

8.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 Gaspia." *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.

Meteors and Meteorites

Alper, J. "It Came from Outer Space." *Astronomy* (November 2002): 36. On the analysis of organic materials in meteorites.

Beatty, J. "Catch a Fallen Star." *Sky & Telescope* (August 2009): 22. On the recovery of meteorites from an impact that was seen in the sky.

Durda, D. "The Chelyabinsk Super-Meteor." *Sky & Telescope* (June 2013): 24. A nice summary, with photos and eyewitness reporting.

Garcia, R., & Notkin, G. "Touching the Stars without Leaving Home." *Sky & Telescope* (October 2008): 32. Hunting and collecting meteorites.

Kring, D. "Unlocking the Solar System's Past." *Astronomy* (August 2006): 32. Part of a special issue devoted to meteorites.

Rubin, A. "Secrets of Primitive Meteorites." *Scientific American* (February 2013): 36. What they can teach us about the environment in which the solar system formed.

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.

Meteors and Meteorites

American Meteor Society: <http://www.amsmeteors.org/>. For serious observers.

British and Irish Meteorite Society: <http://www.bimsociety.org/meteorites1.shtml>.

Meteor Showers Online: <http://meteorshowersonline.com/>. By Gary Kronk.

Meteorite Information: <http://www.meteorite-information.com/>. A great collection of links for understanding and even collecting meteorites.

Meteorites from Mars: <http://www2.jpl.nasa.gov/snc/>. A listing and links from the Jet Propulsion Lab.

Meteors and Meteor Showers: www.astronomy.com/observing/o...meteor-showers. From *Astronomy* magazine.

Meteors: <http://www.skyandtelescope.com/obser...watch/meteors/>. A collection of articles on meteor observing from *Sky & Telescope* magazine.

Nine Planets Meteorites and Meteors Page: <http://nineplanets.org/meteorites.html>.

Some Interesting Meteorite Falls of the Last Two Centuries: www.icq.eps.harvard.edu/meteorites-1.html.

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-tUP8afEI0>. 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).

Meteors and Meteorites

Meteorites and Meteor-wrongs: <https://www.youtube.com/watch?v=VQO335Y3zXo>. Video with Dr. Randy Korotev of Washington U. in St. Louis (7:05).

Rare Meteorites from London's Natural History Museum: <https://www.youtube.com/watch?v=w-Rsk-ywN44>. A tour of the meteorite collection with curator Caroline Smith (18:22). Also see a short news piece about a martian meteorite: <https://www.youtube.com/watch?v=1EMR2r53f2s> (2:54).

What Is a Meteor Shower (and How to Watch Them): <https://www.youtube.com/watch?v=xNmgvlwInCA>. Top tips for watching meteor showers from the At-Bristol Science Center (3:18).

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.
15. In what ways are meteorites different from meteors? What is the probable origin of each?
16. How are comets related to meteor showers?
17. What do we mean by primitive material? How can we tell if a meteorite is primitive?
18. Why do meteors in a meteor shower appear to come from just one point in the sky?

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?
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?

8. What methods do scientists use to distinguish a meteorite from terrestrial material?
9. Why do iron meteorites represent a much higher percentage of finds than of falls?
10. Why is it more useful to classify meteorites according to whether they are primitive or differentiated rather than whether they are stones, irons, or stony-irons?
11. Which meteorites are the most useful for defining the age of the solar system? Why?
12. Suppose a new primitive meteorite is discovered (sometime after it falls in a field of soybeans) and analysis reveals that it contains a trace of amino acids, all of which show the same rotational symmetry (unlike the Murchison meteorite). What might you conclude from this finding?
13. Why are meteorites of primitive material considered more important than other meteorites? Why have most of them been found in Antarctica?

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