National Aeronautics and Space Administration

small worlds

Middle School Classroom Lesson

Where are the small worlds?

Grades: 6-8 Prep Time: ~10 min Lesson Time: ~105 minutes

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

Students 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

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

INSTRUCTIONAL OBJECTIVES (IO)

Students 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.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: April 23, 2018

1.0 Materials

Required Materials:

Please supply:

- Computer or Laptop – 1 per student
  - Supported Browsers: Chrome; Edge; Firefox; Safari

Please Print:

From Student Guide

(A) Where are the small worlds? Prediction Worksheet – 1 per student
(B) Speed vs Distance Results Worksheet – 1 per student
(C) Where is the Oort Cloud? – 1 per student
(D) Where are the small worlds? Evaluation – 1 per student

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

  NASA has a network of Educator Resource Centers across the country offering free educational materials and resources. **Find one near you!**

Optional Materials:

From Teacher Guide

(E) Speed vs Distance Results Worksheet (KEY)
(F) Where is the Oort Cloud? (KEY)
(G) Where are the small worlds? Evaluation (KEY)

From Alignment Document

(N) "Where are the small worlds? Alignment Rubrics

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

2.0 Lesson Timeline

Where are the small worlds?
Lesson Timeline:

Time:

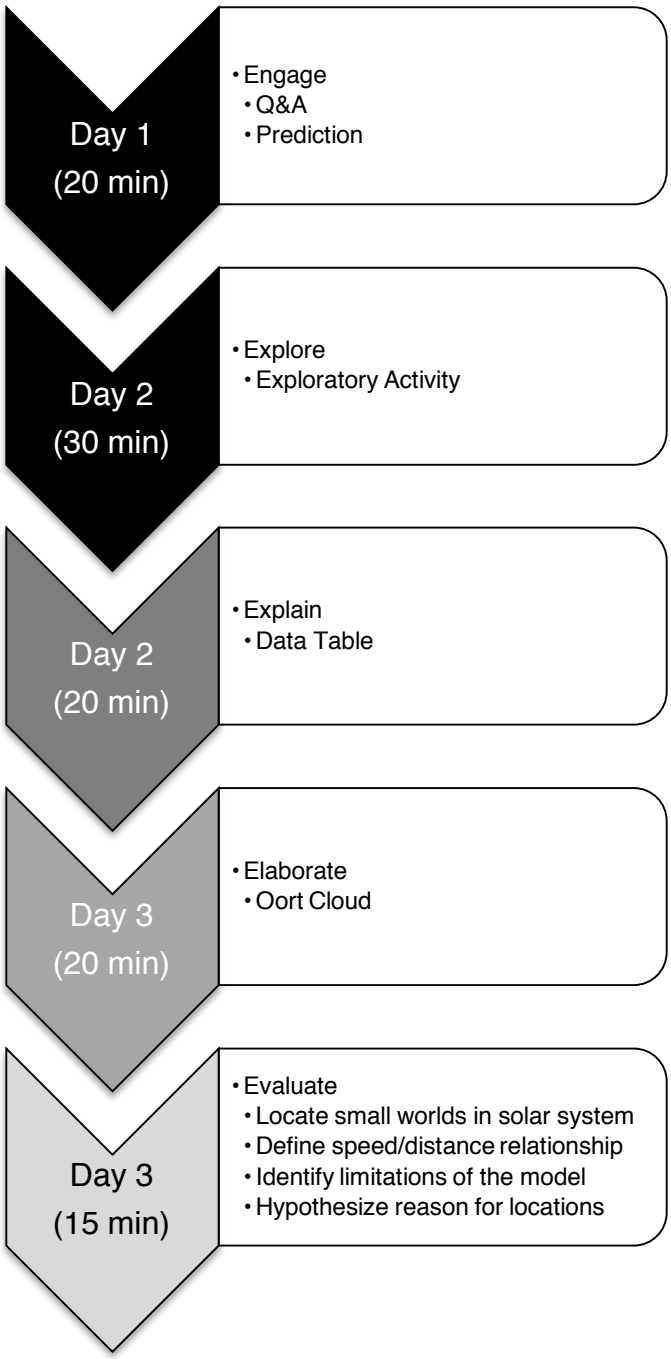
- 105 minutes

Materials:

- Student Guide pages

5-E Inquiry Process:

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



This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

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

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

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, standards alignment documents, and additional resources.

