12.E: Rings, Moons, and Pluto (Exercises)

For Further Exploration

Articles

Moons

Carroll, M. “Titan: What We’ve Learned about a Strange New World.” *Astronomy* (March 2010): 30. Nice review of Cassini mission results.

Elliot, J. “The Warming Wisps of Triton.” *Sky & Telescope* (February 1999): 42. About Neptune’s intriguing moon.

Hayes, A., “Secrets from Titan’s Seas.” *Astronomy* (October 2015): 24. Good review of what we now know and what puzzles us about the hydrocarbon lakes of Titan.

Jewitt, D., et al. “The Strangest Satellites in the Solar System.” *Scientific American* (August 2006): 40. Small irregular moons in the outer solar system.

Lakdawalla, E. “Ice Worlds of the Ringed Planet.” *Sky & Telescope* (June 2009): 27. On the Cassini mission exploration of Enceladus, Iapetus, and other moons.

Mackenzie, D. “Is There Life under the Ice?” *Astronomy* (August 2001): 32. On future exploration of Europa.

Robertson, D. “Where Goes the Rain?” *Sky & Telescope* (March 2013): 26. About the methane weather cycle on Titan and what Cassini experiments are telling us.

Scharf, C. “A Universe of Dark Oceans.” *Sky & Telescope* (December 2014): 20. Subsurface oceans on Europa, Ganymede, Enceladus, and Titan.

Showalter, M. “How to Catch a Moon (or Two) of Pluto.” *Astronomy Beat* (December 2012): www.astrosociety.org/wp-conte...ab2012-106.pdf. On the discovery of small moons around Pluto, written by the person who discovered two of them.

Spencer, J. “Galileo’s Closest Look at Io.” *Sky & Telescope* (May 2001): 40.

Talcott, R. “Cassini Flies through Enceladus’ Geysers.” *Astronomy* (March 2009): 32.

Zimmerman, R. “Does Methane Flow on Titan?” *Astronomy* (February 2014): 22. Ideas about lakes, channels, and rain.

Pluto

Stern, A. “Pluto: Up Close and Personal.” *Astronomy* (July 2015): 22. Good summary of the history of understanding Pluto and our current knowledge on the eve of the New Horizons encounter.

Stern, A. “The Pluto System Explored.” *Astronomy* (November 2015): 24. Fine review of what the team learned from the first few data downloads from New Horizons.

Tombaugh, C. “How I Found Pluto” *Astronomy Beat* (May 2009): astrosociety.org/wp-content/u.../ab2009-23.pdf.

Rings

Beatty, J. “Saturn’s Amazing Rings.” *Sky & Telescope* (May 2013): 18. Good 7-page summary of what we know.

Burns, J., et al. “Bejeweled Worlds.” *Scientific American* (February 2002): 64. On rings throughout the solar system.

Elliot, J., et al. “Discovering the Rings of Uranus.” *Sky & Telescope* (June 1977): 412.

Esposito, L. “The Changing Shape of Planetary Rings.” *Astronomy* (September 1987): 6.

Sobel, D. “Secrets of the Rings.” *Discover* (April 1994): 86. Discusses the outer planet ring systems.

Tiscareno, M. “Ringworld Revelations.” *Sky & Telescope* (February 2007): 32. Cassini results about the rings of Saturn.

Websites

Note: Many of the sites about planets and planetary missions listed for Other Worlds: An Introduction to the Solar System and The Giant Planets also include good information about the moons of the planets.

Cassini Mission to Saturn: http://saturn.jpl.nasa.gov/ and www.esa.int/SPECIALS/Cassini-...ens/index.html and ciclops.org

Jupiter's Moons, at JPL: http://solarsystem.nasa.gov/planets/jupiter/moons

Neptune's Moons, at JPL: http://solarsystem.nasa.gov/planets/neptune/moons

New Horizons Mission: http://pluto.jhuapl.edu. Gives the latest news bulletins and images from the Pluto encounter, plus lots of background information.

Pluto, at JPL: http://solarsystem.nasa.gov/planets/pluto

Saturn's Moons, at JPL: http://solarsystem.nasa.gov/planets/saturn/moons

Uranus' Moons, at JPL: http://solarsystem.nasa.gov/planets/uranus/moons

Apps

Two apps you can buy for iPhones or iPads can show you the positions and features of the moons of Jupiter and Saturn for any selected date:

- Jupiter Atlas: https://itunes.apple.com/us/app/ju[i...352033947?mt=8
- Saturn Atlas: https://itunes.apple.com/us/app/satu...352038051?mt=8

Videos

Amazing Moons: https://www.youtube.com/watch?v=CQjZf2bW9XQ. 2016 NASA video on intriguing moons in our solar system (4:16).

