3.13: Radiation, Spectra, and Astronomical Instruments (Exercises)

For Further Exploration

Articles

Augensen, H. & Woodbury, J. "The Electromagnetic Spectrum." *Astronomy* (June 1982): 6.

Blades, J. C. "Fixing the Hubble One Last Time." *Sky & Telescope* (October 2008): 26. On the last Shuttle service mission and what the Hubble was then capable of doing.

Brown, A. "How Gaia will Map a Billion Stars." *Astronomy* (December 2014): 32. Nice review of the mission to do photometry and spectroscopy of all stars above a certain brightness.

Darling, D. "Spectral Visions: The Long Wavelengths." *Astronomy* (August 1984): 16; "The Short Wavelengths." *Astronomy* (September 1984): 14.

Gingerich, O. "Unlocking the Chemical Secrets of the Cosmos." *Sky & Telescope* (July 1981): 13.

Irion, R. "Prime Time." *Astronomy* (February 2001): 46. On how time is allotted on the major research telescopes.

Jedicke, Peter & Robert. "The Coming Giant Sky Patrols." *Sky & Telescope* (September 2008): 30. About giant telescopes to survey the sky continuously.

Lazio, Joseph, et al. "Tuning in to the Universe: 21st Century Radio Astronomy." *Sky & Telescope* (July 2008): 21. About ALMA and the Square Kilometer Array.

Lowe, Jonathan. "Mirror, Mirror." *Sky & Telescope* (December 2007): 22. On the Large Binocular Telescope in Arizona.

Lowe, Jonathan. "Next Light: Tomorrow's Monster Telescopes." *Sky & Telescope* (April 2008): 20. About plans for extremely large telescopes on the ground.

Mason, Todd & Robin. "Palomar's Big Eye." *Sky & Telescope*(December 2008): 36. On the Hale 200-inch telescope.

Stencil, R. et al. "Astronomical Spectroscopy." *Astronomy* (June 1978): 6.

Subinsky, Raymond. "Who Really Invented the Telescope." *Astronomy*(August 2008): 84. Brief historical introduction, focusing on Hans Lippershey.

Websites

Doppler Effect: http://www.physicsclassroom.com/clas...Doppler-Effect. A shaking bug and the Doppler Effect explained.

Electromagnetic Spectrum: http://imagine.gsfc.nasa.gov/science...spectrum1.html. An introduction to the electromagnetic spectrum from NASA's *Imagine the Universe*; note that you can click the "Advanced" button near the top and get a more detailed discussion.

Rainbows: How They Form and How to See Them: http://www.livescience.com/30235-rai...explainer.html. By meteorologist and amateur astronomer Joe Rao.

Videos

Astronomy from the Stratosphere: SOFIA: https://www.youtube.com/watch?v=NV98BcBBA9c. A talk by Dr. Dana Backman (1:15:32)

Doppler Effect: www.esa.int/spaceinvideos/Vid...ion_video_VP05. ESA video with Doppler ball demonstration and Doppler effect and satellites (4:48).

Galaxies Viewed in Full Spectrum of Light: https://www.youtube.com/watch?v=368K0iQv8nE. Scientists with the Spitzer Observatory show how a galaxy looks different at different wavelengths (6:22)

How a Prism Works to Make Rainbow Colors: https://www.youtube.com/watch?v=JGqsi_LDUn0. Short video on how a prism bends light to make a rainbow of colors (2:44).

Lifting the Cosmic Veil: Highlights from a Decade of the Spitzer Space Telescope: https://www.youtube.com/watch?v=nkrNQcwkY78. A talk by Dr. Michael Bicay (1:42:44)

Tour of the Electromagnetic Spectrum: https://www.youtube.com/watch?v=HPcAWNlVl-8. *NASA Mission Science* video tour of the bands of the electromagnetic spectrum (eight short videos).

Introductions to Quantum Mechanics

Ford, Kenneth. *The Quantum World.* 2004. A well-written recent introduction by a physicist/educator.

Gribbin, John. *In Search of Schroedinger's Cat.* 1984. Clear, very basic introduction to the fundamental ideas of quantum mechanics, by a British physicist and science writer.

Rae, Alastair. *Quantum Physics: A Beginner's Guide.* 2005. Widely praised introduction by a British physicist.

