A model solar system

by Bob Riddle

In January and February 2016, all five of the visible planets will be aligned from east to west (left to right) across the morning skies, relative to the plane of the ecliptic, as shown in Figure 1. The *ecliptic* (green line in Figure 1) is a projection of the Earth's orbit around the Sun. All of the planets in our solar system, including dwarf planets, have an orbital path that is anywhere from nearly parallel to the plane of the ecliptic to an inclination of several degrees (see "Planet Data Tables" in the Resources for orbital information about the eight planets and some of the dwarf planets).

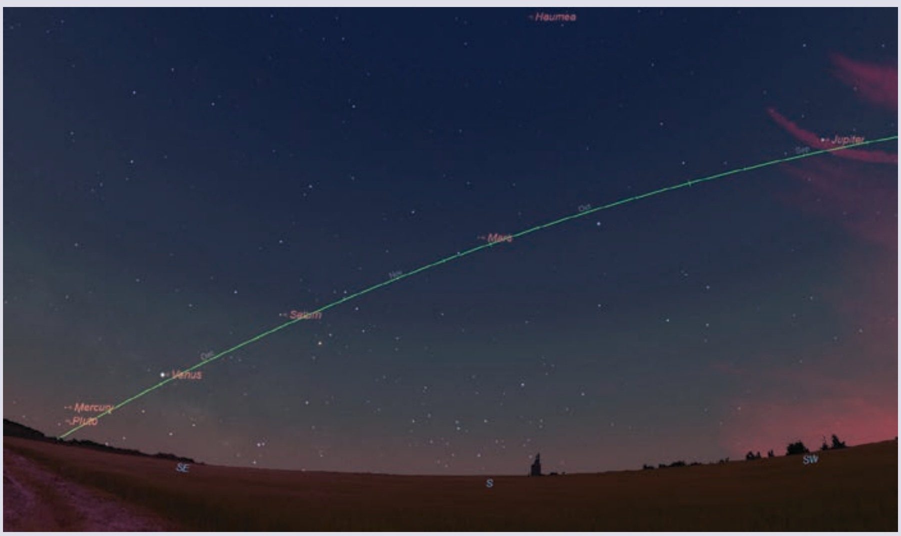
So, while the planets may look like they are aligned, we are actually seeing this phenomenon due to the position of each planet relative to the positions of the Sun and Earth. This may be difficult to imagine, so it is helpful to use a model. Figure 2, which shows the solar system when viewed from above, makes the orientation of the planets clearer.

When viewed from above, a planet's orbital location is given in *degrees of heliocentric longitude*. There are 360° in a planet's orbit. The starting point, 0°, is at the location of Earth's March equinox. All planets and almost all other solar system objects orbit in a counterclockwise direction when viewed from above. This means that from Earth, almost all solar system objects move eastward as they revolve around the Sun—although they appear to move westward due to Earth's rotation.

Over the course of a school year, students can plot the planets' changing orbital positions on polar (circular) graph paper (see Resources) using each planet's heliocentric longitude coordinates, which can be found at the U.S. Naval Observatory's website. Students can also use this website to set the time interval and duration to the number of days between each calculation that they would like to explore. Additionally, heliocentric longitudes provided in monthly intervals from 1980 through 2026 can be found at West Virginia University's Planetarium and Observatory website (see Resources). This website will be of interest to students who want to re-create the arrangement of the planets on their birthday, for example.

Our view from the Earth's surface is obviously not the same as the heliocentric view from above. To help students visualize their view from Earth, ask them to plot the heliocentric positions of the planets, including the Earth, and the Sun. Then provide each student with a small, square piece of transparency plastic. Using Figure 3 as a guide and, using a straightedge, draw two lines, one perpendicular to the other, like a letter T.

