Luna

Our Moon, Luna, will be the focus of my columns for this coming school year. Data and information will be provided so that each month you and your students can follow the Moon and the Earth as the two orbit together around the Sun. Students can use this data, for example, to graph the Moon's changing apparent size and distance, watch for patterns or rhythms to develop, or combine this data with information from the internet to look for any correlations between Moon distance and tides, earthquakes, or volcanic activity.

With the exception of Pluto and Charon, our Moon is unlike other moons in the sense that it probably formed out of a collision that resulted in two objects of somewhat similar size orbiting the Sun together. In addition, our Moon does not orbit its planet equatorially as other moons do. The Moon's orbital path is tilted approximately 5 degrees from the Earth's orbit. From our perspective, the Moon has an orbit that takes it around the Earth. However, as will be seen in a future column, our Moon actually orbits the Sun with the Earth, pivoting around a common center of mass known as the *barycenter*. It does not actually go around the Earth.

Lunar basics

Immigrants brought many of the names we have for a full Moon to this country, and others are the names used by Native Americans. In Colonial America, the September full Moon was known as the *Fruit Moon*, the *Dying Grass Moon*, or the *Barley Moon*. Sometimes the full Moon of September is known as the *Harvest Moon*, but traditionally that name is given to the full Moon closest to the September equinox. By that rule, the October full Moon will be the Harvest Moon this year, and the following month, according to tradition, will be the *Hunter's Moon*.

The Moon, moving along its orbital path, will undergo a daily phase change as it progresses across the sky from west to east. The phase appearance of the Moon will increase from right to left as the Moon waxes through the first half of a lunar cycle toward full Moon. This part of the lunar cycle will be easily observed during the evening hours after sunset. By observing at the same time each evening, two patterns will become apparent: The waxing Moon will be seen further east, and it will rise about 50–60 minutes earlier each day. Following the full Moon phase, the Moon will continue moving eastward daily but it will be waning (decreasing) from right to left in phase appearance. Because waning phases occur late at night, they can be observed during the morning in the daytime sky.

From our perspective on Earth, we describe the Moon in terms of its orbit around the Earth, and say that the Moon's orbit takes about a month. Complicating this is that we use a calendar with months having lengths of 28, 30, or 31 days. So, exactly how long does it take for the Moon to orbit the Earth?

Using the phase cycle as a reference from which to determine the Moon's orbital period, it takes approximately 29.54 days to go from new Moon to new Moon. Called the *synodic* month, this is not the time it actually takes for the Moon to orbit the Earth, but rather the time it takes to return to the same phase. The *sidereal* month is a measure of the actual time and it is determined by using a star other than the Sun as a reference point from which

Questions for students

1. Does the Moon rise and set every day?
   (Yes. Even though we may not be able to see the Moon, it still rises and sets every day. The new Moon, for example, rises and sets with the Sun.)
2. What is the difference between this month's apogee and perigee?
   (406,500 km – 357,175 km = 49,325 km)
3. How is a waxing Moon different from a waning Moon?
   (The Moon increases in phase appearance while it is waxing, and during the waning phases the phase appearance decreases.)
4. Use the celestial coordinates to plot the Moon's position at each quarter phase on the SFA star charts.
5. Start analyzing the data for patterns that may develop during the next several months.

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to find the Moon's orbital period. The sidereal month is approximately 27.33 days, the time it takes the Moon to orbit the Earth, or return to the reference star. If the sidereal month is rounded off to 28 days then it serves as the basis for dividing the lunar cycle into quarters of seven days and emphasizing quarter phases. This is probably the source for the commonly used practice of teaching that there are seven days between quarter phases and that we have a lunar cycle of 28 days.

The difference between the Moon's sidereal month and its synodic month is based on our understanding that the Earth is moving along its orbital path around the Sun while the Moon is following its own orbital path relative to the Earth's orbit. If the Earth were not revolving, and we started the observation with a new Moon phase, the Moon would take 27.33 days, a sidereal month, to return to the same phase. However, because the Earth is revolving at the same time, the Moon would not be at the same phase as when the observation was started. Because the Earth is also revolving, it will take an additional two days or so for the Moon to line up with the Earth and Sun and return to the same phase.

