National Aeronautics and Space Administration

small worlds

Informal Lesson Middle School

Where are the small worlds?

Grades: 6-8 | Prep Time: ~10 min | Activity Time: ~65 minutes

WHAT LEARNERS DO: Use a model to collect data in the solar system.

Learners will explore our solar system from the perspective of the Sun. They will observe the motion of different worlds to determine their location in the solar system. Then they will launch probes to search these small worlds for the caches hidden on them in order to collect the astrocoins inside.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES (IO)
WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT? *NGSS Core Question: ESS1: Earth's Place in the Universe* **What is the universe, and what goes on in stars?** *NGSS ESS1.A: The Universe and its Stars* **What are the predictable patterns caused by Earth's movement in the solar system?** *NGSS ESS1.B: Earth and the Solar System*	*Learners will be able to* **IO1: Use a model to make observations, analyze, and interpret empirical evidence to identify patterns in the phenomena of solar system arrangement.**

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1.0 Materials

Required Materials

Please supply:

- Computer or laptop – 1 per learner
    - Supported Browsers: Chrome; Edge; Firefox; Safari

Please Print:

From Learner Guide

(A)	Where are the small worlds? Prediction Worksheet	– 1 per small group
(B)	Where is the Oort Cloud?	– 1 per small group

Or order Kuiper Belt and Oort Cloud lithographs – 1 per student

- NASA/JPL Educator Resource Center
  4800 Oak Grove Dr.
  MS 180-109
  Pasadena, CA 91109

  Phone: (818) 393-5917
  Fax: (818) 393-4977

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2.0 Activity Timeline

Where are the small worlds?
Activity Timeline:

Time:

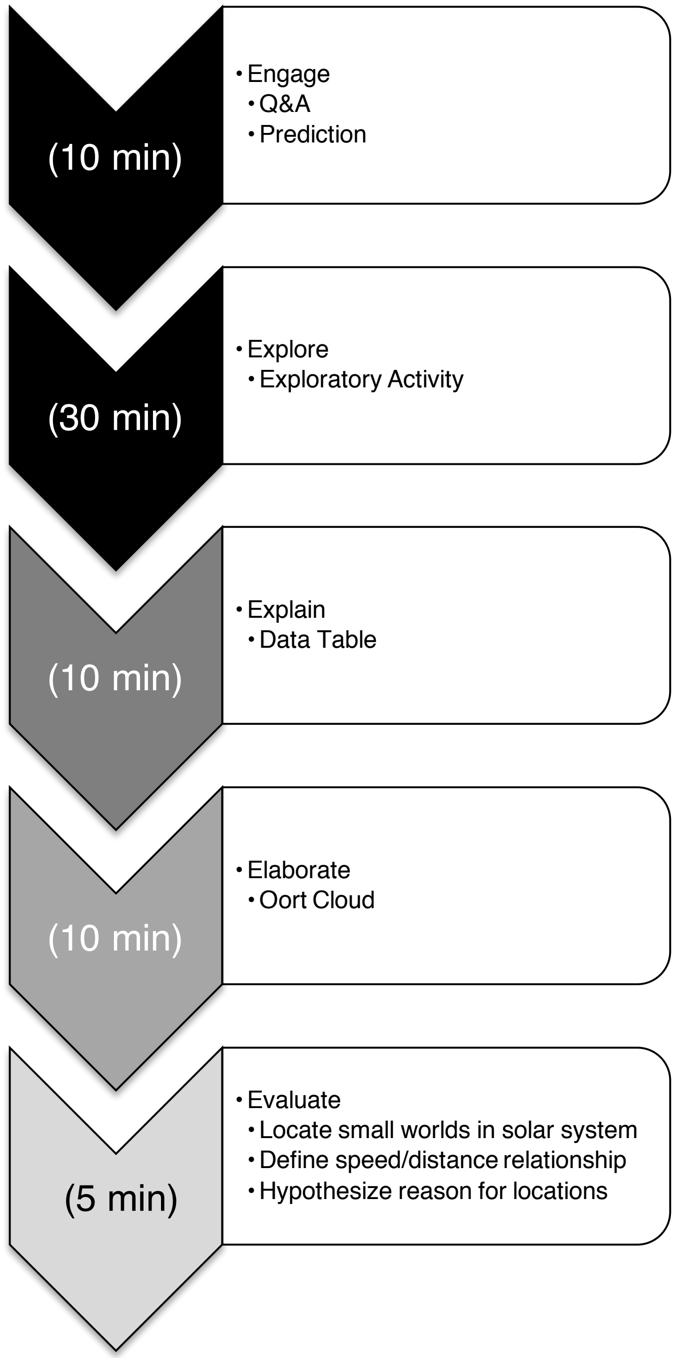
- ~ 65 minutes

Materials:

