

5.5: Exoplanets (Exercises)

For Further Exploration

Articles

Billings, L. "In Search of Alien Jupiters." *Scientific American* (August 2015): 40–47. The race to image jovian planets with current instruments and why a direct image of a terrestrial planet is still in the future.

Heller, R. "Better Than Earth." *Scientific American* (January 2015): 32–39. What kinds of planets may be habitable; super-Earths and jovian planet moons should also be considered.

Laughlin, G. "How Worlds Get Out of Whack." *Sky & Telescope* (May 2013): 26. On how planets can migrate from the places they form in a star system.

Marcy, G. "The New Search for Distant Planets." *Astronomy* (October 2006): 30. Fine brief overview. (The same issue has a dramatic fold-out visual atlas of extrasolar planets, from that era.)

Redd, N. "Why Haven't We Found Another Earth?" *Astronomy* (February 2016): 25. Looking for terrestrial planets in the habitable zone with evidence of life.

Seager, S. "Exoplanets Everywhere." *Sky & Telescope* (August 2013): 18. An excellent discussion of some of the frequently asked questions about the nature and arrangement of planets out there.

Seager, S. "The Hunt for Super-Earths." *Sky & Telescope* (October 2010): 30. The search for planets that are up to 10 times the mass of Earth and what they can teach us.

Villard, R. "Hunting for Earthlike Planets." *Astronomy* (April 2011): 28. How we expect to find and characterize super-Earth (planets somewhat bigger than ours) using new instruments and techniques that could show us what their atmospheres are made of.

Websites

Exoplanet Exploration: <http://planetquest.jpl.nasa.gov/>. PlanetQuest (from the Navigator Program at the Jet Propulsion Lab) is probably the best site for students and beginners, with introductory materials and nice illustrations; it focuses mostly on NASA work and missions.

Exoplanets: www.planetary.org/exoplanets/. Planetary Society's exoplanets pages with a dynamic catalog of planets found and good explanations.

Exoplanets: The Search for Planets beyond Our Solar System: http://www.iop.org/publications/iop/...age_42551.html. From the British Institute of Physics in 2010.

Extrasolar Planets Encyclopedia: <http://exoplanet.eu/>. Maintained by Jean Schneider of the Paris Observatory, has the largest catalog of planet discoveries and useful background material (some of it more technical).

Formation of Stars: https://www.spacetelescope.org/scien...tion_of_stars/. Star Formation page from the Hubble Space Telescope, with links to images and information.

Kepler Mission: kepler.nasa.gov/. The public website for the remarkable telescope in space that is searching planets using the transit technique and is our best hope for finding earthlike planets.

Proxima Centauri Planet Discovery: <http://www.eso.org/public/news/eso1629/>.

Apps

Exoplanet: itunes.apple.com/us/app/exopl...327702034?mt=8. Allows you to browse through a regularly updated visual catalog of exoplanets that have been found so far.

Journey to the Exoplanets: itunes.apple.com/us/app/journ...463532472?mt=8. Produced by the staff of *Scientific American*, with input from scientists and space artists; gives background information and visual tours of the nearer star systems with planets.

Videos

A Star Is Born: www.discovery.com/tv-shows/ot...-star-is-born/. Discovery Channel video with astronomer Michelle Thaller (2:25).

Are We Alone: An Evening Dialogue with the Kepler Mission Leaders: <http://www.youtube.com/watch?v=O7ItAXfl0Lw>. A non-technical panel discussion on Kepler results and ideas about planet formation with Bill Borucki, Natalie Batalha, and Gibor Basri (moderated by Andrew Fraknoi) at the University of California, Berkeley (2:07:01).

Finding the Next Earth: The Latest Results from Kepler: https://www.youtube.com/watch?v=ZbijeR_AALo. Natalie Batalha (San Jose State University & NASA Ames) public talk in the Silicon Valley Astronomy Lecture Series (1:28:38).

From Hot Jupiters to Habitable Worlds: vimeo.com/37696087 (Part 1) and vimeo.com/37700700 (Part 2). Debra Fischer (Yale University) public talk in Hawaii sponsored by the Keck Observatory (15:20 Part 1, 21:32 Part 2).

Search for Habitable Exoplanets: http://www.youtube.com/watch?v=RLWb_T9yaDU. Sara Seeger (MIT) public talk at the SETI Institute, with Kepler results (1:10:35).

Strange Planetary Vistas: http://www.youtube.com/watch?v=_8ww9eLRSCg. Josh Carter (CfA) public talk at Harvard's Center for Astrophysics with a friendly introduction to exoplanets for non-specialists (46:35).

Review Questions

1. Why is it so hard to see planets around other stars and so easy to see them around our own?
2. Why did it take astronomers until 1995 to discover the first exoplanet orbiting another star like the Sun?
3. Which types of planets are most easily detected by Doppler measurements? By transits?
4. List three ways in which the exoplanets we have detected have been found to be different from planets in our solar system.
5. List any similarities between discovered exoplanets and planets in our solar system.
6. What revisions to the theory of planet formation have astronomers had to make as a result of the discovery of exoplanets?
7. Why are young Jupiters easier to see with direct imaging than old Jupiters?

Thought Questions

1. Suppose you wanted to observe a planet around another star with direct imaging. Would you try to observe in visible light or in the infrared? Why? Would the planet be easier to see if it were at 1 AU or 5 AU from its star?
2. Why were giant planets close to their stars the first ones to be discovered? Why has the same technique not been used yet to discover giant planets at the distance of Saturn?
3. Exoplanets in eccentric orbits experience large temperature swings during their orbits. Suppose you had to plan for a mission to such a planet. Based on Kepler's second law, does the planet spend more time closer or farther from the star? Explain.

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