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This Dwarf Planet Hosts an Odd Ring

SOCIETY FOR SCIENCE

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About this Guide

In science, the exceptions offer researchers a chance to think differently about a concept they thought they understood. In this Guide, students will learn how astronomers use a concept called the Roche limit and how a ring around a dwarf planet does not follow the Roche limit rules.

This Guide includes:

Article-based Comprehension Q&A — Students will answer questions about the online *Science News* article "The Kuiper Belt's dwarf planet Quaoar hosts an impossible ring," which describes a recent astronomical discovery that is completely counter to what scientists expected to see. A version of the article, "This dwarf planet hosts an odd ring," appears in the March 11, 2023 issue of *Science News*. Related standards include NGSS-DCI: MS-ESS1; HS-ESS1.

> **Student Comprehension Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Students will review force diagrams and gravitational force and discuss planetary ring and moon formation using the concept of the Roche limit. Learning Outcomes: Applying gravitational forces and interactions in space to understand ring and moon formation. Related standards include NGSS-DCI: HS-ESS1; MS-ESS1; MS-PS2.

> **Student Discussion Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

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Article-based Comprehension, Q&A

Directions for teachers: Ask students to read the online *Science News* article "The Kuiper Belt's dwarf planet Quaoar hosts an impossible ring" and have them answer the following questions. A version of the article, "This dwarf planet hosts an odd ring," appears in the March 11, 2023 issue of *Science News*.

1. What and where is Quaoar? Can you also name the galaxy in which it resides?

Quaoar is a dwarf planet on the edge of our solar system in the Kuiper Belt. Quaoar is in the Milky Way galaxy.

2. Explain when "stellar occultation" occurs and why scientists use the phenomenon to study planets and other objects in space.

Stellar occultation occurs when the light from a distant star is blocked by a planet passing in front of the star as viewed from Earth. When the planet blocks the star, the planet is silhouetted, and light from the star can be seen around the edge of the planet. The changes in the patterns of the starlight around the planet help astronomers learn about a planet's atmosphere and whether it has rings.

3. What did scientists studying Quaoar discover using stellar occultation?

The scientists discovered that Quaoar appears to have no atmosphere, and it has a ring.

4. If a planet has a ring, where is the ring supposed to be relative to the planet, according to current scientific thinking? What makes the Quaoar discovery extraordinary?

In current thinking, rings are expected to be close to a mathematically determined distance from the planet they are near. This distance is called the Roche limit. The ring around Quaoar is far beyond where scientists would have expected to see a ring.

5. In current scientific thinking, what would scientists expect to happen in rings that are far beyond a planet's Roche limit? How is the ring around Quaoar unusual?

Beyond the limit, rings are expected to be unstable as a result of the lower gravitational force from the planet, and the objects in the rings are expected to clump to form one or more moons. Because the ring around Quaoar was found far beyond the planet's Roche limit, scientists would have expected the ring to clump to form one or more moons. However, the ring around Quaoar, so far, has remained a ring.

6. What has this recent discovery done to scientists' thinking about rings around planets, and what will they need to look for to better understand the Quaoar ring finding?

The finding has forced scientists to re-examine what they thought they understood about the rings around bodies in space. The scientists need to continue to observe Quaoar's ring and make more

observations of other rings in the solar system. In particular, the researchers need to find other rings that are far beyond the Roche limit of the planets they surround to see if they behave the same way the Quaoar ring behaves.

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Student Comprehension Worksheet

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1. What and where is Quaoar? Can you also name the galaxy in which it resides?

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Cross-curricular Discussion, Q&A

Directions for teachers: Before beginning this lesson, review the basics of force diagrams and planetary gravitational force. The lesson plan "May the force move you" includes a comprehensive overview of forces. Then, students should read the *Science News* article "The Kuiper Belt's dwarf planet Quaoar hosts an impossible ring" before discussing the questions below. A version of the article, "This dwarf planet has an odd ring," appears in the March 11, 2023 issue of *Science News*. To review exceptions to scientific rules and moon formation, you can pull questions from the How Earth got its moon and Accepting the exceptions lesson plans.