Review Questions

1. What distinguishes one type of electromagnetic radiation from another? What are the main categories (or bands) of the electromagnetic spectrum?
2. What is a wave? Use the terms *wavelength* and *frequency* in your definition.
3. Where in an atom would you expect to find electrons? Protons? Neutrons?
4. Explain how emission lines and absorption lines are formed. In what sorts of cosmic objects would you expect to see each?
5. Explain how the Doppler effect works for sound waves and give some familiar examples.
6. What kind of motion for a star does not produce a Doppler effect? Explain.
7. Explain why light is referred to as electromagnetic radiation.
8. What are the differences between light waves and sound waves?
9. Explain why astronomers long ago believed that space must be filled with some kind of substance (the "aether") instead of the vacuum we know it is today.
10. Explain why we have to observe stars and other astronomical objects from above Earth's atmosphere in order to fully learn about their properties.
11. Explain why hotter objects tend to radiate more energetic photons compared to cooler objects.
12. Explain how we can deduce the temperature of a star by determining its color.
13. Explain what dispersion is and how astronomers use this phenomenon to study a star's light.
14. Explain why glass prisms disperse light.
15. Explain what Joseph Fraunhofer discovered about stellar spectra.
16. Explain how we use spectral absorption and emission lines to determine the composition of a gas.
17. Explain how electrons use light energy to move among energy levels within an atom.
18. Explain why astronomers use the term "blueshifted" for objects moving toward us and "redshifted" for objects moving away from us.
19. If spectral line wavelengths are changing for objects based on the radial velocities of those objects, how can we deduce which type of atom is responsible for a particular absorption or emission line?
20. What are the three basic components of a modern astronomical instrument?
21. What is meant by "reflecting" and "refracting" telescopes?
22. Why are the largest visible-light telescopes in the world made with mirrors rather than lenses?
23. Why do astronomers place telescopes in Earth's orbit? What are the advantages for the different regions of the spectrum?

Thought Questions

1. With what type of electromagnetic radiation would you observe:
   1. A star with a temperature of 5800 K?
   2. A gas heated to a temperature of one million K?
   3. A person on a dark night?
2. Go outside on a clear night, wait 15 minutes for your eyes to adjust to the dark, and look carefully at the brightest stars. Some should look slightly red and others slightly blue. The primary factor that determines the color of a star is its temperature. Which is hotter: a blue star or a red one? Explain.
3. Water faucets are often labeled with a red dot for hot water and a blue dot for cold. Given Wien's law, does this labeling make sense?

4. Astronomers want to make maps of the sky showing sources of X-rays or gamma rays. Explain why those X-rays and gamma rays must be observed from above Earth's atmosphere.
5. The greenhouse effect can be explained easily if you understand the laws of blackbody radiation. A greenhouse gas blocks the transmission of infrared light. Given that the incoming light to Earth is sunlight with a characteristic temperature of 5800 K (which peaks in the visible part of the spectrum) and the outgoing light from Earth has a characteristic temperature of about 300 K (which peaks in the infrared part of the spectrum), explain how greenhouse gases cause Earth to warm up. As part of your answer, discuss that greenhouse gases block both incoming and outgoing infrared light. Explain why these two effects don't simply cancel each other, leading to no net temperature change.
6. An idealized radiating object does not reflect or scatter any radiation but instead absorbs all of the electromagnetic energy that falls on it. Can you explain why astronomers call such an object a blackbody? Keep in mind that even stars, which shine brightly in a variety of colors, are considered blackbodies. Explain why.
7. Explain why each element has a unique spectrum of absorption or emission lines.
8. What happens to the image produced by a lens if the lens is "stopped down" (the aperture reduced, thereby reducing the amount of light passing through the lens) with an iris diaphragm—a device that covers its periphery?
9. The largest observatory complex in the world is on Mauna Kea, the tallest mountain on Earth. What are some factors astronomers consider when selecting an observatory site? Don't forget practical ones. Should astronomers, for example, consider building an observatory on Denali (Mount McKinley) or Mount Everest?
10. Suppose you are looking for sites for a visible-light observatory, an infrared observatory, and a radio observatory. What are the main criteria of excellence for each? What sites are actually considered the best today?
11. Radio astronomy involves wavelengths much longer than those of visible light, and many orbiting observatories have probed the universe for radiation of very short wavelengths. What sorts of objects and physical conditions would you expect to be associated with emission of radiation at very long and very short wavelengths?
12. The dean of a university located near the ocean (who was not a science major in college) proposes building an infrared telescope right on campus and operating it in a nice heated dome so that astronomers will be comfortable on cold winter nights. Criticize this proposal, giving your reasoning.
