Chp 1-Review Questions. Predicting the Motions of the Stars, Sun, and Moon

1. What is the difference between a hypothesis and a theory?
2. How are scientific theories tested?
3. How are constellations useful to astronomers? How many stars are not part of any constellation?
4. A fellow student tells you that only those stars in Figure 1-3b that are connected by blue lines are part of the constellation Orion. How would you respond?
5. Why are different stars overhead at 10:00 p.m. on a given night than two hours later at midnight? Why are different stars overhead at midnight on June 1 than at midnight on December 1?
6. What is the celestial equator? How is it related to Earth's equator? How are the north and south celestial poles related to Earth's axis of rotation?
7. Where would you have to look to see your zenith?
8. How do the stars appear to move over the course of the night as seen from the north pole? As seen from the equator? Why are these two motions different?
9. Using a diagram, explain why the tilt of Earth's axis relative to Earth's orbit causes the seasons as we orbit the Sun.
10. Give two reasons why it is warmer in summer than in winter.
11. What are the March and September equinoxes? What are the northern and southern solstices? How are these four points related to the ecliptic and the celestial equator?
12. How does the daily path of the Sun across the sky change with the seasons? Why does it change?
13. Describe how the seasons would be different if Earth's axis of rotation, rather than having its present 23½° tilt, were tilted (a) by 0° or (b) by 90°.
14. Explain the difference between sunlight and moonlight.
15. Explain why the Moon exhibits phases.
16. At approximately what time does the Moon rise when it is (a) a new moon; (b) a first quarter moon; (c) a full moon; and (d) a third quarter moon?
17. If you lived on the Moon, would you see Earth go through phases? If so, would the sequence of phases be the same as those of the Moon as seen from Earth, or would the sequence be reversed? Explain using Figure 1-21.
18. What is the difference between a sidereal month and a synodic month? Which is longer? Why?
19. What is the difference between the umbra and the penumbra of a shadow?
20. Why doesn't a lunar eclipse occur at every full moon and a solar eclipse at every new moon?
21. Which type of eclipse—lunar or solar—do you think more people on Earth have seen? Why?
22. How is an annular eclipse of the Sun different from a total eclipse of the Sun? What causes this difference?

Chp 1-Discussion Questions. Predicting the Motions of the Stars, Sun, and Moon

1. Scientists assume that "reality is rational." Discuss what this means and the thinking behind it.
2. All scientific knowledge is inherently provisional. Discuss whether this is a weakness or a strength of the scientific method.
3. Examine a list of the 88 constellations. Are there any constellations whose names obviously date from modern times? Where are these constellations located? Why do you suppose they do not have archaic names?
4. In William Shakespeare's Julius Caesar (act 3, scene 1), Caesar says:

But I am constant as the northern star,
Of whose true-fix'd and resting quality
There is no fellow in the firmament.

Translate Caesar's statement about the "northern star" into modern astronomical language. Is the northern star truly "constant"? Was the northern star the same in Shakespeare's time (1564–1616) as it is today?

Chp 1-Collaborative Group Exercises. Predicting the Motions of the Stars, Sun, and Moon

1. A scientific theory is fundamentally different from the everyday use of the word "theory." List and describe any three scientific theories of your choice and creatively imagine an additional three hypothetical theories that are not scientific. Briefly describe what is scientific and what is nonscientific about each of these theories.
2. Using a bright light source at the center of a darkened room or a flashlight, use your fist held at arm's length to demonstrate the difference between a full moon and a lunar eclipse. (Use yourself or a classmate as Earth.) How must your fist "orbit" Earth so that lunar eclipses do not happen at every full moon? Create a simple sketch to illustrate your answers.
3. Imagine you are planning a trip to see a solar eclipse in the future. Using Table 1-2 showing when and where solar eclipses are visible, which solar eclipse would you most want to go see and why?

Chp 2-Review Questions. Decoding the Hidden Messages in Starlight

1. For each of the following wavelengths, state whether it is in the radio, microwave, infrared, visible, ultraviolet, X-ray, or gamma-ray portion of the electromagnetic spectrum and explain your reasoning:
a) 2.6 μm
b) 34 m
c) 0.54 nm
d) 0.0032 nm
e) 0.620 μm
f) 310 nm
g) 0.012 m
2. A cellular phone is actually a radio transmitter and receiver. You receive an incoming call in the form of a wave of frequency 880.65 MHz, what is the wavelength (in meters) of this wave?
3. Using Wien's law and the Stefan-Boltzmann law, explain the color and intensity changes that are observed as the temperature of a hot, glowing object increases.
4. If you double the Kelvin temperature of a hot piece of steel, how much more energy will it radiate per second?
5. The bright star Bellatrix in the constellation Orion has a surface temperature of 21,500 K. What is its wavelength of maximum emission in nanometers? What color is this star?
6. The bright star Antares in the constellation Scorpius (the Scorpion) emits the greatest intensity of light at a wavelength of 853 nm. What is the surface temperature of Antares? What color is this star?
7. Explain how Bohr's model of the atom accounts for spectra.
8. Why do different elements display different patterns of lines in their spectra?
9. What is the Doppler effect? Why is it important to astronomers?
10. If you see a blue star, what does its color tell you about how the star is moving through space? Explain your answer.
11. With the aid of a diagram, describe a refracting telescope.
12. With the aid of a diagram, describe a reflecting telescope.
13. Which dimensions of the telescope determine its light-gathering power?
14. What is the purpose of a telescope eyepiece?
15. Quite often advertisements appear for telescopes that extol their magnifying power. Is this a good criterion for evaluating telescopes? Explain your answer.
16. Explain some of the disadvantages of refracting telescopes compared to reflecting telescopes.
17. What is the angular resolution of a telescope?
18. What is adaptive optics?
19. What is a charge-coupled device (CCD)? Why have CCDs replaced photographic film for recording astronomical images?
20. Why can radio astronomers make observations at any time during the day, whereas optical astronomers are mostly limited to observing at night? (*Hint: Does a radio work any better or worse in the daytime than at night?*)
21. Why must astronomers use satellites and Earth-orbiting observatories to study the heavens at X-ray and gamma-ray wavelengths?