FIGURE 1 The morning sky, planets, and the ecliptic as they will appear on January 25, 2016



Place the T-bar on the Earth with the leg of the letter T pointing toward an outer planet. The T-bar represents the local horizon and the leg of the letter T represents a person facing south. The right end could be labeled west and the left end labeled east. The planet the T-bar points toward is midway between rising and setting. Any planets to the right are in the western part of the sky, and any to the left are in the eastern part of the sky. These positions may represent planet positions during the day or night, depending on where the Sun is with respect to the planet at which the T-leg points.

Because the two inner planets, Mercury and Venus, are located between the Earth and the Sun, they never appear as far from the Sun as the outer planets. Mercury and Venus always rise and set within a few hours of Earth's sunrise or sunset. If the transparency is positioned so that the eastern horizon points toward the Sun and either Mercury or Venus is above the horizon, then it would appear in the morning skies, rising before the Sun. Similarly, positioning the transparency so that the western horizon points toward the Sun shows whether there are any planets in the evening sky.

FIGURE 2 The planets from above as they will appear on January 25, 2016

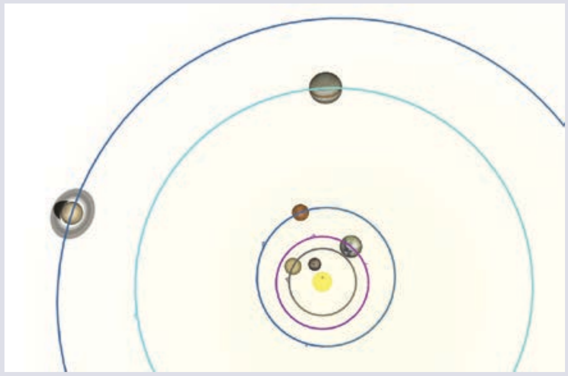
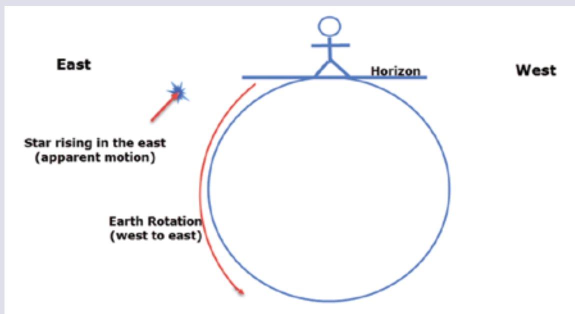


FIGURE 3 My local horizon



Dynamic modeling, or how to hug the sky

One way to engage students in a modeling activity is to have them act out, in this case, the Earth's rotation and the positions of other planets and, to a certain extent, the Sun. In this dynamic model, students learn the direction the Earth rotates (west to east), as well as the apparent rising and setting motion of celestial objects (east to west) due to Earth rotation. Each student should represent Earth at least once in order to strengthen understanding of the motions being modeled, rather than view from an outside perspective another student modeling the Earth.

To model the Earth, as well as a person standing on the Earth and viewing the sky, students should stand with their arms straight out to the sides. The horizon stretches from their left hand and passes in front of them to their right hand. It may help to have students stand and point to where the actual horizon is. Typically, the *horizon* is described as the place where the sky meets the ground and where objects rise and set. In this model, however, students extending an arm straight out away from them in any direction essentially points toward the horizon. The ideal horizon would be flat, as if we were standing on a platter (see Figure 3). However, most of us experience an irregular horizon that includes natural and human-made objects, such as trees and buildings.

In this model, students' left hands represent east, their noses represent south, and their right hands represent west (north is ignored in this model). Have students practice the Earth model on their own, or demonstrate by asking one student to stand in a cleared area to represent the Sun and another student to stand a few feet away with outstretched arms to represent the Earth. (You can also use a desk to represent the Sun.) Have the model Earth turn so that the student's left hand points toward the model Sun. This position represents sunrise, with the Sun on the eastern horizon. Ask students to turn so that their bodies and arms are positioned to show that it is midday, with the Sun to the south (the model Earth's nose). Students should turn toward the left, west to east. At midday, the Sun is halfway between sunrise and sunset, not necessarily noon, but at its highest point above the southern horizon for that day.