B. Reserve computers or tablets for Exploration Day

C. PRINT THE FOLLOWING:

- Student **Worksheets (A-D)** – 1 per student
- Student **Worksheet Kuiper Belt and Oort Cloud** – 1 per student

STEP 1: ENGAGE (~ 20 minutes)

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

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

a. *What are small worlds?*
   i. Responses will vary. Students 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

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

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. Hand out ***(A) Where are the small worlds? Prediction Worksheet.*** Ask students to draw or label their prediction where they believe these small worlds exist.

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

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

B. Hand out or assign computers and ask students 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, students will need access to the results in the Exploratory Activity to complete the next section.

- **Teacher Tip:** If students 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.

- **Teacher Tip:** Students should never hit the browser's "Refresh" or "Back" button.

- **Teacher Tip:** Students are expected to learn from their failures. This failure model is commonly found in the fields of science and engineering. Failure should not be viewed as a value judgement, but as an example of a **F**irst **A**ttempt **I**n **L**earning. It's an example of what doesn't work and students should keep exploring to find what does work.

- **Teacher Tip:** If you would like to analyze student 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 student to see how students 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.

STEP 3: EXPLAIN (~ 20 minutes)
Tabling Results

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

A. When students have completed the Exploratory Activity, hand out ***(B) Speed vs Distance Results Worksheet*** and use their results to complete the sheet.

B. When students have finished the experience, they will need to click the "Restart" button in the upper right hand corner of the screen. This will clear the student's experience for the next class. If the "Restart" button is not clicked, the next set of students will enter the experience in the same place the previous students left off, which might be the end!

Teacher Tip: Earth is used as a frame of reference for students. An AU is a unit of distance which uses the average distance between the Sun and Earth as a standard unit. AU stands for astronomical unit. Earth is at a distance of 1 AU.

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

- **Option 1:** If students 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.
- **Option 2:** If students 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 next class period. This will allow students to see the movement of the objects in the starfield based on object type and distance to complete ***(B) Speed vs Distance Results Worksheet***.

Misconception Alert: Students often have clear misconceptions regarding the distances between planets in the solar system. This lesson and exploratory 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 lesson 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 lesson: https://marsed.asu.edu/solar-system-scale-and-size

STEP 4: ELABORATE (~ 20 minutes)

Where is the Oort Cloud?

A. Hand out ***(C) Where is the Oort Cloud?*** and the ***Kuiper Belt and Oort Cloud*** lithograph set provided at the end of the lesson.

B. Discuss the theoretical presence of the Oort Cloud around the outside of our solar system.

C. Remind students 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

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

is still so much to explore about our own solar system!

⊘ **Misconception Alert:** Students 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 students 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. Give the students opportunity to complete the information contained in ***(C) Where is the Oort Cloud?*** Discuss their results using ***(F) Where is the Oort Cloud Key*** as a guide. 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 (~ 15 minutes)

Evaluate Small World Zones and Use of Model

A. Hand out ***(D) Where are the small worlds? Evaluation*** (three pages).

B. Discuss what a model is with students. All models have limitations because they rely on data in order to function. Humans decide which data sets to include in the model and therefore the model may not contain all of the information we desire to help answer our questions. Models are not complete representations of the natural world they are based upon.

5.0 Evaluation/Assessment

Use the *(N) Where are the small worlds? Alignment Rubric* as a formative assessment, allowing students to improve their work and learn from mistakes during class. The rubric evaluates the activities using the Learning Outcomes identified in the Alignment Documents for the activity.