- Learner Guide pages

5-E Inquiry Process:

- The arrow color represents the 5-E step learners will be primarily engaging in for that class session



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3.0 Vocabulary

analyze	consider data and results to look for patterns and to compare possible solutions
cache	an object that contains a reward
data	facts, statistics, or information
empirical evidence	knowledge gained through direct or indirect observation
explanations	logical descriptions applying scientific information
light-year	the distance light will travel in one Earth year
mission	a spacecraft designed to explore space, seeking to answer scientific questions
model	a simulation that helps explain natural and human-made systems and shows possible flaws
observations	specific details recorded to describe an object or phenomenon
planet	a sphere moving in orbit around the Sun
predict	to declare or state what will happen based on reason and knowledge
relative speed	the speed of one object with respect to another
scale	a comparative relation between objects such as size or distance
small world	a body in the solar system that is not classified as a planet or moon
speed	distance traveled over time
theoretical	based on a hypothesis

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4.0 Procedure

PRIOR KNOWLEDGE & SKILLS

A. Arrangement of the Solar System
B. Planet Names
C. Planet Definition

PREPARATION

A. Visit https://infiniscope.org/lesson/where-are-the-small-worlds/ for access to the digital learning experience and additional resources.

B. PRINT AND LAMINATE THE FOLLOWING:

- Learner **Worksheets (A)** – 1 per small group
- Learner **Worksheets (B)** – 1 per small group

C. PRINT OR ORDER LITHOGRAPHS

STEP 1: ENGAGE (~ 10 minutes)

Set Up the "Where are the small worlds?" Question

A. Facilitate Q&A with learners leading to the "Where are the small worlds?" question (possible learner responses provided beneath each question):

a. *What are small worlds?*
   i. Responses will vary. Learners may have no idea or refer to moons, asteroids, or comets.
b. *What types of objects are found in our solar system?*
   i. Related responses include: planets, Sun, Moon, moons, asteroids, comets, meteoroids
c. *Where do you find the worlds in the solar system?*
   i. Related responses include: in orbit, moons are around planets, terrestrial planets are closer to the Sun, gas planets are further out, asteroids and meteoroids are in the asteroid belt
d. *How many worlds are there?*
   i. Responses may range from 8 to 30 to thousands or millions
e. *Can you see these worlds in the night sky without a telescope?*
   i. Response should be yes or some
f. *Can you see all the possible worlds in the night sky without a telescope?*
   i. Response should be no
g. *Which worlds can you see in the night sky without a telescope?*
   i. Responses may include: the Moon, planets such as Venus, Jupiter, Mars, Saturn
h. *Which worlds are you unable to see without a telescope?*
   i. Responses may vary, but basically center around smaller objects and/or objects that are further away

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i. *Why are these worlds difficult to see?*
   i. They are very small and/or they are far away

j. *For the worlds that you can see in the night sky, how fast do they move?*
   i. Responses will vary

B. Display ***(A) Where are the small worlds? Prediction Worksheet*** and distribute wet erase markers (different colors for each learner if possible). Ask learners to use their marker to draw an "X" on the laminated sheet to predict where they believe these small worlds exist.

STEP 2: EXPLORE (~ 30 minutes)
Where are the small worlds? Exploratory Activity

A. Let the learners know they will be able to answer this question using the Where are the small worlds? Exploratory Activity.

B. Hand out or assign computers and ask learners to access the Where are the small worlds? digital learning experience at https://infiniscope.org/ and choose "***Explore***" to launch the experience.

C. At the conclusion of the activity, learners will need access to the results in the Exploratory Activity to complete the next section.

Educator Tip: If learners seem to be stuck in the activity, it isn't responding in a way that seems correct, or if an error occurs, click the "Restart" button located in the upper right corner of the screen. "Restart" will clear all of their progress and bring them back to the start screen. Hitting the browser's "Refresh" or "Back" button will not restart the activity.

Educator Tip: Learners should never hit the browser's "Refresh" or "Back" button.

