# The icy fringes

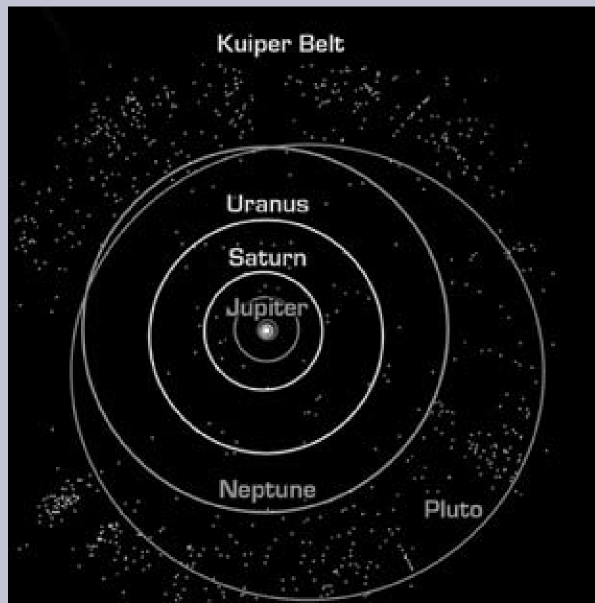
The composition of the planets in our solar system is dictated in part by their distance from the Sun. The Earth-like rocky planets are closer to the Sun, while the gaseous Jovian planets are farther out. Separating the two types is the main asteroid belt. Located within the belt is a frost line, beyond which, objects are less rocky and metallic and composed of more icy compounds. This line is approximately 3.4 AU from the Sun. Within the frost line, temperatures were high enough that only metallic elements were able to condense into objects. Outside the frost line, temperatures were cool enough to allow elements such as hydrogen and helium to condense into gases and ices. These materials accumulated on the large metallic *planetesimals*—the building blocks of the outer planets—which were forming in the region.

Beyond Neptune and to the edge of the solar system is what is collectively known as the *trans-Neptunian region*, and objects in this region are sometimes referred to as TNOs. They are considered to be pristine remnants of the early solar system forming out of the protoplanetary disk. At the lower temperatures further out from the Sun, fewer TNOs formed because of the lack of building materials—fewer rocky objects to serve as the nuclei and smaller amounts of condensable gases that could add icy layers onto the rocks. Various forms of ice are a principal component of many of the outer planet moons. In addition to the icy moons, it has been estimated that there may be around 100,000 other icy objects with diameters greater than 100 km orbiting the Sun in the area of the outer planets and beyond.

## The Kuiper belt

The inner most of the three divisions of the trans-Neptunian region is the *Kuiper belt*. The Kuiper belt ranges from the orbit of Neptune (30 AU) outward to a distance of approximately 50 AU. Curiously, no Kuiper belt objects (KBOs) have been found beyond this point, despite our having the technological capability to do so. Currently, there are around 1,000 known icy objects (see Figure 1) including dwarf planets Pluto and Eris, as well as countless other similar objects, some with moons, such as Neptune's largest moon, Triton, and an assortment of small solar-system bodies like Orcus, Varuna, and Quaoar. The orbits of KBOs are similar to planets in that they are very closely aligned with the plane of the ecliptic and are more circular then elliptical.

**FIGURE 1** The Kuiper belt




This remote region of our solar system is named after Dutch-American astronomer Gerard Kuiper, who proposed its existence in 1951 in an attempt to explain the source location for short-period comets. The solar system beyond Pluto could be the source region for short-period comets—those with orbits of less than 200 years, such as Comet Encke (3.3 years) and Comet Halley (75–76 years). However, a similar proposal was made in 1943 by Irish astronomer Kenneth Edgeworth when he hypothesized that the region of the solar system beyond the planets would be inhabited by numerous small icy objects. The first known KBOs are technically Pluto and Charon; however, on August 30, 1992, after five years of searching, American astronomers David Jewitt and Jane Luu, using a similar blink comparator method as did Pluto discoverer Clyde Tombaugh, discovered the 160 km diameter KBO (discovery name [15760] 1992 QB1).

## Scattered disk objects

Beyond the Kuiper belt, and extending outward to approximately 100 AU, is an area around the solar system where very long-period TNOs travel. They have elliptical orbits that are steeply inclined to the plane of the ecliptic. While some of these objects may have a perihelion within the Kuiper belt, their aphelion is estimated to be near the inner edges of the Oort cloud. Sometimes called an inner Oort cloud object, or even a scattered disk object (SDO), is Sedna, an object possibly the size of Pluto with an orbital period of approximately 12,000 years. Its closest approach to the Sun is 76 AU, while at its most distant is nearly 1,000 AU from the Sun.

