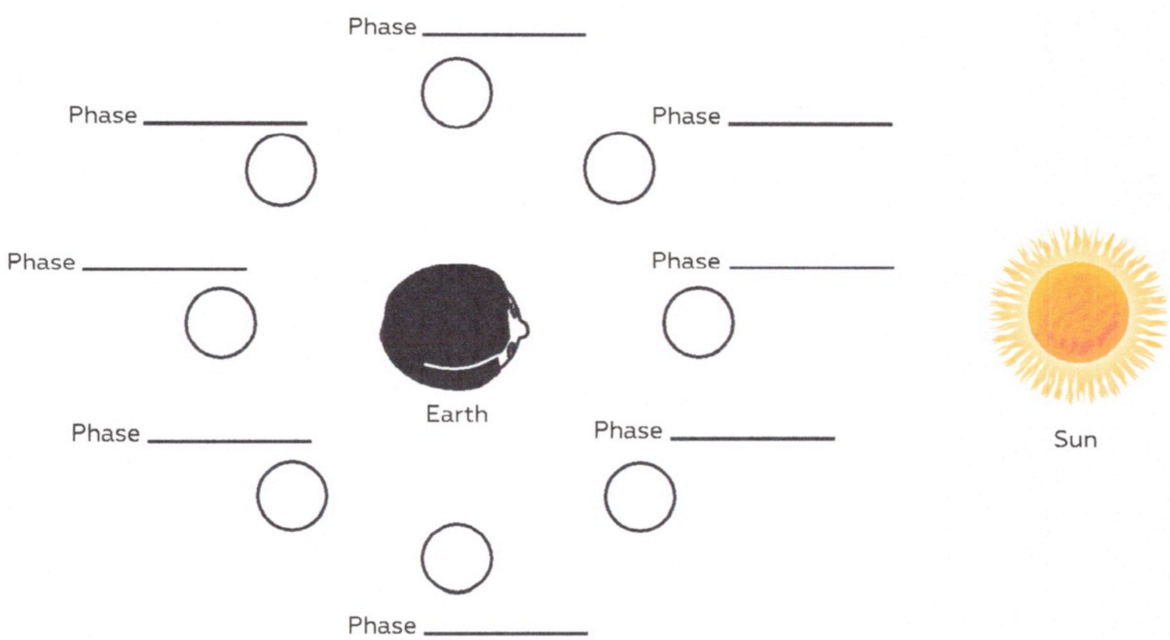
    Teacher note: If you have not already used the first *evaluate* experience (Experience 4.10, "Lunar Phases Revisited"), now is a good time to do Experience 4.10 to assess student understanding of lunar phases.

4.4

Moon Phase Activity Sheet

This diagram represents a view you would see looking down from above at your head when you are modeling the Moon orbiting Earth. Darken the areas on each Moon that are not illuminated by the Sun. Then label each Moon phase as you would see it when your nose (on Earth) is pointed directly at it.

Be sure to use the Moon phase terms: new Moon, full Moon, first quarter, third quarter, waxing crescent, waning crescent, waxing gibbous, and waning gibbous.



4.5

EXPLAIN

EXPERIENCE 4.5

Modeling Eclipses

Overall Concept

Now that students understand where the Moon has to be in its orbit to see each phase, modeling continues by exploring where the Moon, Earth, and Sun have to be to produce solar and lunar eclipses.

Objectives

Students will

1. distinguish between lunar and solar eclipses and
2. understand that solar eclipses only happen when the Moon is in its new phase and lunar eclipses only occur when it's in its full phase.

Procedure

1. If you did Experience 4.2, "What Do We Think We Know?" ask students to review their response to prompt 3, "What are solar and lunar eclipses, and what causes them?" If you did not do Experience 4.2, ask students if they know what an eclipse is. What is the difference between a solar eclipse and a lunar eclipse? Ask them if they have ever seen an eclipse, and if so, whether it was solar or lunar. Have them write responses to the questions in their astronomy lab notebooks. Then explain that this activity will help them understand the difference between these two types of eclipses as well as why they occur.
2. Set up the equipment in the same way as it was used in Experience 4.4, "Modeling the Moon." Have the students explore moving their model Moon in its orbit (always revolving counterclockwise) to determine when the Moon can block the Sun's light from reaching the Earth (a

MATERIALS

For the class:

- Lightbulb on a stand or clamp (or lamp with the shade removed)
- Extension cord

One per student:

- Smoothfoam or Styrofoam ball or light-colored sphere (as a model Moon)
- Pencil
- Blank sheet of paper
- Astronomy lab notebook

solar eclipse) and when the Earth can block the Sun's light from hitting the Moon (a lunar eclipse). If you recently did Experience 4.4, in which you told the students that the shadow of the Earth was not a factor, you may want to tell them that shadows are a factor for eclipses, and they can now feel free to play with shadows. As much as possible, have them use the model to come up with the correct answer. (*Solar eclipses only occur when the Moon is in its new phase. Lunar eclipses only occur when the Moon is in its full phase.*)

3. After the students have explored how to produce the two types of eclipses, reinforce what they observed by having them move the Moon ball in orbit until it completely blocks their view of the lamp. Explain that it is when the Moon is positioned exactly between the Earth and the Sun that it blocks the Sun and produces a solar eclipse. Ask them what phase the Moon must be in to line up and make a solar eclipse. (*New Moon*) This is a good time to show several photographs of different solar eclipses. These are easily found by searching the internet for solar eclipse images.

4. Now ask them to position their Moon balls so that the Sun's light falling on the Moon is blocked by the Earth. Ask them what phase the Moon must be in to produce this lunar eclipse. (*Full Moon*) This is a good time to show several photographs of different lunar eclipses.

5. Have the students take notes in their astronomy lab notebooks and briefly write the reason that we have eclipses. They should explain what is necessary for us to experience a solar eclipse and a lunar eclipse. Ask them to explain what the two types of eclipses have in common. (*The Sun, Earth, and Moon are all lined up.*)

   Teacher note: A question that typically arises at this point is why we don't have solar and lunar eclipses every month since we have a new Moon and full Moon every month. The Moon's orbit around the Earth is out of alignment by 5° from the plane of Earth's orbit around the Sun (the ecliptic). This means the Moon is not lined up with the Earth and the Sun most months. This is the subject of *elaborate* Experience 4.6, "How Often Do Eclipses Occur?" which makes a great extension for this experience.