Educator Tip: If you would like to analyze learner interactions in this activity, you can sign up to join the ***Infiniscope Teaching Network*** (https://infiniscope.org/join/) and enroll your class into the activity. By enrolling, you will gain access to the analytics of the activity by learner to see how they progressed through the activity. You also have the ability to adopt the activity and adapt it to the specific needs of your classroom, school, or community.

Time Management Tip: Should you run out of class time for learners to complete this section there are a couple of options.

- **Option 1:** If learners are enrolled in the class through the Infiniscope Teaching Network, they can log in at home or at school at another time and pick up where they left off.

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- **Option 2:** If learners are NOT enrolled in the class, you could complete the experience up to nine objects found (3 NEO, 3 MAB, 3 KB) and display the activity using a projector. This set up would occur prior to their meeting session. This will allow learners to see the movement of the objects in the starfield based on object type and distance to complete results discussion.

STEP 3: EXPLAIN (~ 10 minutes)

Tabling Results

A. Guide a discussion with the group using the following questions (responses can be approximations):

   a. Observe the speed of Earth, how much slower than Earth do the Near Earth Objects move? The objects in the Main Asteroid Belt? The objects in the Kuiper Belt? *Answers should point to NEO's move very fast compared to the objects in the Kuiper Belt.*

⃠ **Misconception Alert:** Learners often have clear misconceptions regarding the distances between planets in the solar system. This activity attempts to keep the orbits as close to their correct scaling as possible, however the limitation presented by paper and screen size doesn't allow for precision. A great activity that can be used to address this misconception is *Solar System Size and Scale* developed by Arizona State University's Mars Education Program. For access to this activity: https://marsed.asu.edu/solar-system-scale-and-size

STEP 4: ELABORATE (~ 10 minutes)

Where is the Oort Cloud?

A. Discuss the theoretical presence of the Oort Cloud around the outside of our solar system. The following narrative is provided for your convenience:
"There is more out there, but where and how much more?

In the 1950's Jan Oort (pronounced: yaan ort) hypothesized a zone even further out in the solar system. This zone would explain a special class of comets called long-period comets. These comets take longer than 200 years to orbit the Sun.

This theoretical zone is called the Oort Cloud. It is theoretical because even though there is evidence for its existence, no one has seen an Oort Cloud object other than a few comets thought to have come from this zone.

The Oort Cloud is thought to be a cloudy sphere of icy bodies around the entire solar system. It is believed to extend between 5,000 and 100,000 AU. 100,000 AU is almost 2 light-years away from Earth!

This means it takes nearly two full Earth years for light to reach this zone from the Sun. To compare, light travels from the Sun to Earth in just eight minutes!"

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B. Show learners the ***(B) Where is the Oort Cloud?*** and ask them the following questions:

a. If the Oort Cloud is 5,000 – 100,000 AU away from the Sun, how slow would these objects be moving compared to Earth? *So slow we couldn't observe the movement.*

b. Based on this information, why do you think it is so difficult for scientists to confirm the presence of the Oort Cloud? *Answers should focus on the distance of objects in the Oort Cloud. The Oort Cloud is so far away that scientists are unable to make clear observations and measurements of the objects.*

C. Remind learners that science is never done. There is always more to explore or even more experiments to do on what we know today. The scientific theories of today may be revised or completely rewritten in 20 years. That's why we continue to explore. New information either further supports our current explanations of the world and universe or it begins to change our views to consider other possible explanations. In this case, there is still so much to explore about our own solar system!

🛇 **Misconception Alert:** Learners often arrive to science class assuming science is a list of facts to memorize in order to "master" science and become a scientist. Constantly remind learners that science evolves with new information, new experiments, and new technology. The "rules" written in the textbooks today may be totally different in the future with new information.

D. Point out the furthest a NASA mission has ever traveled is past Pluto and into interstellar space. This mission is called Voyager 1.

STEP 5: EVALUATE (~ 5 minutes)
Evaluate Small World Zones and Use of Model

A. Have learners revisit the laminated prediction sheet. As a group, label the location of these small world zones (NEO, MAB, and KB). *See Key (C) Where are the small worlds? Evaluation attached.*

B. Ask learners:

a. How does the distance of the object relate to the relative speed of the object? *The further the object is from the Sun in the solar system, the slower it's relative speed.*

b. Why do you think these small worlds appear in zones instead of all over the solar system? *This response is really a hypothesis to get the learner thinking deeper on the topic.*