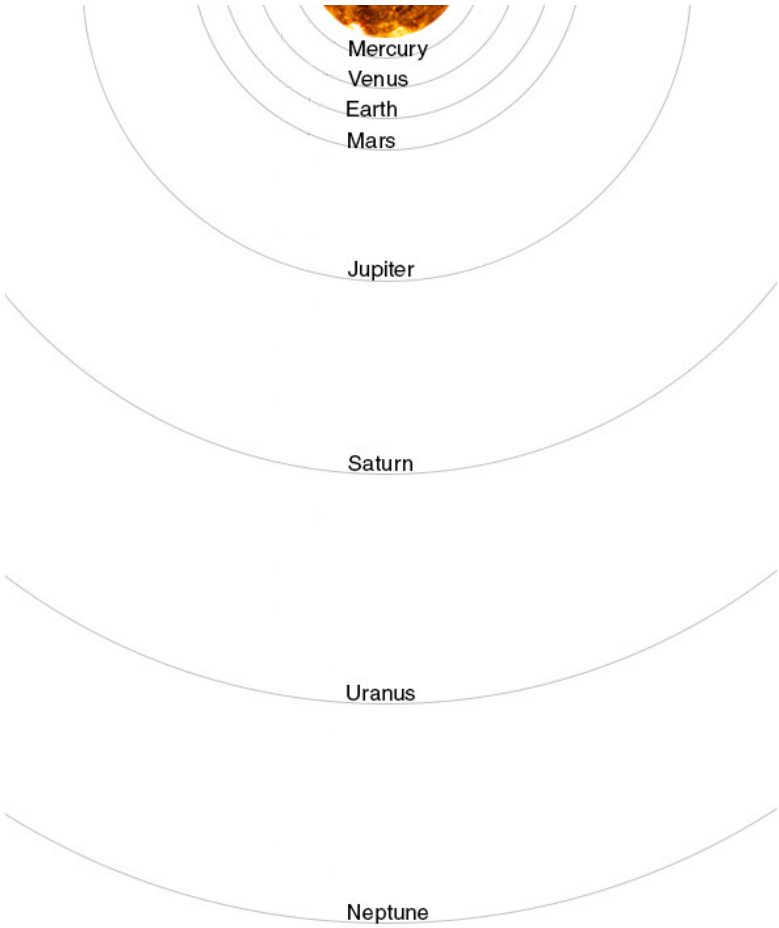
This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(A) Where are the small worlds? Prediction Worksheet

Name: _____

Instructions:

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



This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(B) Speed vs Distance Results Worksheet

Name: _____

Complete the table below using observations from the game.

All of your observations in the game have assumed you were viewing the solar system from the Sun. Earth has been provided as a reference point for your observations. Earth is a distance of 1 AU away from the Sun and is an easy number to work with. An AU is a unit of distance which uses the average distance between the Sun and Earth as a standard unit. AU stands for astronomical unit.

Take a look at your computer screen again. Observe the objects you have identified closely. How fast are they moving compared to Earth? To figure this out, we will need to use a proportional equation.

$$\frac{Earth_{speed}}{Small\ World_{speed}} = \frac{Earth_{distance}}{Small\ World_{distance}}$$

1. For each small world zone, a range of distances has been provided to represent all of the small worlds in that zone. To get started, choose a distance within the range for each small worlds zone and record the distance in the "Distance" column.

2. Using the proportional equation above and the data in the table below, solve for the "Speed of Small World."

3. This relative speed represents the speed of the object, not its relationship to Earth. To find this relationship to Earth, you will need to divide Earth's speed by the speed of the small world. To set up your calculation, write the relative speed you've found in the "1/Speed" column, then solve. Write your final answer in the "Relative Speed Compared to Earth" column.

Small Worlds Zone	Distance from the Sun in AU	Distance	Speed of Small World	1/ Speed	Relative Speed Compared to Earth
Earth (Reference Point)	1	1	1	1/1	1
Near Earth Objects (NEO)	1 – 1.5			1/	
Main Asteroid Belt (MAB)	1.5 - 5			1/	
Kuiper Belt (KB)	30 - 55			1/	

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(C) Where is the Oort Cloud?

