The real shape of the Moon's orbit

In the typical Moon phase lesson, students learn that the rotation period for the Moon is approximately the same as its revolution period around the Earth. This is a situation known as synchronous rotation—where the rotation period is the same as the orbital period. A conclusion drawn from this similarity is that the Moon always has the same side toward the Earth. While that may be correct, it does give rise to the perception that the Moon revolves around the Earth, when in reality the Earth and Moon together revolve around the Sun. It is only from our position on the Earth's surface that it appears as if the Moon orbits around the Earth as the Earth orbits the Sun. From our perspective we can easily observe the Moon moving daily toward the east as it cycles through its phase changes, completing what appears to be a 360-degree circle. However, as your students complete the following activity, they will discover that the Moon's orbit is actually around the Sun, and not around the Earth.

As an introduction to this lesson and activity we review Moon phases. (See the September Scope on the Skies column.) Then, I have students draw a diagram of the Sun, Earth, and Moon such that it shows the Moon's orbital motion relative to the Earth for several months. The diagram does not have to be drawn to scale, as I want students to focus on what they think the Moon's orbital path looks like. Figure 1 is a copy of one student's diagram, and is typical of what many students will draw. Students show the Moon's orbit as a complete circle around the Earth and often will connect these circles with a curved line to the next circle/month. We usually have an interesting discussion about the diagram as students try to explain the curved line connecting each Moon loop.

In order to show the true path the Moon takes relative to the Earth, students can draw a diagram on a piece of paper of the Earth's orbital path and the Moon going through a couple of phase cycles. On the back of the paper, or on another sheet, have students draw a small circle in one corner to represent the Sun. Then draw a curved line the length of the paper from one corner to another to represent a part of the Earth's orbit. Draw a small circle near the bottom of the paper on this line to represent the Earth, and place a dot between the Earth and the Sun for the new Moon phase. Then draw another Earth about an inch further along the Earth's orbit line and place a dot on the Earth's orbit line below the Earth for first quarter phase. Draw another circle for the Earth another inch along the line and place a dot on the opposite side of the Earth for full Moon. Draw another circle for the Earth and place a dot on the Earth's orbit line ahead of the Earth for last quarter phase. Then to complete the lunar phase cycle, draw one more Earth circle another inch along the line and place a dot to show the Moon at new phase. Connect the phase dots as shown in Figure 2. This represents the Earth and Moon during one lunar cycle, or one month.

On a piece of paper, the shape of the Moon's orbit looks like a wavy line; however, by repeating the above steps several times, making the drawing much larger, or drawing to scale proportions, the orbit becomes noticeably smoother, a curved path nearly parallel with the Earth's orbit.

Conjunction function

As the planets and our Moon move about the Sun following their respective orbits, there will be times when some of the planets or the Moon will be in the same direction from the

Bob Riddle (bob-riddle@currentsky.com) *is a science educator living in Lee's Summit, Missouri. Visit his astronomy website at* www.currentsky.com.

Earth and will appear to be close to one another in the sky. These are known as *conjunctions* and they happen regularly throughout the year, especially with the relatively faster-moving Moon or inner planets catching up with the slower-moving planets.

This month, on the 10th, there will be a conjunction between Saturn and the Moon over the southwest horizon, and three planets, Mercury, Mars, and Jupiter, will arrange in a triple conjunction over the southeast horizon. On the 9th, Mercury will pass within 1 degree from Mars, and on the 10th, Mercury will be within 0.1 degree of Jupiter, with Mars close by. Together the three planets will be within a 1-degree field of view on that morning, as Figure 3 shows. Having nearby second magnitude stars (relatively bright stars) from the constellation Scorpius offers a convenient reference point from which to observe the different orbital speeds of the planets.

Visible planets

- Mercury will be at its best morning apparition this year as it will start the month above the eastern horizon at sunrise, and will remain visible for about the first three weeks of the month. It will be in close conjunction with Jupiter and Mars on the 10th.

