13.E: Comets and Asteroids - Debris of the Solar System (Exercises)

For Further Exploration

Articles

Asteroids

Asphang, E. “The Small Planets.” *Scientific American* (May 2000): 46. On asteroids, including results from the NEAR mission.

Beatty, J. “The Falcon’s Wild Flight.” *Sky & Telescope* (September 2006): 34. On the Japanese mission to asteroid Itakawa.

Beatty, J. “NEAR Falls for Eros.” *Sky & Telescope* (May 2001): 35. On the first landing on an asteroid.

Betz, E. “Dawn Mission Reveals Dwarf Planet Ceres.” *Astronomy* (January 2016): 44. First images and discoveries.

Binzel, R. “A New Century for Asteroids.” *Sky & Telescope* (July 2001): 44. Nice overview.

Boslaugh, M. “In Search of Death-Plunge Asteroids.” *Astronomy* (July 2015): 28. On existing and proposed programs to search for Earth-crossing asteroids.

Cooke, B. “Fatal Attraction.” *Astronomy* (May 2006): 46. On near-Earth asteroid Apophis, its orbit, and what we can learn from it.

Durda, D. “Odd Couples.” *Astronomy* (December 2005): 54. On binary asteroids.

Durda, D. “All in the Family.” *Astronomy* (February 1993): 36. Discusses asteroid families.

Oberg, J. “2013’s Historic Russian Meteorite Fall” *Astronomy* (June 2012): 18. On the Chelyabinsk event.

Sheppard, S. “Dancing with the Planets.” *Sky & Telescope* (June 2016): 16. On Trojan asteroids that “follow” planets like Jupiter.

Talcott, R. “Galileo Views Gaspra.” *Astronomy* (February 1992): 52.

Yeomans, D. “Japan Visits an Asteroid.” *Astronomy* (March 2006): 32. On the *Hayabusa* probe exploration of asteroid Itakawa.

Zimmerman, R. “Ice Cream Sundaes and Mashed Potatoes.” *Astronomy* (February 1999): 54. On the NEAR mission.

Comets

Aguirre, E. “The Great Comet of 1997.” *Sky & Telescope* (July 1997): 50. On Comet Hale-Bopp.

Bakich, M. “How to Observe Comets.” *Astronomy* (December 2009): 50. A guide for amateur astronomers.

Gore, R. “Halley’s Comet ’86: Much More Than Met the Eye.” *National Geographic* (December 1986): 758. (Also, the March 1987 issue of *Sky & Telescope* was devoted to what we learned from Halley’s Comet in 1986.)

Hale, A. “Hale-Bopp Plus Ten.” *Astronomy* (July 2005): 76. The co-discoverer of a naked-eye comet tells the story of the discovery and what followed.

Jewett, D. “Mysterious Travelers: Comet Science.” *Sky & Telescope* (December. 2013): 18. Nice summary of what we know about comets and questions we have.

Rao, J. “How Often do Bright Comets Appear?” *Sky & Telescope* (November 2013): 30. Nice summary of bright comets in the last century and what factors make a comet spectacular in our skies.

Sekanina, Z. “Sungrazing Comets.” *Astronomy* (March 2006): 36.

Sheppard, S. “Beyond the Kuiper Belt.” *Sky & Telescope* (March 2015): 26. On Sedna and the Oort cloud.

Stern, S. “Evolution at the Edge.” *Astronomy* (September 2005): 46. How comet nuclei evolve with time.

Talcott, R. “Rendezvous with an Evolving Comet [Rosetta at Comet 67P/C-G].” *Astronomy* (September 2015): 44.

Tytell, D. “Deep Impact’s Hammer Throw.” *Sky & Telescope* (October 2006): 34. On the mission that threw a probe at the nucleus of a comet. See also (June 2005): 40.

Weissman, P. “A Comet Tale.” *Sky & Telescope* (February 2006): 36. A nice review of what we know and don’t know about the physical nature of comets.

Websites

Asteroids

Dawn Mission: http://dawn.jpl.nasa.gov. Discover more about this mission to the largest asteroids.

NEAR-Shoemaker Mission: http://near.jhuapl.edu/. Review background information and see great images from the mission that went by Mathilde and Eros.