Briny Breath of Enceladus: http://www.jpl.nasa.gov/video/details.php?id=846. Brief 2009 JPL film on the geysers of Enceladus (2:36).

Dr. Carolyn Porco's TED Talk on Enceladus: https://www.youtube.com/watch?v=TRQdHrGuVgI (3:26).

Titan: http://www.youtube.com/watch?v=iTrOFefYxFg. Video from Open University, with interviews, animations, and images (8:11).

Europa Mission: http://www.jpl.nasa.gov/events/lectu...r=2016&month=2. 2016 talk by two JPL scientists on NASA's plans for a mission to Jupiter's moon, which may have an underground liquid ocean (1:26:22).

Great Planet Debate: http://gpd.jhuapl.edu/debate/debateStream.php OR https://www.youtube.com/watch?v=RJ8EErV6-6Q. Neil deGrasse Tyson debates Mark Sykes about how to characterize Pluto, in 2008 (1:14:11).

How I Killed Pluto and Why It Had It Coming: http://www.youtube.com/watch?v=7pbj_llmiMg. 2011 Silicon Valley Astronomy Lecture by Michael Brown on the "demotion" of Pluto to a dwarf planet (1:27:13).

Seeking Pluto's Frigid Heart: https://www.youtube.com/watch?v=jIxQXGTl_mo. Dramatic 2016 *New York Times* production, narrated by Dennis Overbye (7:43).

Saturn's Restless Rings: https://www.youtube.com/watch?v=X5zcrEze8L4. 2013 talk by Mark Showalter in the Silicon Valley Astronomy Lecture Series (1:30:59).

Collaborative Group Activities

1. Imagine it's the distant future and humans can now travel easily among the planets. Your group is a travel agency, with the task of designing a really challenging tour of the Galilean moons for a group of sports enthusiasts. What kinds of activities are possible on each world? How would rock climbing on Ganymede, for example, differ from rock climbing on Earth? (If you design an activity for Io, you had better bring along very strong radiation shielding. Why?)
2. In the same spirit as the previous activity, have your agency design a tour that includes the seven most spectacular sights of any kind on all the moons or rings covered in this chapter. What are the not-to-be-missed destinations that future tourists will want to visit and why? Which of the sights you pick are going to be spectacular if you are on the moon's surface or inside the ring, and which would look interesting only from far away in space?
3. In this chapter we could cover only a few of the dozens of moons in the outer solar system. Using the Internet or your college library, organize your group into a research team and find out more about one of the moons we did not cover in detail. Our favorites include Uranus' Miranda, with its jigsaw puzzle surface; Saturn's Mimas, with a "knockout" crater called Herschel; and Saturn's Iapetus, whose two hemispheres differ significantly. Prepare a report to attract tourists to the world you selected.

4. In a novel entitled *2010*, science fiction writer Arthur C. Clarke, inspired by the information coming back from the Voyager spacecraft, had fun proposing a life form under the ice of Europa that was evolving toward intelligence. Suppose future missions do indeed find some sort of life (not necessarily intelligent but definitely alive) under the ice of Europa—life that evolved completely independently from life on Earth. Have your group discuss what effect such a discovery would have on humanity's view of itself. What should be our attitude toward such a life form? Do we have an obligation to guard it against contamination by our microbes and viruses? Or, to take an extreme position, should we wipe it out before it becomes competitive with Earth life or contaminates our explorers with microorganisms we are not prepared to deal with? Who should be in charge of making such decisions?
5. In the same spirit as the previous activity, your group may want to watch the 2013 science fiction film *Europa Report*. The producers tried to include good science in depicting what it would be like for astronauts to visit that jovian moon. How well does your group think they did?
6. A number of modern science fiction writers (especially those with training in science) have written short stories that take place on the moons of Jupiter and Saturn. There is a topical listing of science fiction stories with good astronomy at http://www.astrosociety.org/scifi. Members of your group can look under "Jupiter" or "Saturn" and find a story that interests you and then report on it to the whole class.
7. Work together to make a list of all the reasons it is hard to send a mission to Pluto. What compromises had to be made so that the New Horizons mission was affordable? How would you design a second mission to learn more about the Pluto system?
8. Your group has been asked by NASA to come up with one or more missions to learn about Europa. Review what we know about this moon so far and then design a robotic mission that would answer some of the questions we have. You can assume that budget is not a factor, but your instruments have to be realistic. (Bear in mind that Europa is cold and far from the Sun.)
9. Imagine your group is the first landing party on Pluto (let's hope you remembered to bring long underwear!). You land in a place where Charon is visible in the sky and you observe Charon for one Earth week. Describe what Charon will look like during that week. Now you move your camp to the opposite hemisphere of Pluto. What will Charon look like there during the course of a week?
10. When, in 2006, the International Astronomical Union (IAU) decided that Pluto should be called a dwarf planet and not a planet, they set up three criteria that a world must meet to be called a planet. Your group should use the Internet to find these criteria. Which of them did Pluto not meet? Read a little bit about the reaction to the IAU's decision among astronomers and the public. How do members of your group feel about Pluto's new classification? (After you have discussed it within the group, you may want to watch *The Great Planet Debate* video recommended in "For Further Exploration.")