Want to make it a virtual lesson? Post the online *Science News* article to your virtual classroom. Discuss the article and questions with your class on your virtual platform.

Ring around the planet

1. What are planetary rings? What planets in our solar system have rings?

Planetary rings are disks that orbit around planets and other astronomical objects. These rings can contain gases, dust, rocks, ice, small meteors and other debris. Saturn, Jupiter, Uranus and Neptune have rings.

2. What are moons, and how do scientists think they formed?

Moons are astronomical bodies that orbit planets, dwarf planets and asteroids. Like planets, moons vary greatly in their size, composition and features. Scientists think that many moons formed from disks of gas and dust that circled planets as the planets formed. Some moons are thought to have originated elsewhere in space but were captured into a planet's orbit. There are various hypotheses about the origin of Earth's moon. A commonly accepted hypothesis is that a Mars-sized object struck Earth, and the resulting debris coalesced in orbit to form our moon.

3. Which planets in our solar system have moons?

The planets in our solar system that have moons are Earth (one), Mars (two), Jupiter (92), Saturn (83), Uranus (27) and Neptune (14). Pluto, which is a dwarf planet, has five moons.

Defining limits

1. Describe what the Roche limit tells you about gravity and the interactions of objects in space. Draw a simple diagram that supports your description.

The Roche limit is an estimated distance from a planet or object in a solar system beyond which the gravitational force of the larger body isn't typically strong enough to prevent the gravity of smaller particles from forming a moon. Within the Roche limit, the gravitational force of the larger body overcomes the gravitational forces of smaller objects, preventing them from coalescing to form moons.

Student diagrams will vary but should include a planet, a line defining a Roche limit, a moon outside the Roche limit and a ring inside the limit.

2. On your diagram, add force arrows (vectors) to show the relative forces that are present on a moon beyond the Roche limit. Then show the same for forces on the particles on the rings.

Diagrams will vary, but arrows pointing inward for the moon's own gravitational forces should be longer than the arrows pointing outward, which indicate the gravitational pull from the larger body. The arrows for particles in a ring should have the opposite lengths.

3. Check out the "Far-out ring" illustration in the article. What do you notice about the Roche limits indicated for Haumea, Chariklo and Quaoar? How are the Roche limits for Chariklo and Quaoar similar?

The three objects have different Roche limits. Chariklo and Quaoar both have rings outside their Roche limit.

4. List all factors that you can think of that might impact the predicted Roche limit of a planet.

A planet's composition, size and proximity to the sun. The composition, size, and spread of the ring or moon may also impact the Roche limit.

Defying limits

1. What does "The dwarf planet Quaoar has a ring that is too big for its metaphorical fingers" mean?

Quaoar's ring appears to be well beyond its Roche limit, so the metaphor of a ring on a finger is being used to explain that the ring is bigger than scientists thought it was supposed to be.

2. Why do you think scientists make generalizations and create limits and rules like the Roche limit? What is the downside of generalizing?

Student answers will vary, but will likely include something about how using generalizations and categories simplifies the process of looking at many specific examples. Treating each example as an individual case to memorize or look up would require much more time and effort. The downside of making generalizations is that it may cause us to overlook or minimize the exceptions that are not the norm.

3. How can identifying exceptions to the scientific generalizations or rules help advance scientific knowledge? Explain.

Understanding the limitations of generalizations or rules can help scientists better understand a topic and revise those rules if necessary. It is these exceptions that might open new lines of scientific questioning.

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Student Discussion Worksheet

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Ring around the planet

1. What are planetary rings? What planets in our solar system have rings?

2. What are moons, and how do scientists think they formed?

3. Which planets in our solar system have moons?

Defining limits

1. Describe what the Roche limit tells you about gravity and the interactions of objects in space. Draw a simple diagram that supports your description.

2. On your diagram, add force arrows (vectors) to show the relative forces that are present on a moon beyond the Roche limit. Then show the same for forces on the particles on the rings.

3. Check out the "Far-out ring" illustration in the article. What do you notice about the Roche limits indicated for Haumea, Chariklo and Quaoar? How are the Roche limits for Chariklo and Quaoar similar?

4. List all factors that you can think of that might impact the predicted Roche limit of a planet.

Defying limits

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