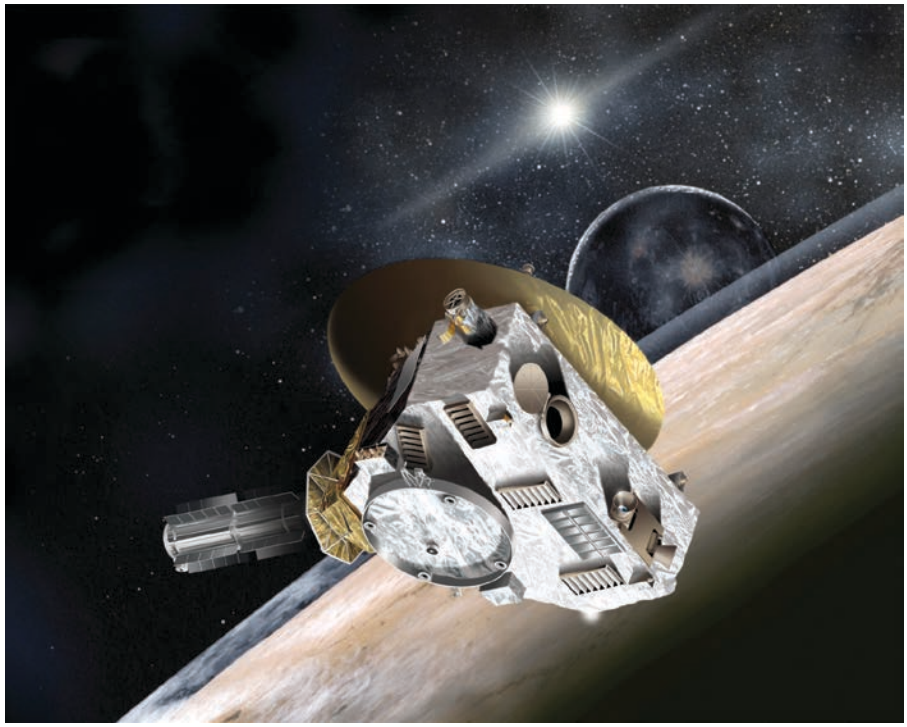
Far out! Exploring the outer reaches of our solar system

by Bob Riddle

On July 14, 2015, the *New Horizons* spacecraft will pass one of the larger objects in the Kuiper Belt: Pluto, one of the many dwarf planets orbiting the Sun in this region of the solar system.

The *New Horizons* mission began its journey to the outer solar system on January 19, 2006 (see Resources for mission website). Several months after launch, *New Horizons* crossed the orbit of Mars and set aim for Jupiter, which it passed in 2007. As *New Horizons* flew by Jupiter, the spacecraft used the planet's powerful gravitational attraction to increase its speed by about 9,000 mph (14,404 km/h) and continued on toward Pluto. Then, for the following eight years, the spacecraft was in hibernation mode as it completed the interplanetary-cruise phase of the mission, which officially ended in June 2015. In hibernation mode, most systems were turned off; however, the spacecraft communicated weekly with mission control, and each year the spacecraft was brought out of hibernation for a systems check. During the hibernation phase, the *New Horizons* spacecraft crossed the orbit of Saturn in 2008, Uranus in 2011, and Neptune in 2014. In December 2014, the spacecraft was brought out of hibernation mode with all systems working, and it has been "awake" and operational since then.



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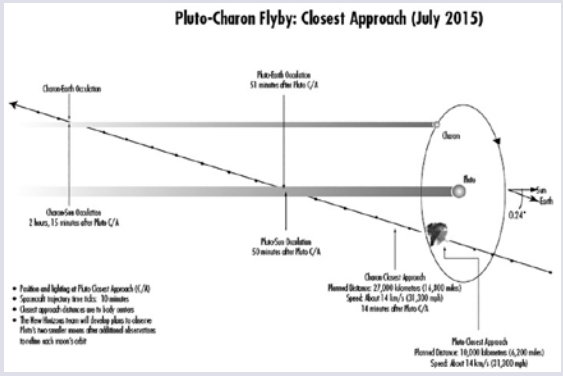
New Horizons Pluto Kuiper Belt Flyby

During July's flyby mission, *New Horizons* will approach Pluto and its five known moons at a speed of about 49,890 km/h (31,000 mph), passing about 9,978 km (6,200 mi.) from Pluto. Because the spacecraft will pass Pluto so quickly, observations and data collection were actually begun in earnest in June 2015, one month before the end of the interplanetary cruise phase. Observations and data collection on Pluto will continue until mid-July. Due to the orientation of Pluto and its largest moon, Charon, at the time of the flyby, the two will be casting a shadow that the spacecraft will pass through, setting up two *occultations* of the Earth, meaning that from the spacecraft's perspective, Pluto and Charon will pass in front of the Earth, blocking the Earth from view momentarily (see Figure 1).