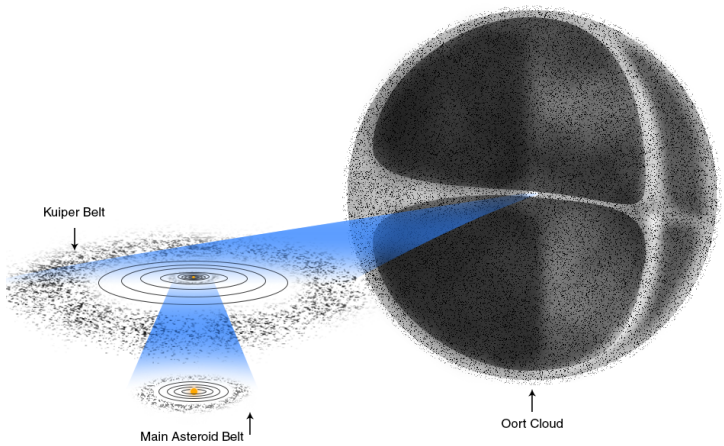
Name: _____

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!



Small Worlds Zone	Distance in AU	Relative Speed Compared to Earth
Near Earth Object (NEO)	1 – 1.5	
Main Asteroid Belt (MBA)	1.5 - 5	
Kuiper Belt (KB)	30 - 55	
Oort Cloud	5,000 – 100,000	

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!

Let's revisit the table you created on the previous page. The Oort Cloud distance has been added.

Fill in the speeds from the previous table, but this time, think about how much slower the Oort Cloud objects may move compared to Earth. If the Oort Cloud is at a distance of 5,000 – 100,000 AU, how slow would these objects be moving compared to Earth? Use the same proportion to solve.

Based on this information, why do you think it is so difficult for scientists to confirm the presence of the Oort Cloud?

_____

_____

_____

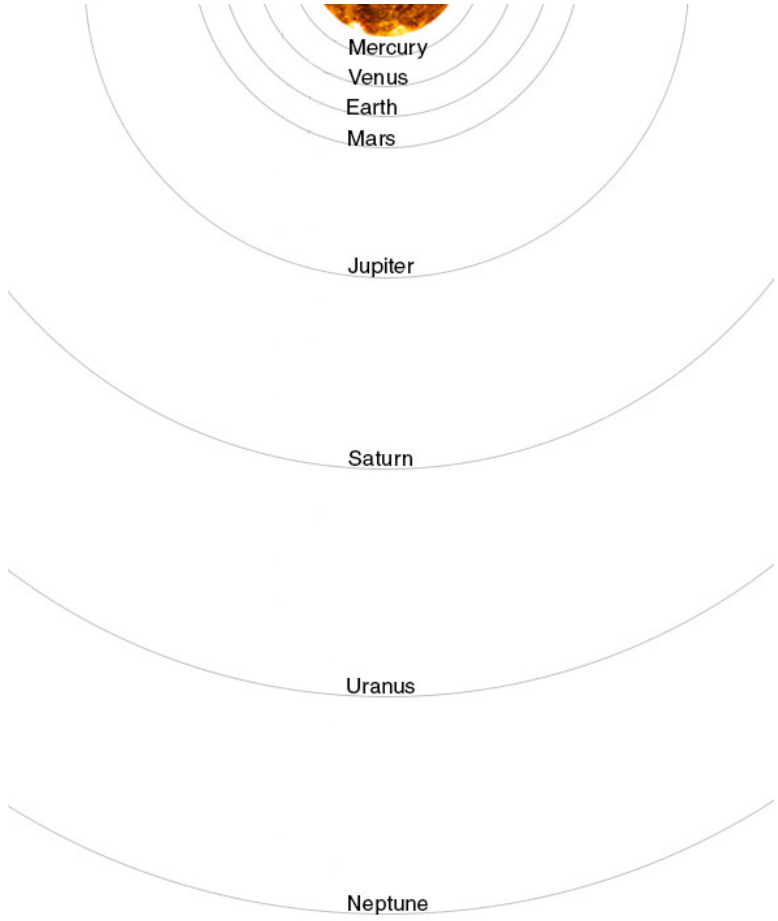
This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(D) Where are the small worlds? Evaluation (Page 1 of 3)

Name: _____

Instructions:

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



This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(D) Where are the small worlds? Evaluation (Page 2 of 3)

Name: _____

Explain the relationship between the relative speed of objects in the solar system and their distance. How can we use this information to locate their distance in the solar system? Support your claims using observations from the *Where are the small worlds?* exploratory activity and your data tables.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(D) Where are the small worlds? Evaluation (Page 3 of 3)

Name: _____

The *Where are the small worlds?* exploratory activity is a model of the solar system. This model contains all of the planets plus 5 small worlds for each zone. All of the objects are represented with their correct orbit shape and position in that orbit for day/time.

