11.15: Between the Stars - Gas and Dust in Space (Exercises)

For Further Exploration

Articles

Goodman, A. “Recycling the Universe.” *Sky & Telescope* November (2000): 44. Review of how stellar evolution, the interstellar medium, and supernovae all work together to recycle cosmic material.

Greenberg, J. “The Secrets of Stardust.” *Scientific American* December (2000): 70. The makeup and evolutionary role of solid particles between the stars.

Knapp, G. “The Stuff between the Stars.” *Sky & Telescope* May (1995): 20. An introduction to the interstellar medium.

Nadis, S. “Searching for the Molecules of Life in Space.” *Sky & Telescope* January (2002): 32. Recent observations of water in the interstellar medium by satellite telescopes.

Olinto, A. “Solving the Mystery of Cosmic Rays.” *Astronomy* April (2014): 30. What accelerates them to such high energies.

Reynolds, R. “The Gas between the Stars.” *Scientific American* January (2002): 34. On the interstellar medium.

Websites and Apps

Barnard, E. E., Biographical Memoir: www.nasonline.org/publication...ard-edward.pdf.

Cosmicopia: helios.gsfc.nasa.gov/cosmic.html. NASA’s learning site explains about the history and modern understanding of cosmic rays.

DECO: https://wipac.wisc.edu/deco. A smart-phone app for turning your phone into a cosmic-ray detector.

Hubble Space Telescope Images of Nebulae: http://hubblesite.org/gallery/album/nebula/. Click on any of the beautiful images in this collection, and you are taken to a page with more information; while looking at these images, you may also want to browse through the slide sequence on the meaning of colors in the Hubble pictures (http://hubblesite.org/gallery/behind...ning_of_color/).

Interstellar Medium Online Tutorial: www-ssg.sr.unh.edu/ism/intro.htm. Nontechnical introduction to the interstellar medium (ISM) and how we study it; by the University of New Hampshire astronomy department.

Messier Catalog of Nebulae, Clusters, and Galaxies: http://astropixels.com/messier/messiercat.html. Astronomer Fred Espenak provides the full catalog, with information and images. (The Wikipedia list does something similar: en.Wikipedia.org/wiki/List_o...ssier_objects.)

Nebulae: What Are They?: http://www.universetoday.com/61103/what-is-a-nebula/. Concise introduction by Matt Williams.

Videos

Horsehead Nebula in New Light: www.esa.int/spaceinvideos/Vid...a_in_new_light. Tour of the dark nebula in different wavelengths; no audio narration, just music, but explanatory material appears on the screen (03:03).

Hubblecast 65: A Whole New View of the Horsehead Nebula: http://www.spacetelescope.org/videos/heic1307a/. Report on nebulae in general and about the Horsehead specifically, with ESO astronomer Joe Liske (06:03).

Interstellar Reddening: https://www.youtube.com/watch?v=H2M80RAQB6k. Video demonstrating how reddening works, with Scott Miller of Penn State; a bit nerdy but useful (03:45).

Review Questions

1. Why do nebulae near hot stars look red? Why do dust clouds near stars usually look blue?
2. Describe the characteristics of the various kinds of interstellar gas (HII regions, neutral hydrogen clouds, ultra-hot gas clouds, and molecular clouds).
3. Prepare a table listing the different ways in which dust and gas can be detected in interstellar space.
4. Describe how the 21-cm line of hydrogen is formed. Why is this line such an important tool for understanding the interstellar medium?
5. Describe the properties of the dust grains found in the space between stars.
6. Why is it difficult to determine where cosmic rays come from?

7. What causes reddening of starlight? Explain how the reddish color of the Sun's disk at sunset is caused by the same process.
8. Why do molecules, including H2 and more complex organic molecules, only form inside dark clouds? Why don't they fill all interstellar space?
9. Why can't we use visible light telescopes to study molecular clouds where stars and planets form? Why do infrared or radio telescopes work better?
10. The mass of the interstellar medium is determined by a balance between sources (which add mass) and sinks (which remove it). Make a table listing the major sources and sinks, and briefly explain each one.
11. Where does interstellar dust come from? How does it form?

Thought Questions

1. Figure 20.1.1 in Section 20.1 shows a reddish glow around the star Antares, and yet the caption says that is a dust cloud. What observations would you make to determine whether the red glow is actually produced by dust or whether it is produced by an H II region?
2. If the red glow around Antares is indeed produced by reflection of the light from Antares by dust, what does its red appearance tell you about the likely temperature of Antares? Look up the spectral type of Antares in Appendix J. Was your estimate of the temperature about right? In most of the images in this chapter, a red glow is associated with ionized hydrogen. Would you expect to find an H II region around Antares? Explain your answer.
3. Even though neutral hydrogen is the most abundant element in interstellar matter, it was detected first with a radio telescope, not a visible light telescope. Explain why. (The explanation given in Analyzing Starlight for the fact that hydrogen lines are not strong in stars of all temperatures may be helpful.)
4. Suppose someone told you that she had discovered H II around the star Aldebaran. Would you believe her? Why or why not?
5. Describe the spectrum of each of the following:
    1. starlight reflected by dust,
    2. a star behind invisible interstellar gas, and
    3. an emission nebula.
6. According to the text, a star must be hotter than about 25,000 K to produce an H II region. Both the hottest white dwarfs and main-sequence O stars have temperatures hotter than 25,000 K. Which type of star can ionize more hydrogen? Why?
7. From the comments in the text about which kinds of stars produce emission nebulae and which kinds are associated with reflection nebulae, what can you say about the temperatures of the stars that produce NGC 1999 (Figure 20.3.5 in Section 20.3)?
8. One way to calculate the size and shape of the Galaxy is to estimate the distances to faint stars just from their observed apparent brightnesses and to note the distance at which stars are no longer observable. The first astronomers to try this experiment did not know that starlight is dimmed by interstellar dust. Their estimates of the size of the Galaxy were much too small. Explain why.
9. New stars form in regions where the density of gas and dust is relatively high. Suppose you wanted to search for some recently formed stars. Would you more likely be successful if you observed at visible wavelengths or at infrared wavelengths? Why?
10. Thinking about the topics in this chapter, here is an Earth analogy. In big cities, you can see much farther on days without smog. Why?
11. Stars form in the Milky Way at a rate of about 1 solar mass per year. At this rate, how long would it take for all the interstellar gas in the Milky Way to be turned into stars if there were no fresh gas coming in from outside? How does this compare to the estimated age of the universe, 14 billion years? What do you conclude from this?
12. Astronomers recently detected light emitted by a supernova that was originally observed in 1572, just reaching Earth now. This light was reflected off a dust cloud; astronomers call such a reflected light a "light echo" (just like reflected sound is called an echo). How would you expect the spectrum of the light echo to compare to that of the original supernova?