Comets

Deep Impact Mission: http://www.nasa.gov/mission_pages/deepimpact/main/.

Kuiper Belt: http://www2.ess.ucla.edu/~jewitt/kb.html. David Jewitt of the University of Hawaii keeps track of the objects that have been discovered.

Missions to Comets: http://solarsystem.nasa.gov/missions/target/comets. Read about NASA's current and past missions to comets.

Stardust Mission: http://stardust.jpl.nasa.gov/home/index.html. Learn about this mission to collect a sample of a comet and bring it back to Earth.

Videos

Asteroids

Sweating the Small Stuff: The Fear and Fun of Near-Earth Asteroids: https://www.youtube.com/watch?v=5gyAvc5OhII. Harvard Observatory Night Lecture by Jose-Luis Galache (1:18:07).

Unveiling Dwarf Planet Ceres: https://www.youtube.com/watch?v=_G9LudkLWOY. A vonKarman Lecture by Dr. Carol Raymond, Oct. 2015, also includes Vesta results (1:18:38).

Comets

Great Comets, Comets in General, and Comet ISON: https://www.youtube.com/watch?v=DiBkYAnQ_C. Talk by Frank Summers, Space Telescope Science Institute (1:01:10).

Press Conference on the Impact of Comet Shoemaker-Levy 9 with Jupiter: https://www.youtube.com/watch?v=B-tUP8afEIo. Day 2 after impact; July 17, 1994; with the discoverers and Heidi Hammel (1:22:29).

Rosetta: The Story So Far: https://www.ras.org.uk/events-and-me...e-story-so-far. Royal Astronomical Society Lecture by Dr. Ian Wright (1:00:29).

Collaborative Group Activities

1. Your group is a congressional committee charged with evaluating the funding for an effort to find all the NEAs (near-Earth asteroids) that are larger than 0.5 kilometers across. Make a list of reasons it would be useful to humanity to find such objects. What should we (could we) do if we found one that will hit Earth in a few years?
2. Many cultures considered comets bad omens. Legends associate comets with the deaths of kings, losses in war, or ends of dynasties. Did any members of your group ever hear about such folktales? Discuss reasons why comets in earlier times may have gotten this bad reputation.
3. Because asteroids have a variety of compositions and a low gravity that makes the removal of materials quite easy, some people have suggested that mining asteroids may be a way to get needed resources in the future. Make a list of materials in asteroids (and comets that come to the inner solar system) that may be valuable to a space-faring civilization. What are the pros and cons of undertaking mining operations on these small worlds?
4. As discussed in the feature box on Comet Hunting as a Hobby in Section 13.4, amateur comet hunters typically spend more than 400 hours scanning the skies with their telescopes to find a comet. That's a lot of time to spend (usually alone, usually far from city lights, usually in the cold, and always in the dark). Discuss with members of your group whether you can see yourself being this dedicated. Why do people undertake such quests? Do you envy their dedication?
5. The largest Kuiper belt objects known are also called dwarf planets. All the planets (terrestrial, jovian, and dwarf) in our solar system have so far been named after mythological gods. (The dwarf planet names have moved away from Roman mythology to include the gods of other cultures.) Have your group discuss whether we should continue this naming tradition with newly discovered dwarf planets. Why or why not?
6. The total cost of the Rosetta mission to match courses with a comet was about 1.4 billion Euros (about $1.6 billion US). Have your group discuss whether this investment was worth it, giving reasons for whichever side you choose. (On the European

Space Agency website, they put this cost in context by saying, “The figure is barely half the price of a modern submarine, or three Airbus 380 jumbo jets, and covers a period of almost 20 years, from the start of the project in 1996 through the end of the mission in 2015.”)

7. If an Earth-approaching asteroid were discovered early enough, humanity could take measures to prevent a collision. Discuss possible methods for deflecting or even destroying an asteroid or comet. Go beyond the few methods mentioned in the text and use your creativity. Give pros and cons for each method.