As observations of the other four known moons are made, refinements will be made by mission control scientists in calculations of the moons' respective orbits. Using new data from the spacecraft, the scientists may decide to perform flyby encounters of some of these other moons. Following the Pluto–Charon flybys, the

New Horizons spacecraft will continue outward through the Kuiper Belt, with the potential for additional flybys of Kuiper Belt objects.

FIGURE 1 Pluto encounter timeline

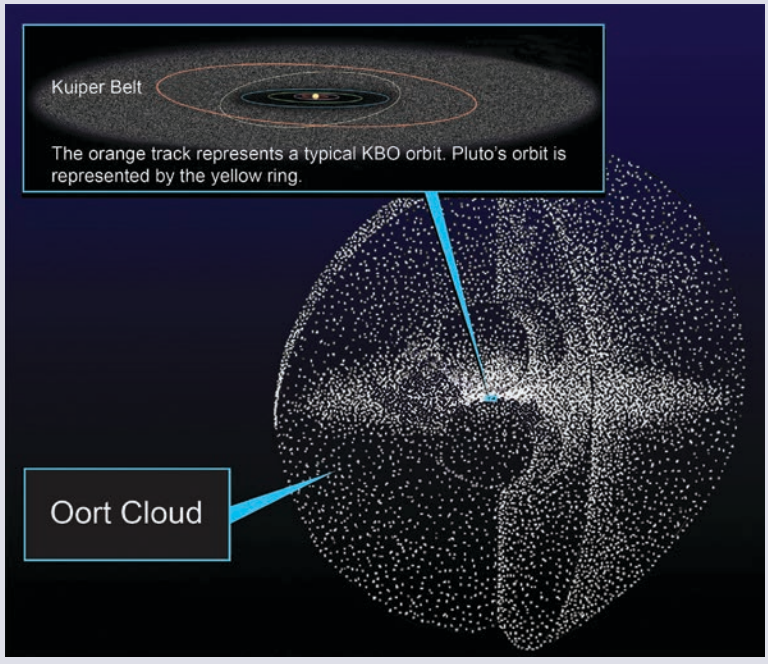


HTTP://PLUTO.JHUAPL.EDU/MISSION

The Kuiper Belt: Home of the comets

The *Kuiper Belt* is a flattened, doughnut-shaped ring of objects orbiting around the Sun that contains leftover planetesimals from the formation of the solar system (see "For Students" question below for more information about planetesimals). It stretches from around Neptune's orbit, 30 AU (4,487,936,121 km or 2,788,674,218 mi.), outward to about 50 AU (7,479,893,535 km or 4,647,790,363 mi.). (One AU, or *astronomical unit*, is the average Earth-to-Sun distance of 149,668,992 km [93,000,000 mi.]). The objects found within the Kuiper Belt all orbit the Sun in the same direction as the planets and follow tilted orbital paths that are more inclined from the plane of the ecliptic than planets and their moons are.

FIGURE 2 Kuiper Belt and Oort Cloud



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Some of the objects in the Kuiper Belt are comets, which are classified based on their respective location relative to the rest of the solar system (see Figure 2). Most comets with relatively short *orbital periods* (the time it takes the comet to complete one revolution around the Sun) of less than 200 years come from the Kuiper Belt. However, some of these short-period comets come from distances not much farther than Jupiter's orbit, relative to the Sun. The regular period of Halley's Comet makes it the best known of the short-period comets; it returns to the inner solar system every 76 years.