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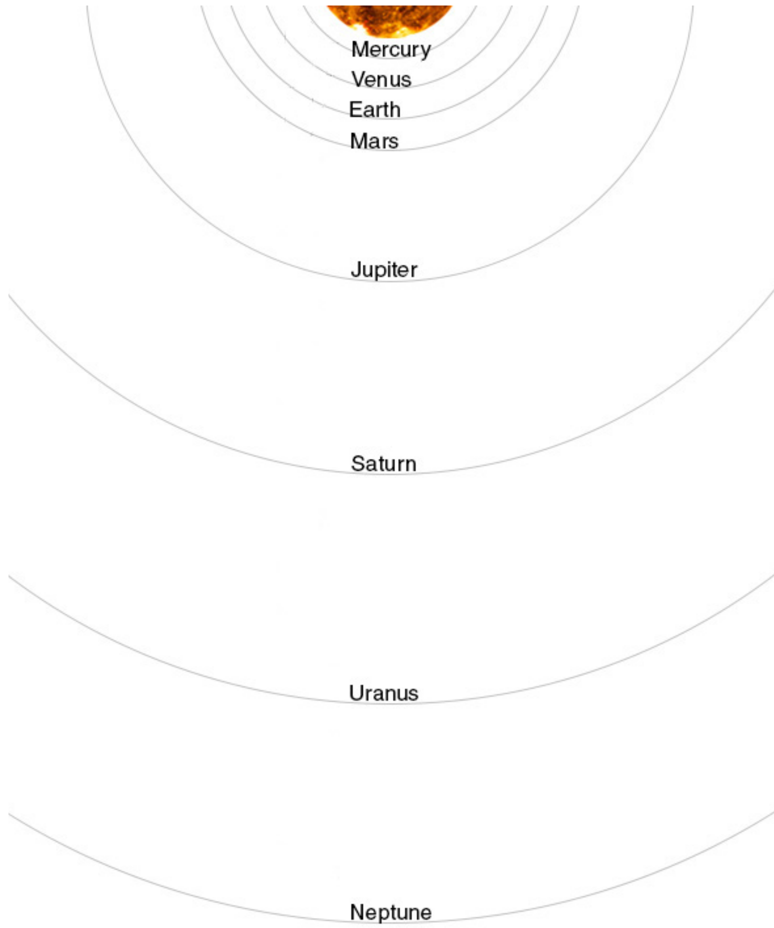
(A) Where are the small worlds? Prediction Worksheet

Instructions:

Draw, label or shade the area or areas you think the small worlds are found in the solar system.



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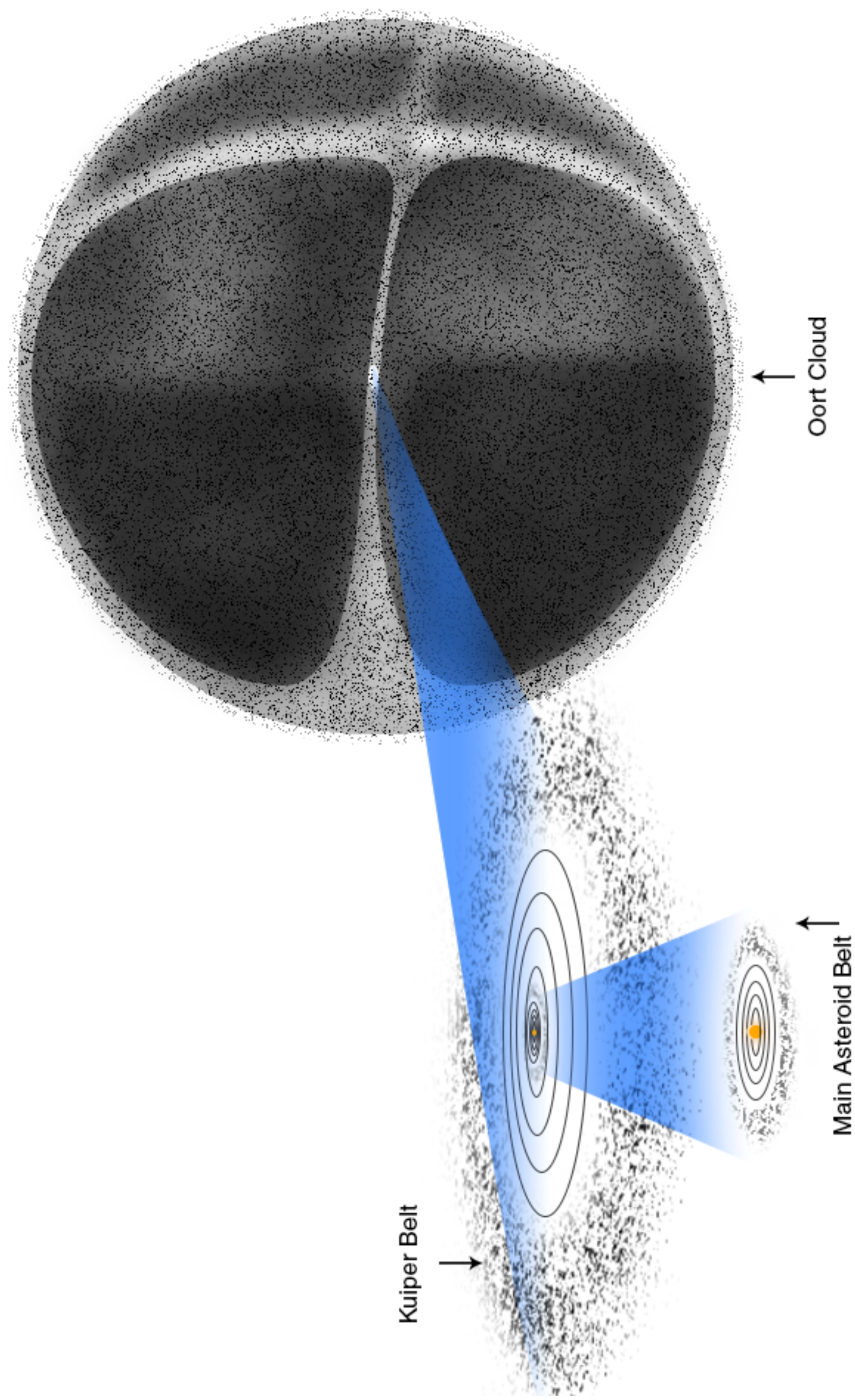
(B) Where is the Oort Cloud?