However, all models have limitations. *Limitations* are issues with the model that keep you from completing certain tasks or better understanding how they work. ***Name one limitation*** you experienced with this model. How did it keep you from fully understanding or testing your ideas?

_____

_____

_____

_____

_____

_____

_____

These small worlds appear in zones, similar to planet orbits. ***What do <u>you</u> think*** would be a possible explanation for these small worlds appearing in specific zones and not being evenly spread out across the solar system?

_____

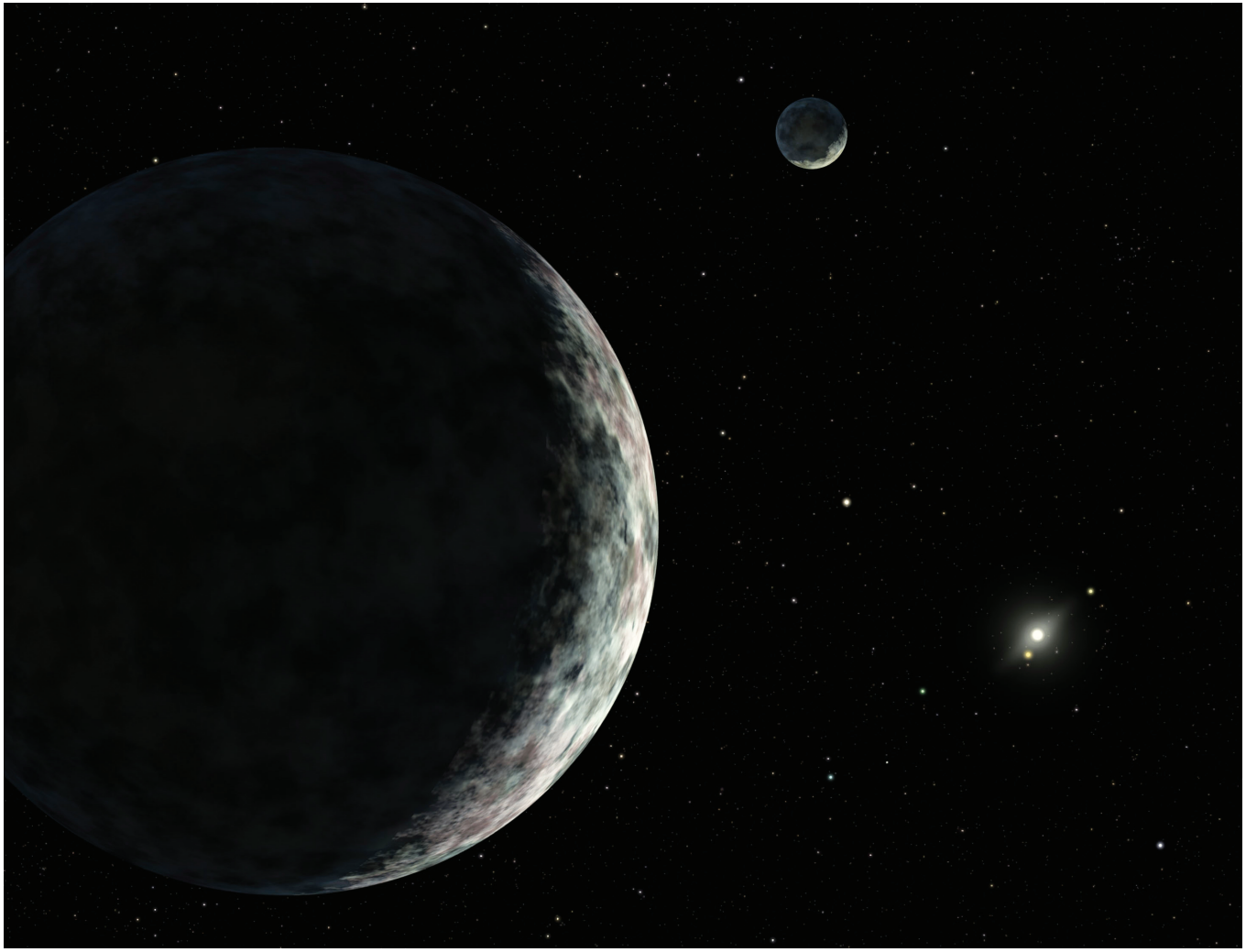
_____

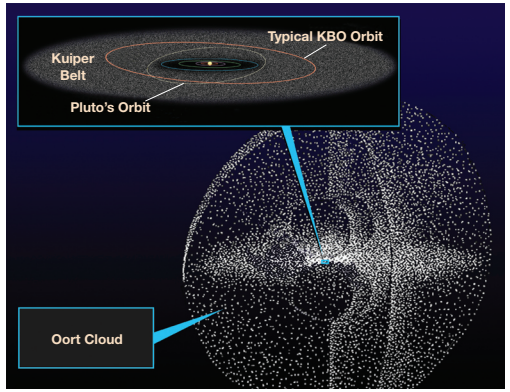
_____

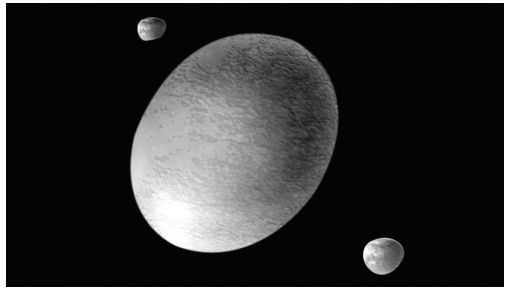
_____

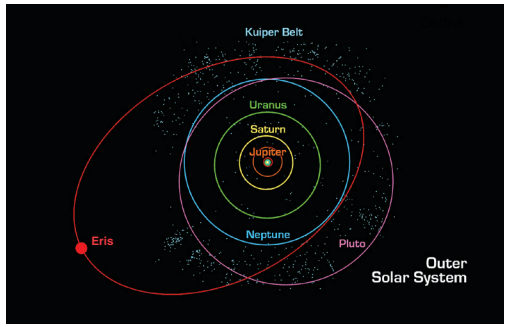
_____

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.









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

(E) Speed vs Distance Results Worksheet (KEY)

Complete the table below using observations from the game.

All of your observations in the game have assumed you were viewing the solar system from the Sun. Earth has been provided as a reference point for your observations. Earth is a distance of 1 AU away from the Sun and is an easy number to work with. An AU is a unit of distance which uses the average distance between the Sun and Earth as a standard unit. AU stands for astronomical unit.