This difference is easily observable and typically each month there will be an opportunity to find a bright reference star to use. Find

FIGURE 1 **September 1, 9:00 p.m. The waxing gibbous Moon east of Antares.**

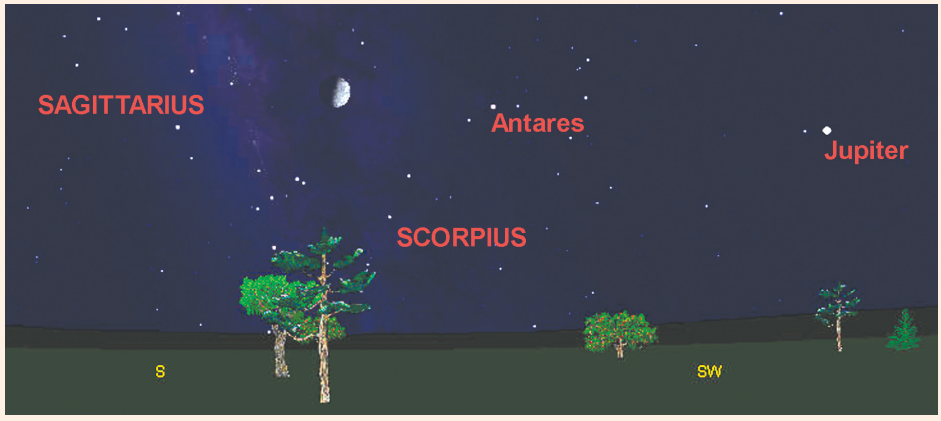


FIGURE 2 **September 28, 9:00 p.m. The waxing crescent Moon near Antares.**

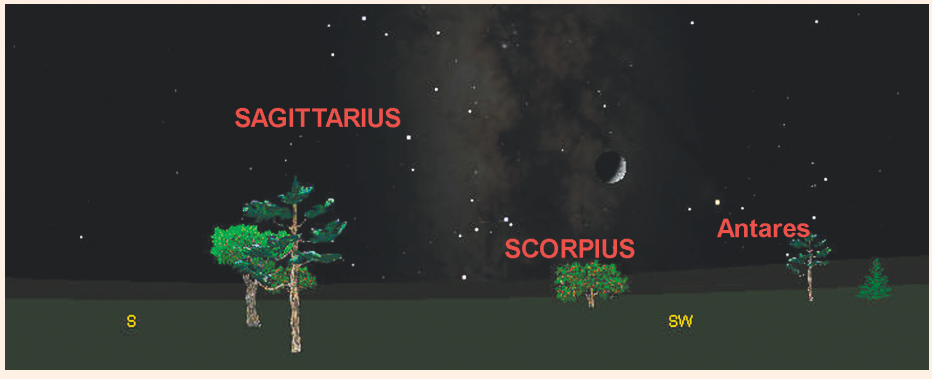
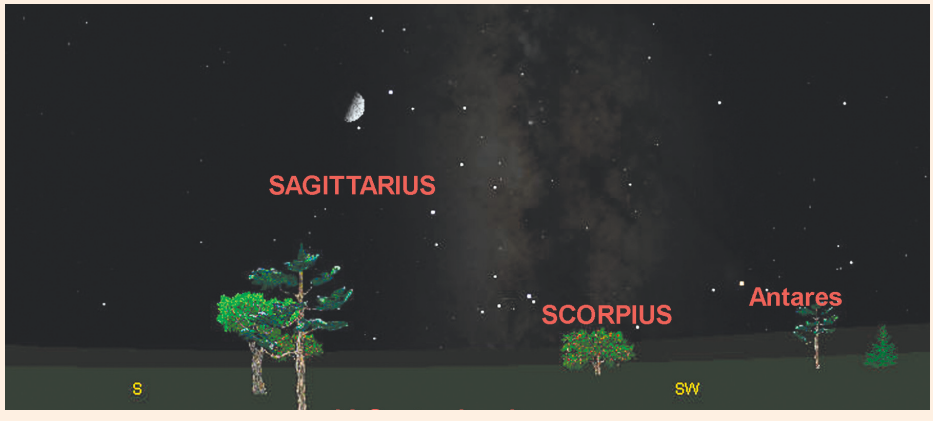