Review Questions

1. What are the moons of the outer planets made of, and how is their composition different from that of our Moon?
2. Compare the geology of Callisto, Ganymede, and Titan.
3. What is the evidence for a liquid water ocean on Europa, and why is this interesting to scientists searching for extraterrestrial life?
4. Explain the energy source that powers the volcanoes of Io.
5. Compare the properties of Titan's atmosphere with those of Earth's atmosphere.
6. How was Pluto discovered? Why did it take so long to find it?
7. How are Triton and Pluto similar?
8. Describe and compare the rings of Saturn and Uranus, including their possible origins.
9. Why were the rings of Uranus not observed directly from telescopes on the ground on Earth? How were they discovered?
10. List at least three major differences between Pluto and the terrestrial planets.
11. The Hubble Space Telescope images of Pluto in 2002 showed a bright spot and some darker areas around it. Now that we have the close-up New Horizons images, what did the large bright region on Pluto turn out to be?
12. Saturn's E ring is broad and thin, and far from Saturn. It requires fresh particles to sustain itself. What is the source of new E-ring particles?

Thought Questions

1. Why do you think the outer planets have such extensive systems of rings and moons, while the inner planets do not?
2. Ganymede and Callisto were the first icy objects to be studied from a geological point of view. Summarize the main differences between their geology and that of the rocky terrestrial planets.

3. Compare the properties of the volcanoes on Io with those of terrestrial volcanoes. Give at least two similarities and two differences.
4. Would you expect to find more impact craters on Io or Callisto? Why?
5. Why is it unlikely that humans will be traveling to Io? (Hint: Review the information about Jupiter's magnetosphere in The Giant Planets.)
6. Why do you suppose the rings of Saturn are made of bright particles, whereas the particles in the rings of Uranus and Neptune are black?
7. Suppose you miraculously removed all of Saturn's moons. What would happen to its rings?
8. We have a lot of good images of the large moons of Jupiter and Saturn from the Galileo and Cassini spacecraft missions (check out NASA's Planetary Photojournal site, at http://photojournal.jpl.nasa.gov, to see the variety). Now that the New Horizons mission has gone to Pluto, why don't we have as many good images of all sides of Pluto and Charon?
9. In the Star Wars movie *Star Wars Episode VI: Return of the Jedi*, a key battle takes place on the inhabited "forest moon" Endor, which supposedly orbits around a gas giant planet. From what you have learned about planets and moons of the solar system, why would this be an unusual situation?

Figuring for Yourself

1. Which would have the longer orbital period: a moon 1 million km from the center of Jupiter, or a moon 1 million km from the center of Earth? Why?
2. How close to Uranus would a spacecraft have to get to obtain the same resolution as in Example with a camera that has an angular resolution of 2 arcsec?
3. Saturn's A, B, and C Rings extend 75,000 to 137,000 km from the center of the planet. Use Kepler's third law to calculate the difference between how long a particle at the inner edge and a particle at the outer edge of the three-ring system would take to revolve about the planet.
4. Use the information in Appendix G to calculate what you would weigh on Titan, Io, and Uranus' moon Miranda.
5. The average distance of Enceladus from Saturn is 238,000 km; the average distance of Titan from Saturn is 1,222,000 km. How much longer does it take Titan to orbit Saturn compared to Enceladus?