Take a look at your computer screen again. Observe the objects you have identified closely. How fast are they moving compared to Earth? To figure this out, we will need to use a proportional equation.

$$\frac{Earth_{speed}}{Small\ World_{speed}} = \frac{Earth_{distance}}{Small\ World_{distance}}$$

1. For each small world zone, a range of distances has been provided to represent all of the small worlds in that zone. To get started, choose a distance within the range for each small worlds zone and record the distance in the "Distance" column.

2. Using the proportional equation above and the data in the table below, solve for the "Speed of Small World."

3. This speed represents the speed of the object, not its relationship to Earth. To find this relationship to Earth, you will need to divide Earth's speed by the speed of the small world. To set up your calculation, write the relative speed you've found in the "1/Speed" column, then solve. Write your final answer in the "Relative Speed Compared to Earth" column.

Example responses:

Small Worlds Zone	Distance from the Sun in AU	Distance	Speed of Small World	1/ Speed	Relative Speed Compared to Earth
Earth (Reference Point)	1	1	1	1/1	1
Near Earth Objects (NEO)	1 – 1.5	**1.2**	**1.2**	1/**1.2**	**0.83**
Main Asteroid Belt (MAB)	1.5 - 5	**3**	**3**	1/**3**	**0.33**
Kuiper Belt (KB)	30 - 55	**55**	**55**	1/**55**	**0.018**