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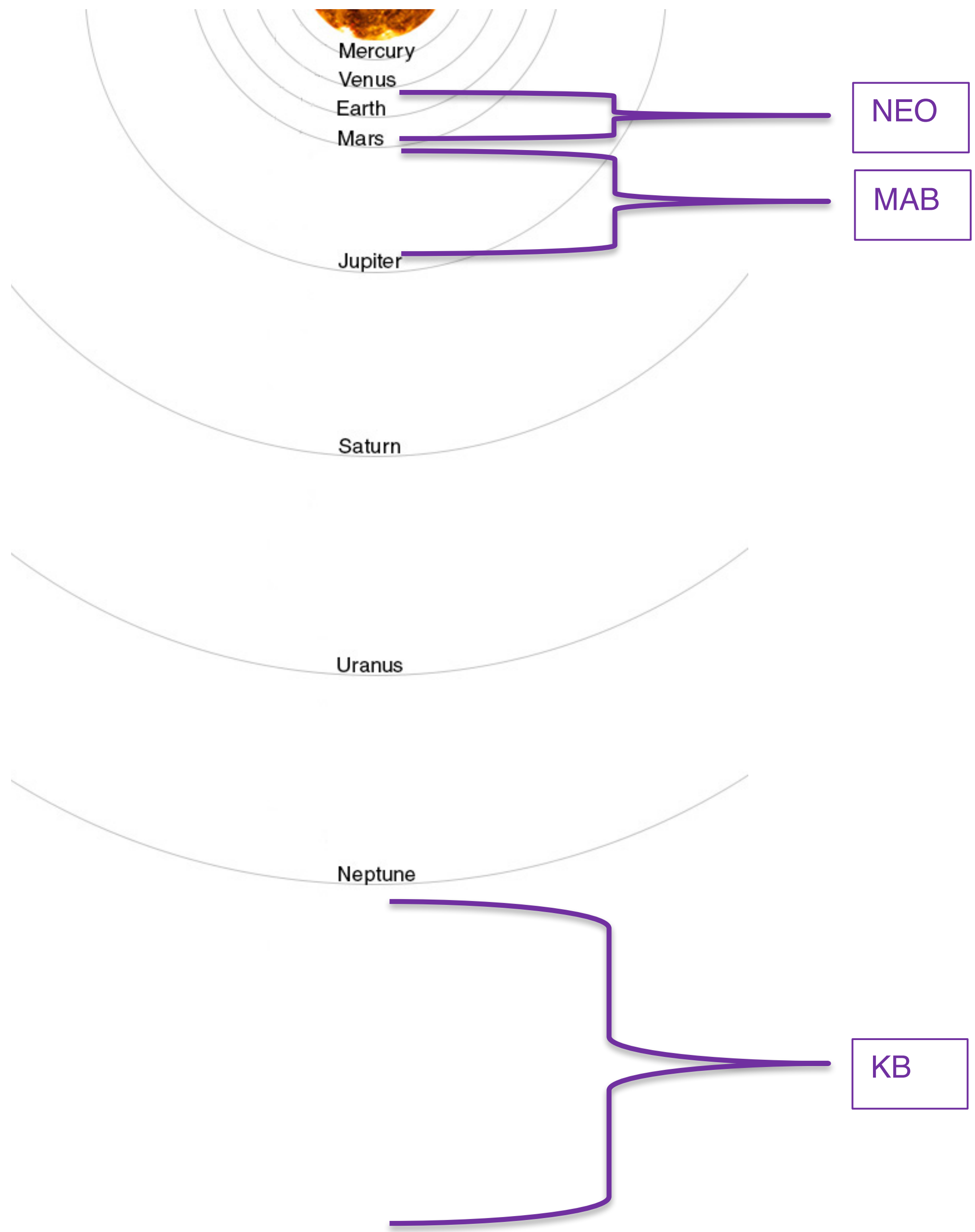
(C) Where are the small worlds? Evaluation (KEY)