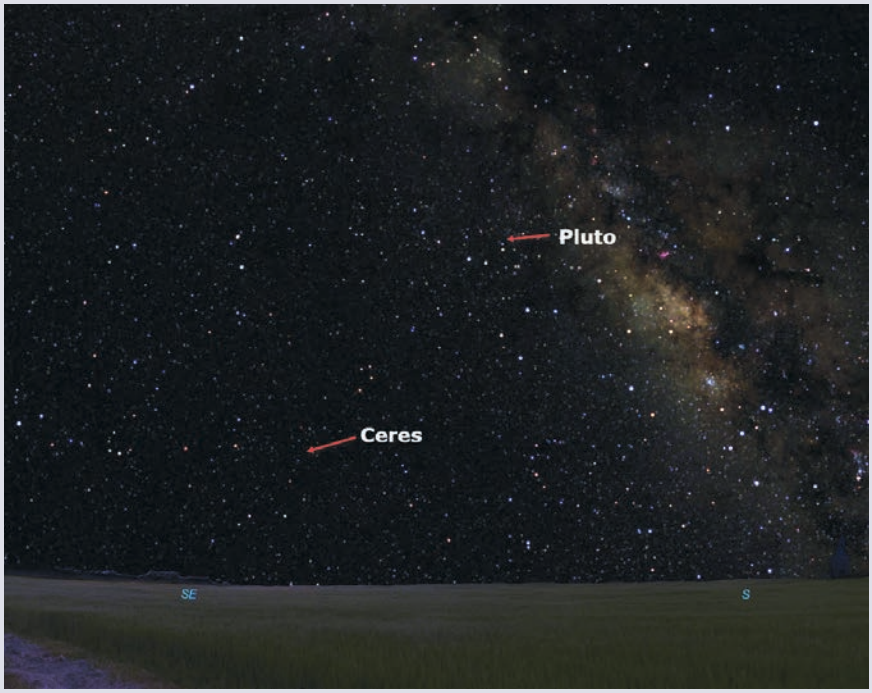
Farther out from the Sun than the Kuiper Belt, the Oort Cloud, which surrounds the solar system, contains additional planetesimals; however, these objects' respective orbits around the Sun are very random compared to the comets in the Kuiper Belt. Oort Cloud objects have considerably longer periods than Kuiper Belt comets and orbit the Sun from many different angles and directions. It is thought that these comets were "propelled" by gravitational interactions from their original orbits closer to the Sun to where they are now, similar to the way the *New Horizons* spacecraft used a gravity assist from Jupiter to "propel" it toward Pluto. These interactions also cause the randomness in the objects' orbits. One of the recent and more memorable long-period objects from the Oort Cloud was Comet Pan-STARRS (C/2011 L4),

which brightened enough at perihelion to become visible with the naked eye (see Resources for more information about comets).

Connecting past and future

There are not many generational events in our lifetime that we are able to connect with like we can with Halley's Comet. This comet has a very long history of sightings dating back to Chinese records from around 240 BCE. The last time Halley's Comet passed by the Earth was in 1986 and, with a 76-year period, it will next appear in 2061. It is possible that you or your students know someone born in 1986 and that many will still be around when Halley's Comet returns. Mark Twain was born during the 1835 comet passage and coincidentally passed away with the comet's return in 1910. If possible, show your students a short video of "Halley Came to Jackson" by Mary Chapin Carpenter (see Resources). It tells a story about a girl born in 1910 who is shown Halley's Comet as a baby and again in 1986 at an older age. Follow this up by having students imagine what they and the world will be like in 2061.

FIGURE 3 Location of two dwarf planets on July 16



Pluto data

- Diameter: 2,274 km (1,413 mi.)
- Average distance from the Sun: 5,913,514,070 km (3,674,487,288 mi.; 39.5294 AU)
- Rotational period: 6.3872 Earth days
- Orbital period: 248.54 Earth years
- Tilt of axis: 122.52°
- Orbital inclination: 17.148°
- Equatorial surface gravity: 0.4 m/s^2 (Earth: 9.8 m/s2)
- Atmospheric composition: Nitrogen, methane

Is it a planet or a comet?

Pluto, which was discovered in 1930 by Claude Tombaugh, is the most well-known and studied member of the Kuiper Belt. For many years, it has been an enigma when considered with the eight planets. Although it is a "hard" planet with rocky terrain, similar to the planets closest to the Sun, it is in a part of the solar system where the planets are mostly liquids and gases. Pluto seems to belong in neither group. With an orbital inclination of nearly 18° relative to the plane of the ecliptic, Pluto orbits the Sun at a steeper angle than the eight planets, making it more similar to the Kuiper Belt comets.

So what is Pluto? It is round like a planet and it orbits the Sun like a planet; however, Pluto fits the current definition of a dwarf planet better because of its distance from the Sun (see Resources for more information about dwarf planets). Pluto is also the first of a group collectively called trans-Neptunian objects,

or plutoids. Over the past few years, other objects in the Kuiper Belt have been discovered, some of which have been approximately the same size as Pluto. One of these objects, Eris, which was discovered in 2003, is estimated to be larger than Pluto. The discovery of Eris, as well as many more objects like it, contributed to the impetus to redefine Pluto as a dwarf planet. To get a sense of the number of objects in the Kuiper Belt, visit the Minor Planet website (see Resources). There, under the "Observers" tab, choose "Lists and Plots," then scroll down to the links for plots or graphic displays of the known Kuiper Belt objects. ■

Visible planets

Mercury will be visible over the northeastern horizon at sunrise for the last half of June and first half of July before moving behind the Sun at superior conjunction at the end of July. Watch for Mercury to reappear in the evening skies at sunset during August.

Venus will be visible over the western horizon at sunset during June and July as it heads toward inferior conjunction during mid-August.

