SN IN HIGH SCHOOLS

April 15, 2017

How Earth Got its Moon

Article-Based Observation

Directions: After reading the article "How Earth got its moon," answer these questions:

1. **What was the moon-formation idea proposed in the mid-1970s?**

2. **Why does the author describe Earth's moon as an "oddball"?**

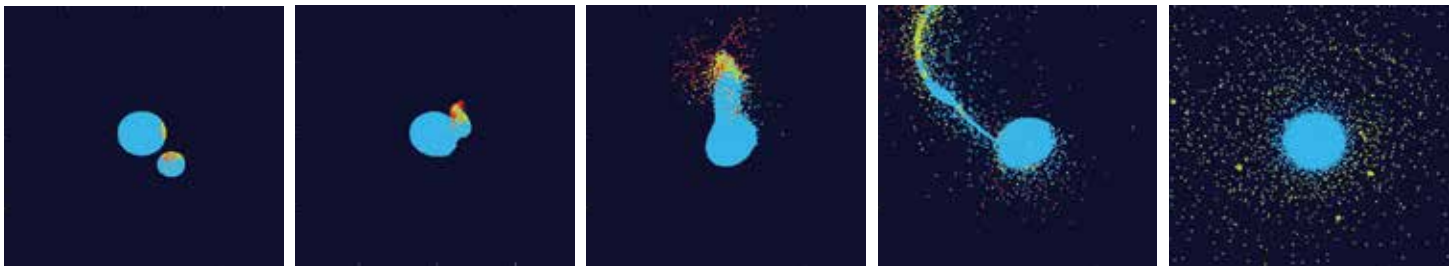
3. **A study in 2001 analyzed rocks collected during the Apollo mission to the moon. How did these lunar rocks support the hypothesis that the moon was formed by multiple impacts and contradict the giant-impact hypothesis?**

4. **What did planetary scientist Raluca Rufu and her colleagues learn recently that supports the multi-impact hypothesis? Explain how their findings support this hypothesis and why scientists were not able to figure this out previously.**

5. **According to planetary scientist Nicolas Dauphas, how does the isotopic combination of materials that make up Earth tell a story that supports the idea of a single impact? What does Dauphas say supplied the Earth's mass?**

6. **Planetary scientist Sarah Stewart states that we need to test all the new ideas about the moon's formation. Describe the recent test that used temperature to help explain how the moon formed, and explain which moon-formation idea is consistent with the results.**

7. **Explain the similarities and differences between the graphic titled "Making moons" and the computer simulation images shown below.**



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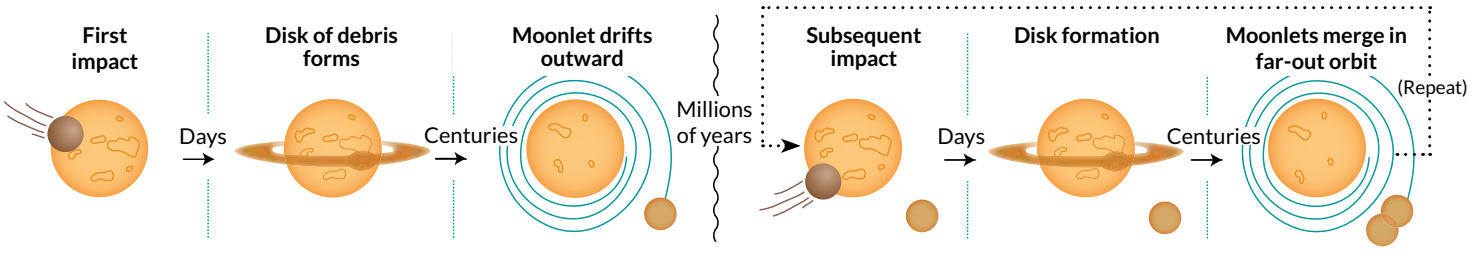
Making moons The multi-impact hypothesis says several small hits sent terrestrial materials into orbit that eventually formed our large moon.



R. RUFU *ET AL*/*NATURE GEOSCIENCE* 2017

SN EDUCATOR GUIDE April 15, 2017

How Earth Got its Moon

Responses to Article-Based Observation

1. **What was the moon-formation idea proposed in the mid-1970s?** Possible student response: Scientists proposed the "giant-impact hypothesis." According to this idea, a Mars-sized body called Theia collided with the Earth 4.5 billion years ago with such force that debris from both Earth and Theia was thrown into orbit, eventually combining to form the Earth's moon.

2. **Why does the author describe Earth's moon as an "oddball"?** Possible student response: Most of the solar system's moons orbit gas giant planets that are farther away from the sun than Earth is. Earth's moon is large compared with the moons of Mars, the only other terrestrial planet with moons. Mars' moons are small enough to be asteroids that were caught by its gravity, but Earth's moon is probably too big to have been captured by gravity.

3. **A study in 2001 analyzed rocks collected during the Apollo mission to the moon. How did these lunar rocks support the hypothesis that the moon was formed by multiple impacts and contradict the giant-impact hypothesis?** Possible student response: The 2001 study of lunar rocks shows that Earth and its moon have identical mixes of oxygen isotopes. If the moon was a mixture of material from the two planets, the moon's composition should be different than Earth's.