FIGURE 1 **Part of a student drawing showing the Earth and Moon orbiting the Sun**

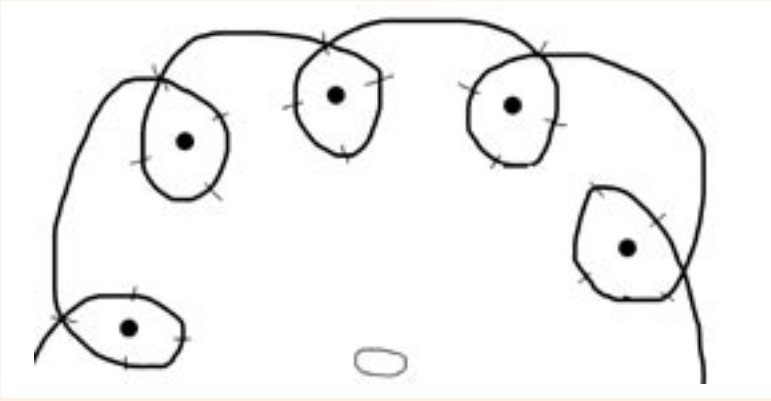

FIGURE 2 **Earth and Moon orbits for one month, as drawn by a student**

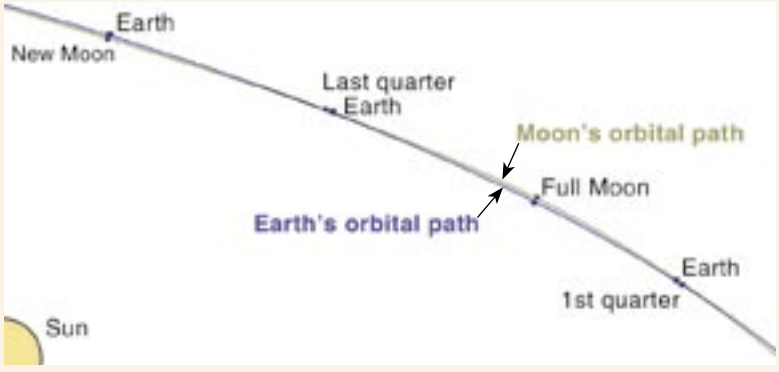

FIGURE 3 **Triple conjunction as seen through 7 x 50 binoculars**

Questions for students

1. With regard to the Earth-Moon system, what is the barycenter and where is it located?
   (The barycenter is the center of mass, the balance point between the Earth and Moon, and is the point about which the two pivot as they orbit the Sun together. The barycenter is located approximately 1,700 km (1,056 miles) below the surface of the Earth.)
2. Look up Kepler's laws of planetary motion and answer the following question: At which point in an orbit—apogee or perigee—is the Moon moving the fastest? Which of Kepler's three laws explains this?
   (According to Kepler's second law, the Moon will move faster near perigee and then more slowly at apogee.)

The December Long Nights Moon

Date	Moon event
12/1	Perigee Distance: 365,926 km Apparent size: 0.5443°
12/5	Full Moon Right ascension: 5^h 7'; Declination: 27°33'
12/12	Last quarter Right ascension: 11^h 4'; Declination: 6°6' Descending node Illuminated fraction: 0.52%
12/13	Apogee Distance: 404,410 km Apparent size: 0.4925°
12/20	New Moon Right ascension: 17^h 24'; Declination: –28°29'
12/26	Ascending node Illuminated fraction: 0.34%
12/27	First quarter Right ascension: 23^h 54'; Declination: –0°3' Perigee Distance: 370,347 km Apparent size: 0.5378°

- Venus will return to the evening skies, but will be low over the southwest horizon at sunset for the duration of this month.
- Mars will rise one to two hours before the Sun this month, and will slowly move higher over the eastern horizon with each passing day. Watch for Mars to be in conjunction with Mercury on the 9th, and Jupiter on the 12th.
- Jupiter will come back into view as a morning planet this month, and will be visible low over the eastern horizon at sunrise.
- Saturn will rise with the bright stars of Regulus several hours after sunset and will be visible high over the southern horizon at sunrise. Saturn will begin retrograde motion this month near the constellation Leo, and will form a distinctive small triangle with Regulus and Algieba.

Resources

SFA star charts—*observe.phy.sfasu.edu*

Daily Moon rise and set—*aa.usno.navy.mil/data/docs/RS_OneDay.html*

Monthly Sun and Moon rise and set—*www.sunrisesunset.com/custom_srss_calendar.asp*

Gravity simulator software—*www.orbitsimulator.com/gravity/articles/barycenter.html*