Instructions:

Label the areas **(NEO, MAB, and KB)** representing where the small worlds are found in the solar system.



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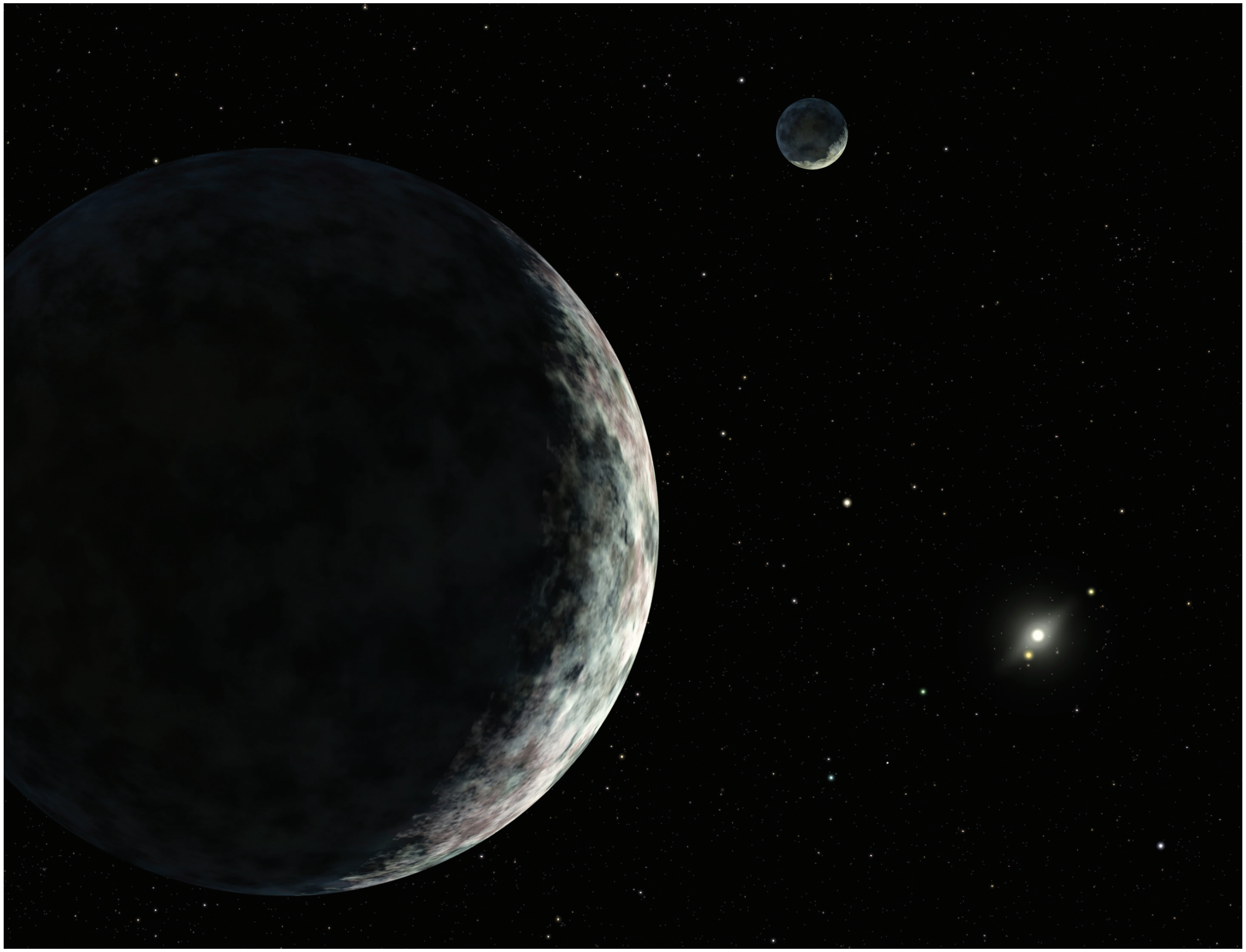
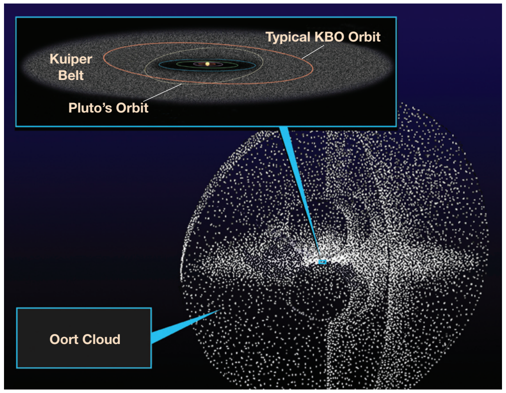
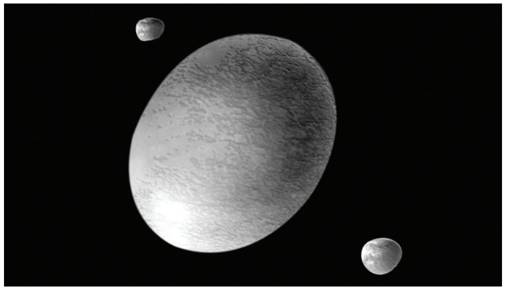
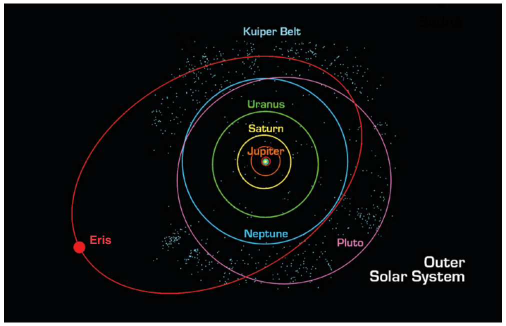