Mars will be in conjunction with the Sun and will not be visible during June and July. Mars will reappear in the morning skies during the latter half of August.

Jupiter will be visible but low over the western horizon during June and July, and by August, it will be too close to the Sun to be seen.

Saturn will be visible all night during our summer months and will be in retrograde until mid-August.

For students

1. What are *planetesimals*? *(A* planetesimal *is an object that is theorized to have formed during the early stages of solar system formation. Over time, they collided with other planetesimals and gradually coalesced into planets.)*
2. For about 20 years, Pluto was closer to the Sun then Neptune. At the Minor Planet website (see Resources), there is an animation of the outer solar system showing the movement of Kuiper Belt objects at 200-day intervals over a 100-year period, including Pluto (represented in the animation with a white, crossed circle). During which years was Pluto closer than Neptune? *(Between 1979 and 1999, Pluto was closer to the Sun than Neptune.)*
3. Since Pluto crosses Neptune's orbit, will the two planets ever collide? *(Pluto orbits the Sun twice for every three orbits that Neptune completes. This is called orbital resonance and, as a result, they will not collide because of their respective orbital periods.)*
4. Research the names used for Pluto and its Moons. How is a name determined and what, if any, are the rules or guidelines for naming a planet or moon?

Note: The September issue of *Science Scope* will provide strategies for using the Pluto debate (planet versus dwarf planet) to introduce argumentation and critical-thinking skills into the middle level science classroom.

June

1	Waxing gibbous Moon near Saturn
2	Full Moon
6	Venus at eastern elongation
9	Last quarter Moon
	Moon at perigee 369,700 km (221,820 mi.)
10	Moon at descending node
13	Venus very near Beehive open star cluster
14	Mars at solar conjunction
16	New Moon
	Cassini flyby of Dione
18	Spring equinox on Mars
20	Waxing crescent Moon near Venus
21	June solstice: 12:38 pm EDT
23	Mercury near Aldebaran
	Moon at apogee 404,100 km (242,460 mi.)
24	First quarter Moon
	Mercury western elongation
	Moon at ascending node
28	Moon near Saturn
30	Venus–Jupiter conjunction

July

1 Full Moon
Venus near Jupiter

5 Moon at perigee 367,100 km (220,260 mi.)
Cassini flyby of Pan and Telesto
Dwarf planet Ceres occults dim star

6 Earth at aphelion: 1.0167 AU (152,096,155 km; 94,508,169 mi.)

7 Moon descending node
Cassini flyby of Titan
Dwarf planet Pluto at opposition

8 Last quarter Moon

12 Moon near Aldebaran

14 Venus near Regulus
New Horizons flyby of dwarf planet Pluto

15 New Moon

16 Mercury near Mars

18 Waxing crescent Moon near Jupiter and Venus

21 Moon at apogee: 404,800 km (242,880 mi.)
Moon at ascending node

23 Mercury at superior conjunction
First quarter Moon
Dwarf planet Ceres closest to Earth

25 *Cassini* flyby of Titan

26 Moon near Saturn

27 *Cassini* flyby of Dione and Enceladus

31 Full Moon
Venus near Jupiter

August

2 Moon at perigee: 362,100 km (217,260 mi.)

3 Moon at descending node

5 Mercury near Venus

6 Last quarter Moon

7 Mercury near Regulus and Jupiter

8 Moon near Aldebaran

13 Perseid shower: ZHR = 90

14 New Moon

15 Venus at inferior conjunction

16 Waxing crescent Moon near Mercury

17 Moon at ascending node
Moon at apogee: 405,900 km (243,540 mi.)
Cassini flyby of Dione and Tethys

19 Mars near Beehive open star cluster

22 Moon near Saturn
First quarter Moon

26 Jupiter at solar conjunction

29 Full Moon
Venus near Mars

30 Moon at perigee: 358,300 km (214,980 mi.)

31 Moon at descending node
Neptune at opposition

Resources

Astronomy Day—*www.astroleague.org/al/astroday/astroday.html*
Definition of a planet—*www.iau.org/static/resolutions/Resolution_GA26-5-6.pdf*
"Halley Came to Jackson"—*http://youtu.be/Om3j8VP1oCI*
Halley's Comet—*www.space.com/19878-halleys-comet.html*
International Astronomical Union Minor Planet Center—*www.minorplanetcenter.net*
New Horizons mission—*http://pluto.jhuapl.edu*
Pluto fact sheet—*http://nssdc.gsfc.nasa.gov/planetary/factsheet/plutofact.html*
Information about Pluto—*www.iau.org/public/themes/pluto*
Riddle, B. Scope on the Skies: Comet of the century? *Science Scope* 37 (3): 86–90.
Space Day—*www.spaceday.org*

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