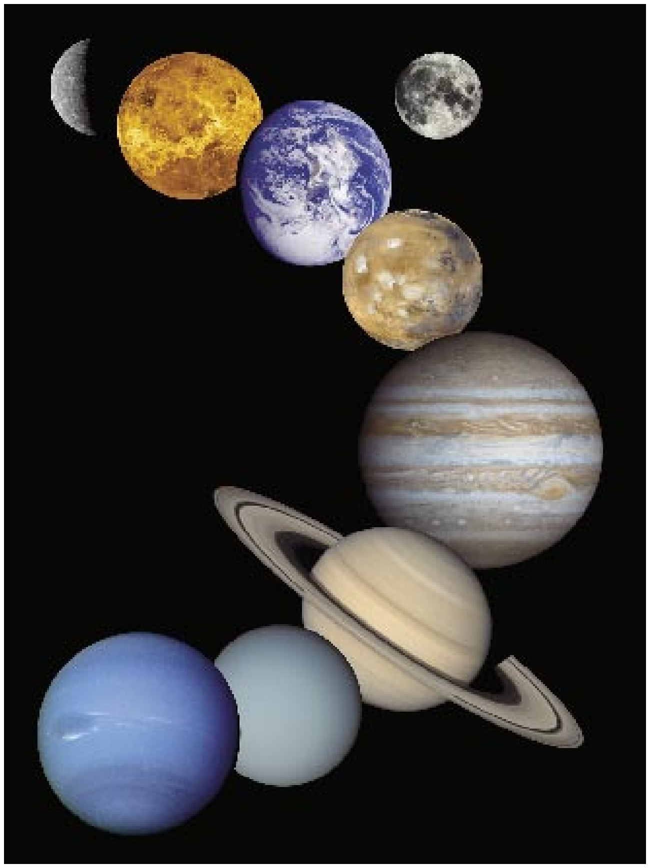
Dance of the planets

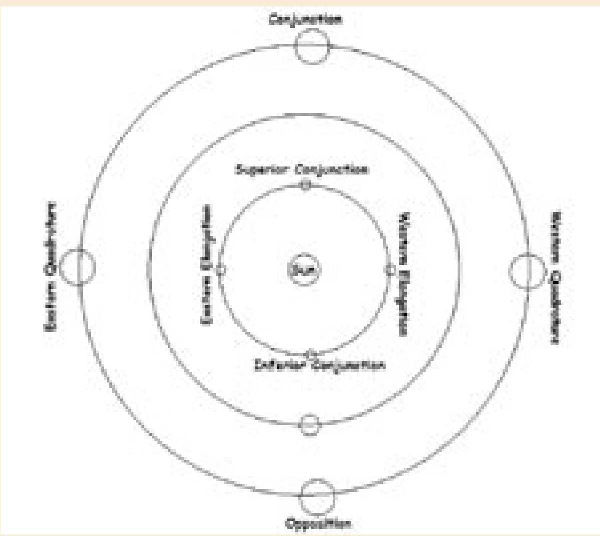


As students continue their monthly plotting of the planets along the ecliptic they should start to notice differences between inner and outer planet orbital motions, and their relative position or separation from the Sun. Both inner and outer planets have direct eastward motion, as well as retrograde motion. Inner planets Mercury and Venus, however, are limited in their separation from the Sun because they orbit between the Earth and the Sun. An inner planet can never be at opposition, on the opposite side of the Earth from the Sun, for example. Conversely, an outer planet such as Mars can be at opposition but never at inferior conjunction (come between the Earth and the Sun).

Figure 1 shows the possible positions an inner and an outer planet may reach relative to the Earth and the Sun. It models an overhead view of the solar system but has been simplified to show only the Sun, an inner planet, the Earth, and an outer planet. If there were motion in this model the planets would be revolving counterclockwise around the Sun, as viewed from above. It is important for students to understand that, in this model, the planets are not moving, orbits are shown to be circular, and it is definitely not drawn to scale.

During the next two months, both inner planets and outer planets will reach some of the positions shown on Figure 1. Tracking the planets with the supplied coordinate positions, noting the Sun's position along the ecliptic, and then comparing this with Figure 1 will help students to better visualize where each planet is relative to the Sun. Then, using the suggestion given last month for turning the star chart at a specific angle and using a dark paper for the horizon, students can also see where these planets are relative to the horizon and their rising or setting times.