Kuiper Belt and Oort Cloud

In 1950, Dutch astronomer Jan Oort proposed that certain comets come from a vast, extremely distant, spherical shell of icy bodies surrounding the solar system. This giant swarm of objects is now named the Oort Cloud, occupying space at a distance between 5,000 and 100,000 astronomical units. (One astronomical unit, or AU, is the mean distance of Earth from the Sun: about 150 million kilometers or 93 million miles.) The outer extent of the Oort Cloud is considered to be the "edge" of our solar system, where the Sun's physical and gravitational influence ends.

The Oort Cloud probably contains 0.1 to 2 trillion icy bodies in solar orbit. Occasionally, giant molecular clouds, stars passing nearby, or tidal interactions with the Milky Way's disc disturb the orbit of one of these bodies in the outer region of the Oort Cloud, causing the object to streak into the inner solar system as a so-called long-period comet. These comets have very large, eccentric orbits and are observed in the inner solar system only once.

In contrast, short-period comets take less than 200 years to orbit the Sun and they travel along the plane in which most of the planets orbit. They are presumed to come from a disc-shaped region beyond Neptune called the Kuiper Belt, named for astronomer Gerard Kuiper. The objects in the Oort Cloud and in the Kuiper Belt are presumed to be remnants from the formation of the solar system about 4.6 billion years ago.

The Kuiper Belt extends from about 30 to 55 AU and is probably populated with hundreds of thousands of icy bodies larger than 100 kilometers (62 miles) across and an estimated trillion or more comets.

In 1992, astronomers detected a faint speck of light from an object about 42 AU from the Sun — the first time a Kuiper Belt object (or KBO for short) had been sighted. More than 1,300 KBOs have been identified since 1992. (They are sometimes called Edgeworth–Kuiper Belt objects, acknowledging another astronomer who also is credited with the idea, and they are sometimes called transneptunian objects or TNOs for short.)