## Heliosphere and heliopause

Radiating outward from the Sun in all directions are the solar wind, charged particles, and electrons and protons, streaming from the Sun's upper atmosphere. On Earth, as with other planets with magnetic fields, we see an effect of the solar wind in the form of auroras. However, as distance increases from the Sun, the effect or strength of the solar wind decreases to the point where the strength of the interstellar medium wind is greater. The *interstellar medium* is the material between stars and is composed of the dust and gases from which stars may form, as well as electromagnetic radiation. The area within the measurable strength of the solar wind is called the *heliosphere* (see Figure 2), and the region where the transition from solar wind to interstellar medium wind takes place is known as the *heliopause*. While the exact distance to the heliopause is not known, we may soon have a better idea as instruments on both the *Voyager 1* (85 AU) and *Voyager 2* (76 AU) spacecraft are indicating the changes. Instruments on board the spacecraft measure the amounts of radiation received from the Sun and compare this with background radiations from other stars and the galaxy. When the ratio changes in favor of radiation not from the Sun, or when the Sun's radiation is essentially zero, the spacecraft has truly left the solar system—an area defined by the distance the Sun's radiation reaches.

## Oort cloud

Far beyond the heliopause, extending from the Kuiper belt to an estimated distance of 50,000 AU, is a hypothesized, but never observed spherical-shaped cloud of icy objects and comets surrounding the solar system. Named after Dutch astronomer Jon Oort, it was proposed as a source for the long-period comets like Comet Hale-Bopp, which we see once in a lifetime. The Oort cloud represents the outer-most regions of the protoplanetary disk. The icy objects condensing within the inner regions of the Oort cloud are under some influence, albeit weak, from the Sun's gravity, while in the outer regions, the objects may be more influenced by gravitational interactions with other stars.

## Visible planets

**Mercury** will rise about an hour before the Sun and will be visible, but low, over the eastern horizon for the first week of December.

**Venus** will rise three to four hours before the Sun and will be very visible, shining brightly over the south-southeastern horizon at sunrise.

**Mars** will be at opposition this month, so it will rise around sunset and be visible all night, setting at sunrise.

**Jupiter** will be visible, but very low over the western horizon at sunset, and will set about an hour after the Sun.

**Saturn** will rise before midnight and will be easily seen over the southeastern horizon near the star Regulus at sunrise.

## Celestial events

| | |
|---|---|
| 12/1 | Last quarter Moon, Saturn near Moon |
| 12/9 | New Moon |
| 12/13 | Geminid meteor shower peak |
| 12/17 | First quarter Moon |
| 12/19 | Mars closest to Earth (0.5893 AU) |
| 12/22 | December solstice (0608 UT) |
| 12/23 | Jupiter in conjunction with Sun |
| 12/24 | Full Moon, Mars near Moon, Mars at opposition |
| 12/28 | Saturn near Moon |
| 12/31 | Last quarter Moon |

**FIGURE 2** The scale of the heliosphere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## Questions for students

1. Use the internet to research the origins of the names used for the Kuiper belt objects. Is there a pattern to the names used? What do they have in common? (*The names are chosen based on guidelines from the International Astronomical Union. Trans-Neptunian objects [TNOs] are named after creation deities.*)
2. What were some of the conditions in the outer regions of the solar system that prevented TNOs from becoming as large as the objects closer to the Sun? (*At the fringes of the protoplanetary disk, there was not as much material from which these objects could form. There was less gas condensing and fewer solid icy or rocky objects to serve as condensation nuclei.*)
3. Use the internet to research some of the known KBOs, and for comparison, make a data table of the properties of the objects. Which are dwarf planets and which are small solar-system bodies?
4. *Voyager 1* and *2* are not the same distance from the Sun, yet both are indicating their proximity to the heliopause. What does this suggest about the shape of the heliosphere? (*This suggests that the heliosphere is not perfectly symmetrical or regular in shape.*)

## Resources

Eight planets—*http://seds.lpl.arizona.edu/nineplanets/nineplanets/neptune.html*
Exploring the planets—*www.nasm.si.edu/ceps/etp/etp.htm*
JPL education gateway—*http://education.jpl.nasa.gov*
Meteor showers online—*http://meteorshowersonline.com/geminids.html*
SFA star charts—*www.midnightkite.com/starcharts.html*
Solar system exploration—*http://sse.jpl.nasa.gov/index.cfm*
The scale of the heliosphere—*http://interstellar.jpl.nasa.gov/interstellar/probe/introduction/scale.html*
What lurks in the outer solar system?—*http://science.nasa.gov/headlines/y2001/ast13sep_1.htm*

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