FIGURE 1 **Planet positions relative to the Earth and the Sun**



December solstice

While plotting the planet positions, students should also note that the Sun is continuously moving, following its apparent path along the ecliptic. They should watch for the day when the Sun reaches the coordinates of right ascension (RA) 18 hours and –23.5 degrees declination. When the Sun is at this location, Northern Hemisphere autumn will end and Northern Hemisphere winter will begin. The opposite seasons will end and begin for the Southern Hemisphere.

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Tracking the planets

Throughout the school year, data will be provided through this column for students to track the annual motion of the planets by plotting their position on either graph paper or a star chart using celestial coordinates. (See Resources for a free star chart source.)

Planet	11/3	11/17	11/24
Mercury			
Right ascension	$16^h05^m47^s$	$16^h33^m47^s$	$16^h05^m43^s$
Declination	–23°42′35″	–23°34′57″	–20°16′37″
Distance	1.03010	0.74794	0.67780
Venus			
Right ascension	$17^h49^m32^s$	$18^h49^m17^s$	$19^h15^m32^s$
Declination	–27°01′03″	–26°35′28″	–25°43′36″
Distance	0.67294	0.56690	0.51502
Mars			
Right ascension	$2^h57^m10^s$	$2^h37^m28^s$	$2^h29^m53^s$
Declination	16°06′26″	15°27′56″	15°14′21″
Distance	0.46543	0.49267	0.51911
Jupiter			
Right ascension	$13^h59^m43^s$	$14^h11^m15^s$	$14^h16^m55^s$
Declination	–11°05′58″	–12°07′01″	–12°35′59″
Distance	6.42225	6.36153	6.31587
Saturn			
Right ascension	$8^h54^m45^s$	$8^h56^m06^s$	$8^h56^m14^s$
Declination	17°54′42″	17°51′22″	17°51′58″
Distance	9.04801	8.81844	8.70770
Uranus			
Right ascension	$22^h35^m45^s$	$22^h35^m28^s$	$22^h35^m34^s$
Declination	–9°42′27″	–9°43′31″	–9°42′40″
Distance	19.61545	19.84376	19.96337
Neptune			
Right ascension	$21^h09^m24^s$	$21^h09^m51^s$	$21^h10^m14^s$
Declination	–16°31′52″	–16°29′59″	–16°28′19″
Distance	29.97103	30.21138	30.32872
Pluto			
Right ascension	$17^h30^m21^s$	$17^h32^m10^s$	$17^h33^m10^s$
Declination	–15°38′52″	–15°43′29″	–15°45′34″
Distance	31.74816	31.88994	31.94276

Planet	12/1	12/15	12/29
Mercury			
Right ascension	$15^h35^m29^s$	$16^h02^m36^s$	$17^h21^m52^s$
Declination	–16°51′58″	–18°39′32″	–22°56′52″
Distance	0.74720	1.06687	1.29821
Venus			
Right ascension	$19^h38^m16^s$	$20^h08^m59^s$	$20^h11^m34^s$
Declination	–24°31′21″	–21°29′26″	–18°24′11″
Distance	0.46461	0.37143	0.29897
Mars			
Right ascension	$2^h24^m44^s$	$2^h22^m27^s$	$2^h29^m56^s$
Declination	15°08′41″	15°26′53″	16°21′49″
Distance	0.55335	0.64162	0.74998
Jupiter			
Right ascension	$14^h22^m28^s$	$14^h33^m07^s$	$14^h42^m53^s$
Declination	–13°03′41″	–13°54′46″	–14°39′11″
Distance	6.26032	6.12138	5.94950
Saturn			
Right ascension	$8^h55^m59^s$	$8^h54^m25^s$	$8^h51^m32^s$
Declination	17°54′06″	18°02′48″	18°16′37″
Distance	8.60190	8.41236	8.26288
Uranus			
Right ascension	$22^h35^m49^s$	$22^h36^m47^s$	$22^h38^m20^s$
Declination	–9°40′54″	–9°34′35″	–9°24′53″
Distance	20.08432	20.32294	20.54584
Neptune			
Right ascension	$21^h10^m44^s$	$21^h12^m00^s$	$21^h13^m36^s$
Declination	–16°26′11″	–16°20′38″	–16°13′35″
Distance	30.44193	30.64919	30.82130
Pluto			
Right ascension	$17^h34^m11^s$	$17^h36^m20^s$	$17^h38^m28^s$
Declination	–15°47′26″	–15°50′34″	–15°52′48″
Distance	31.98248	32.02045	32.00203