Because KBOs are so distant, their sizes are difficult to measure. The calculated diameter of a KBO depends on assumptions about how brightness relates to size. With infrared observations by the Spitzer Space Telescope, most of the largest KBOs have known sizes.

One of the most unusual KBOs is Haumea, part of a collisional family orbiting the Sun, the first found in the Kuiper Belt. The parent body, Haumea, apparently collided with another object that was roughly half its size. The impact blasted large icy chunks away and sent Haumea reeling, causing it to spin end-over-end every four hours. It spins so fast that it has pulled itself into the shape of a squashed American football. Haumea and two small moons — Hi'iaka and Namaka — make up the family.

In March 2004, a team of astronomers announced the discovery of a planet-like transneptunian object orbiting the Sun at an extreme distance, in one of the coldest known regions of our solar system. The object (2003VB12), since named Sedna for an Inuit goddess who lives at the bottom of the frigid Arctic ocean, approaches the Sun only briefly during its 10,500-year solar orbit. It never enters the Kuiper Belt, whose outer boundary region lies at about 55 AU — instead, Sedna travels in a long, elliptical orbit between 76 and nearly 1,000 AU from the Sun. Since Sedna's orbit takes it to such an extreme distance, its discoverers have suggested that it is the first observed body belonging to the inner Oort Cloud.

In July 2005, a team of scientists announced the discovery of a KBO that is slightly (about 10 percent) larger than Pluto. The object, temporarily designated 2003UB313 and later named Eris, orbits the Sun about every 560 years, its distance varying from about 38 to 98 AU. (For comparison, Pluto travels from 29 to 49 AU in its solar orbit.) Eris has a small moon named Dysnomia.

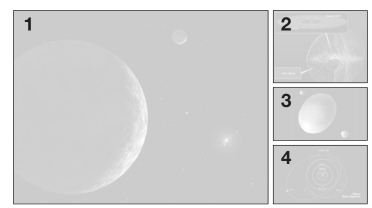
The discovery of Eris — orbiting the Sun and larger than Pluto (which was then designated the ninth planet) — forced astronomers to consider whether Eris should be classified as the tenth planet. Instead, in 2006, the International Astronomical Union created a new class of objects called *dwarf planet*, and placed Pluto, Eris, and the asteroid Ceres in this category. As of September 2009, Pluto, Eris, Haumea, and a fourth object, Makemake, have been formally classified as dwarf planets. These four are also classified as KBOs (or TNOs).

While no spacecraft has yet traveled to the Kuiper Belt, NASA's New Horizons spacecraft, which is scheduled to arrive at Pluto in 2015, plans to study one or more KBOs after the Pluto mission is complete.

SIGNIFICANT DATES

1943 — Astronomer Kenneth Edgeworth suggests that a reservoir of comets and larger bodies resides beyond the planets.
1950 — Astronomer Jan Oort theorizes that a vast population of comets may exist in a huge cloud on the distant edges of our solar system.
1951 — Astronomer Gerard Kuiper predicts the existence of a belt of icy objects just beyond the orbit of Neptune.
1992 — After five years of searching, astronomers David Jewitt and Jane Luu discover the first KBO, 1992QB1.
2002 — Scientists using the 48-inch Oschin telescope at Palomar Observatory find Quaoar, the first large KBO hundreds of kilometers in diameter. This object was photographed in 1980 but was not noticed in those images.
2004 — Astronomers using the 48-inch Oschin telescope announce the discovery of Sedna (2003VB12).
2005 — Astronomers announce the discovery of 2003UB313. This object, later named Eris, is slightly larger than Pluto.
2008 — The Kuiper Belt object provisionally known as 2005FY9 ("Easterbunny") was recognized in July as a dwarf planet and named Makemake (pronounced MAHkeh-MAHkeh) after the Polynesian (Rapa Nui) creation god. In September, 2003EL61 ("Santa") was designated a dwarf planet and given the name Haumea after the Hawaiian goddess of fertility and childbirth.

ABOUT THE IMAGES



1 Artist's concept of Eris and its moon. The Sun is in the distance.

2 An illustration of the Kuiper Belt and Oort Cloud in relation to the solar system.

3 Artist's concept of Haumea and its two small moons.

4 A diagram showing solar system orbits. The highly tilted orbit of Eris is in red.

FOR MORE INFORMATION

solarsystem.nasa.gov/kuiper