14.E: Cosmic Samples and the Origin of the Solar System (Exercises)

For Further Exploration

Note: Resources about exoplanets are provided in The Birth of Stars and the Discovery of Planets outside the Solar System.

Articles

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.

Evolution of the Solar System and Protoplanetary Disks

Jewitt, D., & Young, E. “Oceans from the Skies.” *Scientific American* (March 2015): 36–43. How did Earth and the other inner planets get their water after the initial hot period?

Talcott, R. “How the Solar System Came to Be.” *Astronomy* (November 2012): 24. On the formation period of the Sun and the planets.

Young, E. “Cloudy with a Chance of Stars.” *Scientific American* (February 2010): 34. On how clouds of interstellar matter turn into star systems.

Websites

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.

Evolution of the Solar System and Protoplanetary Disks

Circumstellar Disk Learning Site: http://www.disksite.com/. By Dr. Paul Kalas.

Disk Detective Project: http://www.diskdetective.org/. The WISE mission is asking the public to help them find protoplanetary disks in their infrared data.

Videos

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).

Evolution of the Solar System and Protoplanetary Disks

Origins of the Solar System: www.pbs.org/wgbh/nova/space/o...ar-system.html. Video from Nova ScienceNow narrated by Neil deGrasse Tyson (13:02).

Where Do Planets Come From?: https://www.youtube.com/watch?v=zdIJUdZWlXo. Public talk by Anjali Tripathi in March 2016 in the Center for Astrophysics Observatory Nights Series (56:14).

Collaborative Group Activities

1. Ever since the true (cosmic) origin of meteorites was understood, people have tried to make money selling them to museums and planetariums. More recently, a growing number of private collectors have been interested in purchasing meteorite fragments, and a network of dealers (some more reputable than others) has sprung up to meet this need. What does your group think of all this? Who should own a meteorite? The person on whose land it falls, the person who finds it, or the local, state, or federal government where it falls? What if it falls on public land? Should there be any limit to what people charge for meteorites? Or should all meteorites be the common property of humanity? (If you can, try to research what the law is now in your area. See, for example, www.space.com/18009-meteorite...ds-rules.html.)
2. Your group has been formed to advise a very rich person who wants to buy some meteorites but is afraid of being cheated and sold some Earth rocks. How would you advise your client to make sure that the meteorites she buys are authentic?
3. Your group is a committee set up to give advice to NASA about how to design satellites and telescopes in space to minimize the danger of meteor impacts. Remember that the heavier a satellite is, the harder (more expensive) it is to launch. What would you include in your recommendations?
4. Discuss what you would do if you suddenly found that a small meteorite had crashed in or near your home. Whom would you call first, second, third? What would you do with the sample? (And would any damage to your home be covered by your insurance?)
5. A friend of your group really wants to see a meteor shower. The group becomes a committee to assist her in fulfilling this desire. What time of year would be best? What equipment would you recommend she gets? What advice would you give her?
6. Work with your group to find a table of the phases of the Moon for the next calendar year. Then look at the table of well-known meteor showers in this chapter and report on what phase the Moon will be in during each shower. (The brighter the Moon is in the night sky, the harder it is to see the faint flashes of meteors.)
7. Thinking that all giant planets had to be far from their stars (because the ones in our solar system are) is an example of making theories without having enough data (or examples). Can your group make a list of other instances in science (and human relations) where we have made incorrect judgments without having explored enough examples?
8. Have your group list and then discuss several ways in which the discovery of a diverse group of exoplanets (planets orbiting other stars) has challenged our conventional view of the formation of planetary systems like our solar system.

Review Questions

1. A friend of yours who has not taken astronomy sees a meteor shower (she calls it a bunch of shooting stars). The next day she confides in you that she was concerned that the stars in the Big Dipper (her favorite star pattern) might be the next ones to go. How would you put her mind at ease?
2. In what ways are meteorites different from meteors? What is the probable origin of each?
3. How are comets related to meteor showers?
4. What do we mean by primitive material? How can we tell if a meteorite is primitive?
5. Describe the solar nebula, and outline the sequence of events within the nebula that gave rise to the planetesimals.

6. Why do the giant planets and their moons have compositions different from those of the terrestrial planets?
7. How do the planets discovered so far around other stars differ from those in our own solar system? List at least two ways.
8. Explain the role of impacts in planetary evolution, including both giant impacts and more modest ones.
9. Why are some planets and moons more geologically active than others?
10. Summarize the origin and evolution of the atmospheres of Venus, Earth, and Mars.
11. Why do meteors in a meteor shower appear to come from just one point in the sky?

Thought Questions

1. What methods do scientists use to distinguish a meteorite from terrestrial material?
2. Why do iron meteorites represent a much higher percentage of finds than of falls
3. 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?
4. Which meteorites are the most useful for defining the age of the solar system? Why?
5. 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?
6. How do we know when the solar system formed? Usually we say that the solar system is 4.5 billion years old. To what does this age correspond?
7. We have seen how Mars can support greater elevation differences than Earth or Venus. According to the same arguments, the Moon should have higher mountains than any of the other terrestrial planets, yet we know it does not. What is wrong with applying the same line of reasoning to the mountains on the Moon?
8. Present theory suggests that giant planets cannot form without condensation of water ice, which becomes vapor at the high temperatures close to a star. So how can we explain the presence of jovian-sized exoplanets closer to their star than Mercury is to our Sun?
9. Why are meteorites of primitive material considered more important than other meteorites? Why have most of them been found in Antarctica?

Figuring for Yourself

1. How long would material take to go around if the solar nebula in Example $14.3.1$ in Section 14.3 became the size of Earth's orbit?
2. Consider the differentiated meteorites. We think the irons are from the cores, the stony-irons are from the interfaces between mantles and cores, and the stones are from the mantles of their differentiated parent bodies. If these parent bodies were like Earth, what fraction of the meteorites would you expect to consist of irons, stony-irons, and stones? Is this consistent with the observed numbers of each? (Hint: You will need to look up what percent of the volume of Earth is taken up by its core, mantle, and crust.)
3. Estimate the maximum height of the mountains on a hypothetical planet similar to Earth but with twice the surface gravity of our planet.