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

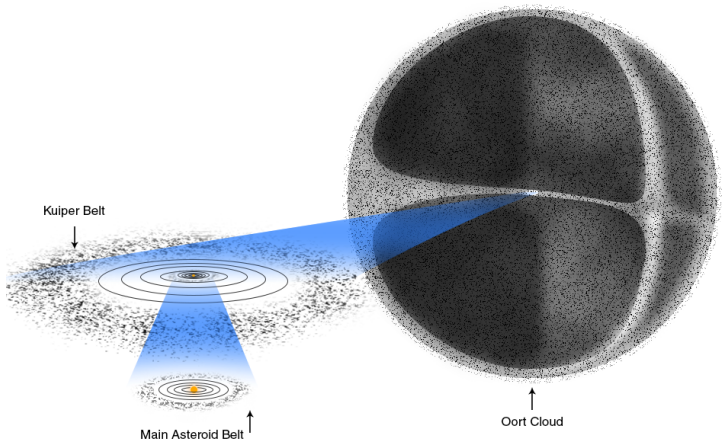
(F) Where is the Oort Cloud? (KEY)

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!



Example responses:

Small Worlds Zone	Distance in AU	Relative Speed compared to Earth
Near Earth Object (NEO)	1 – 1.5	**0.83**
Main Asteroid Belt (MBA)	1.5 - 5	**0.33**
Kuiper Belt (KB)	30 - 55	**0.018**
Oort Cloud	5,000 – 100,000	**0.00001**

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!

Let's revisit the table you created on the previous page. The Oort Cloud distance has been added.

Fill in the speeds from the previous table, but this time, think about how much slower the Oort Cloud objects may move compared to Earth. If the Oort Cloud is at a distance of 5,000 – 100,000 AU, how slow would these objects be moving compared to Earth?

Based on this information, why do you think it is so difficult for scientists to confirm the presence of the Oort Cloud?

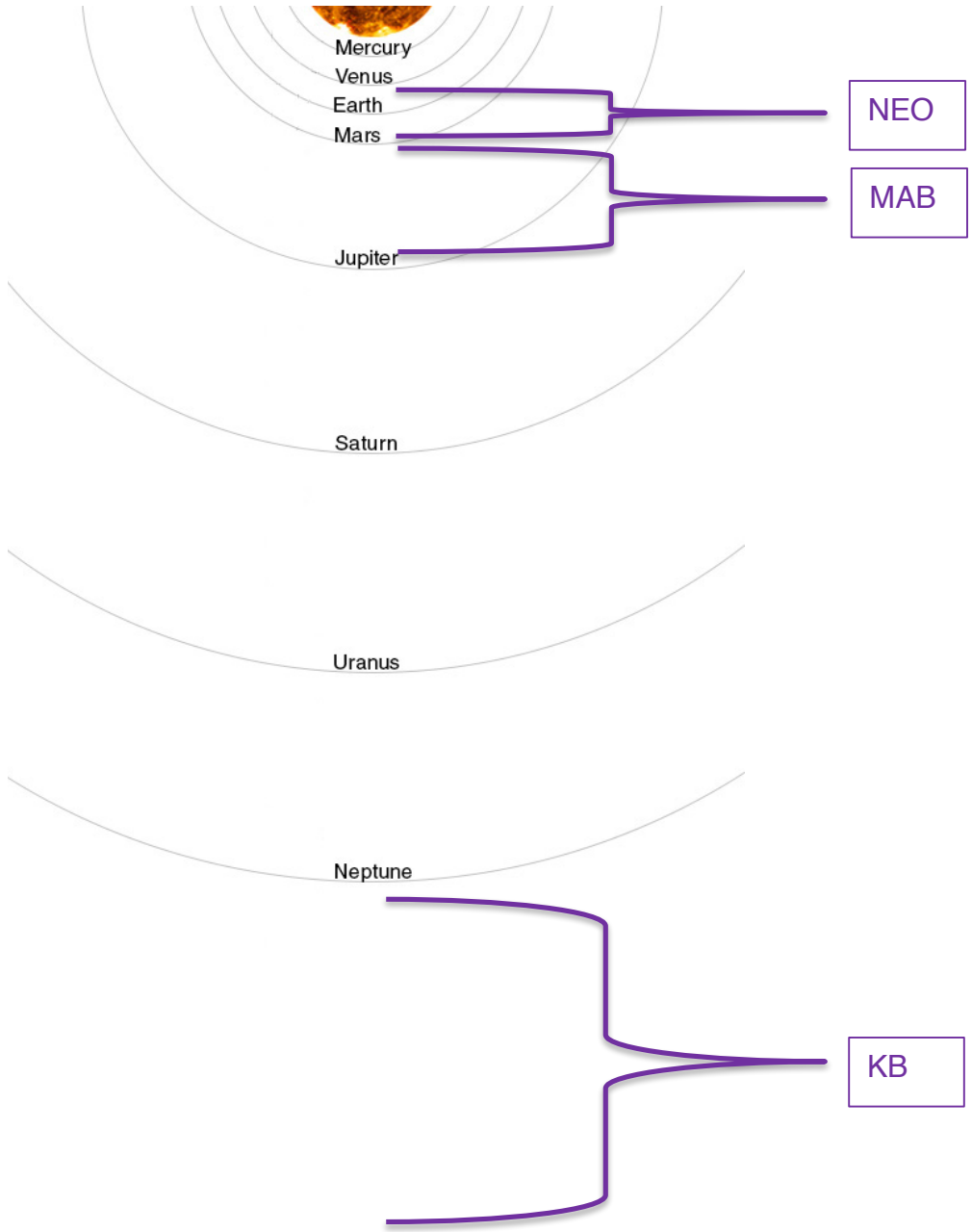
Answers should focus on the distance of objects in the Oort Cloud. Objects in the Oort Cloud are so far away that scientists are unable to make clear observations and measurements of the objects.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(G) Where are the small worlds? Evaluation (Page 1 of 3 - KEY)