Review Questions

1. Why are asteroids and comets important to our understanding of solar system history?
2. Give a brief description of the asteroid belt.
3. Describe the main differences between C-type and S-type asteroids.
4. In addition to the ones mentioned in the previous, what is the third, rarer class of asteroids?
5. Vesta is unusual as it contains what mineral on its surface? What does the presence of this material indicate?
6. Compare asteroids of the asteroid belt with Earth-approaching asteroids. What is the main difference between the two groups?
7. Briefly describe NASA’s Spaceguard Survey. How many objects have been found in this survey?
8. Who first calculated the orbits of comets based on historical records dating back to antiquity?
9. Describe the nucleus of a typical comet and compare it with an asteroid of similar size.
10. Describe the two types of comet tails and how each are formed.
11. What classification is given to objects such as Pluto and Eris, which are large enough to be round, and whose orbits lie beyond that of Neptune?
12. Describe the origin and eventual fate of the comets we see from Earth.
13. What evidence do we have for the existence of the Kuiper belt? What kind of objects are found there?
14. Give brief descriptions of both the Kuiper belt and the Oort cloud.

Thought Questions

1. Give at least two reasons today’s astronomers are so interested in the discovery of additional Earth-approaching asteroids.
2. Suppose you were designing a spacecraft that would match course with an asteroid and follow along its orbit. What sorts of instruments would you put on board to gather data, and what would you like to learn?
3. Suppose you were designing a spacecraft that would match course with a comet and move with it for a while. What sorts of instruments would you put on board to gather data, and what would you like to learn?
4. Suppose a comet were discovered approaching the Sun, one whose orbit would cause it to collide with Earth 20 months later, after perihelion passage. (This is approximately the situation described in the science-fiction novel *Lucifer’s Hammer* by Larry Niven and Jerry Pournelle.) What could we do? Would there be any way to protect ourselves from a catastrophe?
5. We believe that chains of comet fragments like Comet Shoemaker-Levy 9’s have collided not only with the jovian planets, but occasionally with their moons. What sort of features would you look for on the outer planet moons to find evidence of such collisions? (As an extra bonus, can you find any images of such features on a moon like Callisto? You can use an online site of planetary images, such as the *Planetary Photojournal*, at photojournal.jpl.nasa.gov.)
6. Why have we found so many objects in the Kuiper belt in the last two decades and not before then?
7. Why is it hard to give exact diameters for even the larger objects in the Kuiper belt?

Figuring for Yourself

1. Refer to Example 13.4.1 in Section 13.4. How would the calculation change if a typical comet in the Oort cloud is only 1 km in diameter?
2. Refer to Example 13.4.1 in Section 13.4. How would the calculation change if a typical comet in the Oort cloud is larger—say, 50 km in diameter?
3. The calculation in Example 13.4.1 in Section 13.4 refers to the known Oort cloud, the source for most of the comets we see. If, as some astronomers suspect, there are 10 times this many cometary objects in the solar system, how does the total mass of cometary matter compare with the mass of Jupiter?
4. If the Oort cloud contains 1012 comets, and ten new comets are discovered coming close to the Sun each year, what percentage of the comets have been “used up” since the beginning of the solar system?
5. The mass of the asteroids is found mostly in the larger asteroids, so to estimate the total mass we need to consider only the larger objects. Suppose the three largest asteroids—Ceres (1000 km in diameter), Pallas (500 km in diameter), and Vesta (500

km in diameter)—account for half the total mass. Assume that each of these three asteroids has a density of 3×10^3 g/cm^3 and calculate their total mass. Multiply your result by 2 to obtain an estimate for the mass of the total asteroid belt. How does this compare with the mass of the Oort cloud?

6. Make a similar estimate for the mass of the Kuiper belt. The three largest objects are Pluto, Eris, and Makemake (each roughly 2000 km). In addition, assume there are eight objects (including Haumea, Orcus, Quaoar, Ixion, Varuna, and Charon, and objects that have not been named yet) with diameters of about 1000 km. Assume that all objects have Pluto's density of 2×10^3 g/cm^3. Calculate twice the mass of the largest 13 objects and compare it to the mass of the main asteroid belt.
7. What is the period of revolution about the Sun for an asteroid with a semi-major axis of 3 AU in the middle of the asteroid belt?
8. What is the period of revolution for a comet with aphelion at 5 AU and perihelion at the orbit of Earth?