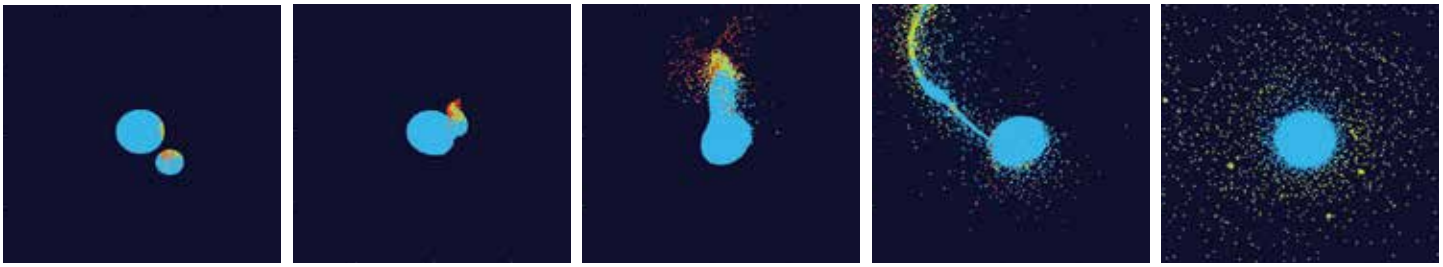
4. **What did planetary scientist Raluca Rufu and her colleagues learn recently that supports the multi-impact hypothesis? Explain how their findings support this hypothesis and why scientists were not able to figure this out previously.** Possible student response: When the proposal of multiple impacts was first suggested in 1989, the computer power needed to run the necessary simulations was not available. Recently, Rufu and colleagues designed a computer simulation of multiple impacts to Earth. In the simulation, impactors that hit Earth directly transferred energy deep into Earth, sending terrestrial material into space. This material combined over centuries to form small moons, and over roughly 100 million years, about 20 small moons merged to form one moon.

5. **According to planetary scientist Nicolas Dauphas, how does the isotopic combination of materials that make up Earth tell a story that supports the idea of a single impact? What does Dauphas say supplied the Earth's mass?** Possible student response: Dauphas reported that most of the material making up Earth comes from the same material as a single type of meteorite called an enstatite chondrite. The placement of different elements helped Dauphas develop a timeline showing when different types of space rocks added to the Earth's mass. For example, iron-loving elements, such as ruthenium, sink deeper into the Earth's crust. Therefore, any ruthenium near the Earth's crust likely arrived later in the Earth's development. The timeline shows that around three-fourths of Earth's

mass came from enstatite chondrite and its precursors. If Theia formed at the same approximate distance from the sun as Earth, its composition would be similar.

6. **Planetary scientist Sarah Stewart states that we need to test all the new ideas about the moon's formation. Describe the recent test that used temperature to help explain how the moon formed, and explain which moon-formation idea is consistent with the results.** Possible student response: The moon's isotopic abundances were compared with that of glasses formed by a nuclear blast. Due to the extremely high temperatures created by the blast, the glasses lacked light isotopes of zinc, which had been leached out. Lunar rocks did not have zinc isotopes either, suggesting they had been exposed to extreme temperatures. Both moon-formation ideas are consistent with this hypothesis. Scientists say that either one large impact or many smaller impacts could have caused high enough temperatures to leach the light zinc isotopes from the rock.

7. **Explain the similarities and differences between the graphic titled "Making moons" and the computer simulation images shown below.** Possible student response: The simulation images show the result of a collision between early Earth and a Theia-like protoplanet to form a beltlike array of debris from both planets. The "Making moons" graphic also shows how a beltlike array of debris forms from an impactor. The impactor in this diagram is presumably smaller, as the diagram is outlining the multi-impact formation idea. This diagram also shows the results of subsequent impacts and moonlet merger.



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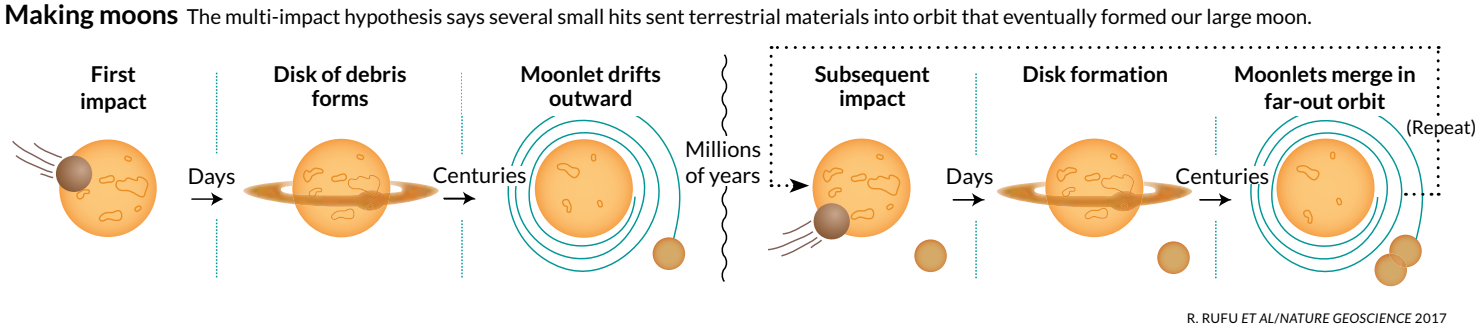

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