FIGURE 3 **September 30, 9:00 p.m. Waxing gibbous Moon.**



Moon data and events for September

Date	Moon event
9/1	Waxing gibbous Moon east of Antares
9/7	Full Moon Right ascension: 23^{h}29′; Declination: –4°39′ Partial lunar eclipse
9/8	Ascending node Illuminated fraction: 1.0% Perigee distance: 357,175 km Apparent size: 0.5576°
9/14	Last quarter Right ascension: 6^{h}5′; Declination: 27°57′
9/22	New Moon Right ascension: 12^h 23′; Declination: –4°26′
9/21	Descending node Illuminated fraction: 0.0%
9/22	Annular eclipse Apogee distance: 406,500 km Apparent size: 0.4899°
9/28	Waxing crescent Moon east of Antares
9/29	First quarter Right ascension: 18^{h}12′; Declination: –29°19′

an evening when the Moon is close to a bright star and note the phase and age in days of the Moon. The age of the Moon would be the number of days since new Moon. Next, count the days until the Moon returns to that same spot relative to the star. Will the Moon be at the same phase and be the same age in days?

Figures 1–3 show a view toward the southern horizon after sunset on three days during September. On the evening of September 1 at 9:00 p.m. local time, the 8.5-day-old waxing gibbous Moon will be east (to the left), of the reddish star Antares in Scorpius, the Scorpion. Further to the right will be the bright planet Jupiter. After approximately 27 days, on September 28, the Moon will return to approximately the same location east of Antares. However, it will be only a 6-day-old waxing crescent Moon. That was the sidereal month. To complete the synodic month, it will take an additional two days of Earth revolution for the Moon to return to an 8-day-old waxing gibbous phase. The Moon will also be further east of Antares.

Use the link to "Your Sky" (see Resources) for an online star map that may be set to any day and time for any latitude and longitude location. This can be used to model the difference between a synodic and sidereal month. Use the Earth-Moon Viewer link at the bottom of the "Your Sky" web page to generate data and an image of the Moon for any day and time.

A pair of eclipses

Lunar and solar eclipses occur as eclipse pairs separated by approximately 14 days. During the calendar year there can be as many as three pairs of eclipses, and, depending on the dates, there can be as many as seven eclipses. An eclipse happens only when the alignment between the Earth, Moon, and the Sun are such that the Moon either blocks the Sun from view, or alternately passes through some or all of the Earth's shadow.

This month, there will be the second eclipse pair for the year with a partial lunar eclipse on September 7, followed by an annular solar eclipse on September 22. Neither of these eclipses will be visible from the continental United States; however, we will see a total lunar eclipse in March.

Visible planets

- Venus will be visible very low over the eastern horizon before sunrise during the first week of the month.
- Jupiter will be visible over the southwest horizon to the right of the reddish giant star Antares in Scorpius, the Scorpion.
- Saturn will be visible over the eastern horizon before sunrise to the right of the much brighter Venus, and will continue to rise higher each morning, becoming more visible.

Resources

The Moon—*www.nineplanets.org/luna.html*
Moon names—*http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970314a.html*
Your Sky—*www.fourmilab.ch/yoursky*
Daily Moon rise and set—*http://aa.usno.navy.mil/data/docs/RS_OneDay.html*
Monthly Sun and Moon rise and set—*www.sunrisesunset.com/custom_srss_calendar.asp*
Partial lunar eclipse map—*http://sunearth.gsfc.nasa.gov/eclipse/OH/image1/LE2006Sep07-Fig4.GIF*
Annular solar eclipse map—*http://sunearth.gsfc.nasa.gov/eclipse/OH/image1/SE2006Sep22-Fig5.GIF*