Instructions:

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



This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(G) Where are the small worlds? Evaluation (Page 2 of 3 – KEY)

Explain the relationship between the relative speed of objects in the solar system and their distance. How can we use this information to locate their distance in the solar system? Support your claims using observations from the *Where are the small worlds?* exploratory activity and your data tables.

A rubric to evaluate this explanation can be found in the Alignment Documents provided on https://infiniscope.org/lesson/where-are-the-small-worlds/. This question addresses the learning outcome LO1b and can be evaluated using the following rubrics:

- **Where are the small worlds? NGSS Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? NGSS Alignment Rubric.***
- **Where are the small worlds? NRC Framework Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? NRC Framework Rubric.***
- **Where are the small worlds? CC Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? Common Core State Standards Alignment Rubric.***
- **Where are the small worlds? 21st Century Skills Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? 21st Century Skills Alignment Rubric.***

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

(G) Where are the small worlds? Evaluation (Page 3 of 3 - KEY)

The *Where are the small worlds?* exploratory activity is a model of the solar system. This model contains all of the planets plus 5 small worlds for each zone. All of the objects are represented with their correct orbit shape and position in that orbit for day/time.

However, all models have limitations. *Limitations* are issues with the model that keep you from completing certain tasks or better understanding how they work. ***Name one limitation*** you experienced with this model. How did it keep you from fully understanding or testing your ideas?

A rubric to evaluate this explanation can be found in the Alignment Documents provided on https://infiniscope.org/lesson/where-are-the-small-worlds/. This question addresses the learning outcome LO1c and can be evaluated using the following rubrics:

- **Where are the small worlds? NGSS Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? NGSS Alignment Rubric.***
- **Where are the small worlds? NRC Framework Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? NRC Framework Rubric.***
- **Where are the small worlds? 21st Century Skills Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? 21st Century Skills Alignment Rubric.***

These small worlds appear in zones, similar to planet orbits. ***What do you think*** would be a possible explanation for these small worlds appearing in specific zones and not being evenly spread out across the solar system?

A rubric to evaluate this explanation can be found in the Alignment Documents provided on https://infiniscope.org/lesson/where-are-the-small-worlds/. This question addresses the learning outcome LO1d and can be evaluated using the following rubrics:

- **Where are the small worlds? NGSS Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? NGSS Alignment Rubric.***
- **Where are the small worlds? NRC Framework Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? NRC Framework Rubric.***
- **Where are the small worlds? CC Alignment Document Middle School *(N) Teacher Resource. Where are the small worlds? Common Core State Standards Alignment Rubric.***

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.