Provide enough space and then, using Figure 2 as a guide, position six students around the model Sun to represent Jupiter, Mars, Saturn, Venus, Mercury, and Earth. Remind students that both the Earth's rotation and the planets' revolutions are counterclockwise, or toward the left. To model how the planets look in the morning skies, ask the model Earth to turn his or her back toward the model Sun. If a student's nose represents midday, then the back of the head represents midnight. With arms outstretched, the model Earth should slowly turn so that the left hand, the eastern horizon, points toward Jupiter, which rises shortly after midnight local time. As the model Earth slowly turns, each of the planets will be aligned with Earth's left hand in turn, modeling that planet as it rises above the horizon. The model Earth should stop turning just before the model Sun is aligned with the left hand. This final position models what we see from Earth in the morning: the planets arranged across the sky, above the horizon from east to west at sunrise due to Earth's rotation. It is important to show students the accuracy of any model; in this case, explain to them that this model does not show that planets got to their respective orbital positions by revolving around the Sun toward the east (see "For Students" for an extension about model limitations). ■

For students

1. The dynamic model of the Earth as it rotates is based on how celestial objects appear to move across our skies. How would this model be different in the southern hemisphere? (*The Earth rotates from west to east regardless of the hemisphere; however, from the southern hemisphere, the apparent motion of celestial objects is viewed as moving from east, through north, to west.*)
2. An interesting challenge in making models is ensuring that all components of the model are to scale. With our solar system, it is easy to make a model in which either the planet sizes or the planet distances are to scale, but not both at the same time. Watch the short video "To Scale: The Solar System" to see one solution to making a scale model (see Resources). Also check to see whether your city has a walkable scale model of the solar system (see "Voyage a Journey" in Resources). Then use the online "Build a solar system" calculator to find a solar system model that would fit on the school playground.

Visible planets

Mercury will become visible in the morning skies toward the end of the month.

Venus will rise about two hours before the Sun and will be very visible over the eastern horizon at sunrise.

Mars will rise before Saturn and will be located over the southern horizon at sunrise, up and to the right from Saturn.

Jupiter will rise around midnight and will be located over the southwest horizon at sunrise, up and to the right from Mars.

Saturn will rise before Venus and will be located up and to the right of Venus.

January

1	Last quarter Moon
2	Moon at apogee: 404,300 km (251,220 mi.)
	Earth at perihelion: 147,099,586 km (91,403,445 mi.; 0.9833 AU)
3	Moon near Mars and Spica
	Summer solstice on Mars
4	Quadrantid meteor shower peak
7	Moon near Venus and Saturn
9	New Moon
14	Mercury at inferior conjunction
	Moon at descending node
	Moon perigee: 369,600 km (229,659 mi.)
16	First quarter Moon
	Cassini flyby of Titan

19	Moon very near Aldebaran
	New Horizons's launch anniversary (2006)
23	Full Moon
25	Moon near Regulus
27	Moon ascending node
28	Moon near Jupiter
30	Moon apogee: 404,600 km (251,407 mi.)
	Moon near Spica
31	Last quarter Moon
	Moon near Pluto

Resources

Build a solar system—*www.exploratorium.edu/ronh/solar_system*

Cassini Solstice mission—*http://saturn.jpl.nasa.gov*

City-sized solar system model—*http://peoriariverfrontmuseum.org/dome-planetarium/community-solar-system*

Free, printable polar graph paper—*www.printablepaper.net/preview/polar-10deg-2in-index-letter*

Heliocentric longitudes—*http://planetarium.wvu.edu/heliocentric-longitudes*

New Horizons mission—*http://pluto.jhuapl.edu*

Planet data tables—*www.windows2universe.org/our_solar_system/planets_orbits_table.html*

To Scale: The Solar System video—*http://vimeo.com/139407849*

U.S. Naval Observatory—*http://aa.usno.navy.mil/data/docs/geocentric.php*

Voyage a Journey—*http://voyagesolarsystem.org*

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