Follow the planets

Mercury will reach its greatest eastern elongation on November 3 and will be visible to the left or east of the Sun, over the western horizon, setting shortly after sunset. By November 24, Mercury will have reached inferior conjunction. Around December 1 Mercury will reappear in the morning skies to the right or west of the Sun. By December 12 Mercury will reach its greatest western elongation—still rising before the Sun. It will then start moving back toward the Sun and superior conjunction in February. During this time period, from our perspective on the Earth's surface, Mercury will appear to move out to the left from the Sun, and then reverse directions and move to the right side of the Sun.

Venus will follow the same pattern as Mercury, only taking longer because of its greater distance from the Sun. Coincidentally, Venus will reach its greatest eastern elongation on November 3. However, due to its larger orbit, Venus will take longer than Mercury to move to the other side of the Sun and western elongation.

Mars will reach opposition on November 7. The positioning of Mars relative to the Earth and the Sun will be similar to a full Moon phase. The Earth will be between Mars and the Sun, or Mars will be on the opposite side of the Earth from the Sun. And, like a full Moon, an outer planet will rise at sunset and set at sunrise, and will be visible all night. A month later, on December 10, Mars will end retrograde motion and resume direct eastward motion.

Jupiter will be moving from conjunction with the Sun in October toward quadrature (a point when an outer planet is at 90 degrees from the Earth and Sun—see Figure 1) and will appear in the east as a morning star. By the end of November, Jupiter will be well placed for viewing over the eastern horizon before sunrise as its separation from the Sun will continue to increase.

Saturn will rise around midnight during the first part of November and two months later, by the end of the year, Saturn will be rising about four hours earlier. On November 22 Saturn will stop its direct eastward motion and begin retrograde motion.

Compare the loops

Once students have enough monthly coordinate data for the planets, they can plot the retrograde loops of various planets and compare them, especially with regard to size and shape of the retrograde loop or path each planet follows.

Moon phases	November	December
New Moon	11/2	12/1
First quarter	11/9	12/8
Full Moon	11/16	12/15
Last quarter	11/23	12/23
New Moon	——	12/31

Internet resources

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

Sun or Moon rise—*aa.usno.navy.mil*

Ephemeris generator—*ssd.jpl.nasa.gov/cgi-bin/eph*

Custom sunrise/sunset calendar—*sunrisesunset.com/custom_srss_calendar.asp*

Questions for students

1. Why is Mercury so difficult to observe? From which position would Mercury be best viewed? *(Mercury is difficult to observe because it is not far from the Sun, and as a result, has a smaller angular separation. Mercury would best be viewed when at either elongation.)*
2. Determine the number of days between when Mercury is at greatest eastern elongation and greatest western elongation. How does this compare with the number of days it takes Mercury to go from greatest western elongation back to greatest eastern elongation? If there is a difference, how would you account for the difference? *(Between eastern and western elongation is 39 days; November 3–December 12. Between western and eastern elongation is 74 days, December 12–February 24. The difference is that as Mercury moves west from eastern elongation, the Sun is also apparently moving east due to Earth's revolution. The combined motions toward each other will move them toward one another. When Mercury moves east from western elongation, it is moving in the same direction the Sun is apparently moving, and so it takes it longer to catch up with and pass the Sun.)*
3. After plotting the 2005 retrograde loop for Mars, predict how you think the retrograde loop for Saturn will compare. (Data for this will be in the May column, when Saturn ends retrograde motion.) *(This is a prediction that could suggest that the retrograde loop for Saturn may be greater, smaller, take more time, or less time than it would for a planet closer to the Earth.)*
4. At which position (see Figure 1) would an outer planet be best viewed from Earth? Explain how this position is the best. *(The best time for viewing an outer planet would be when it is at opposition. It is the best time because the planet will be visible from sunrise to sunset, and it may also coincide with when the planet is closest to the Sun, perihelion.)*

Elongations 2005–2006

Mercury Apparition	Date	Elongation	Venus Apparition	Date	Elongation
	2005			2005	
Evening	11/3	3.5°E	Evening	11/3	47.1°E
Morning	12/12	21.1°W			
	2006			2006	
Evening	2/24	18.1°E			
Morning	4/8	27.8°W	Morning	3/25	46.5°W
Evening	6/20	24.9°E			