Chp 2-Discussion Questions. Decoding the Hidden Messages in Starlight

1. The human eye is most sensitive over the same wavelength range at which the Sun emits the greatest intensity of light. Suppose creatures were to evolve on a planet orbiting a star somewhat hotter than the Sun. To what wavelengths would their vision most likely be sensitive?
2. Why do you suppose that ultraviolet light can cause skin cancer but ordinary visible light does not?
3. If you were in charge of selecting a site for a new observatory, what factors would you consider important?
4. Discuss the advantages and disadvantages of using a small telescope in Earth's orbit versus a large telescope on a mountaintop.

Chp 2-Collaborative Group Exercises. Decoding the Hidden Messages in Starlight

1. The Doppler effect describes how relative motion impacts wavelength. With a classmate, stand up and demonstrate each of the following: (a) a blueshifted source for a stationary observer; (b) a stationary source and an observer detecting a redshift; and (c) a source and an observer both moving in the same direction, but the observer is detecting a redshift. Create simple sketches to illustrate what you and your classmate did.
2. Stand up and have everyone in your group join hands, making as large a circle as possible. If a telescope mirror were built as big as your circle, what would be its diameter?
3. Are there enough students in your class to stand and join hands and make two large circles that recreate the sizes of the two Keck telescopes? Explain how you determined your answer.

Chp 3-Review Questions. Analyzing Scales and Motions of the Universe

1. Write the following numbers using powers-of-ten notation:
   a) 10 million
   b) 60 thousand
   c) four one-thousandths
   d) 38 billion
   e) your age in months
2. How is an astronomical unit (AU) defined? Give an example of a situation in which this unit of measure would be convenient to use.
3. Give the word or phrase that corresponds to the following standard abbreviations:
   a) km
   b) cm
   c) s
   d) km/s
   e) mi/h
   f) m
   g) m/s
   h) h
   i) ly
   j) g
   k) kg

Which of these are units of speed? (*Hint: You may have to refer to a dictionary. All of these abbreviations should be part of your working vocabulary.*)

4. A reporter once described a light-year as "the time it takes light to reach us traveling at the speed of light." How would you correct this statement?
5. When the *Voyager 2* spacecraft sent back pictures of Neptune during its flyby of that planet in 1989, the spacecraft's radio signals traveled for 4 hours at the speed of light to reach Earth. How far away was the spacecraft? Give your answer in kilometers, using powers-of-ten notation. (Hint: See the preceding question.)
6. How did the ancient Greeks explain why the Sun and the Moon slowly change their positions relative to the background stars?
7. In what direction does a planet move relative to the stars when it is in direct motion? When it is in retrograde motion? How do these compare with the direction in which we see the Sun move relative to the stars?
8. (a) In what direction does a planet move relative to the horizon over the course of one night? (b) The answer to (a) is the same whether the planet is in direct motion or retrograde motion. What does this tell you about the speed at which planets move on the celestial sphere?
9. What is the significance of Occam's razor as a tool for analyzing theories?
10. How did the models of Aristarchus and Copernicus explain the retrograde motion of the planets?
11. At what configuration (for example, superior conjunction, greatest eastern elongation, and so on) would it be best to observe Mercury or Venus with an Earth-based telescope? At what configuration would it be best to observe Mars, Jupiter, or Saturn? Explain your answers.

12. Which planets can never be seen at opposition? Which planets can never be seen at inferior conjunction? Explain your answers.
13. What is the difference between the synodic period and the sidereal period of a planet?
14. What are the foci of an ellipse? If the Sun is at one focus of a planet's orbit, what is at the other focus?
15. What are Kepler's three laws? Why are they important?
16. At what point in a planet's elliptical orbit does it move fastest? At what point does it move slowest? At what point does it sweep out an area at the fastest rate?
17. The orbit of a spacecraft about the Sun has a perihelion distance of 0.1 AU and an aphelion distance of 0.4 AU. What is the semimajor axis of the spacecraft's orbit? What is its orbital period?
18. A comet with a period of 125 years moves in a highly elongated orbit about the Sun. At perihelion, the comet comes very close to the Sun's surface. What is the comet's average distance from the Sun? What is the farthest it can get from the Sun?
19. What observations did Galileo make that reinforced the heliocentric model? Why could these observations not have been made before Galileo's time?
20. Why does Venus have its largest angular diameter when it is new and its smallest angular diameter when it is full?
21. What are Newton's three laws? Give an everyday example of each law.
22. How much force do you have to exert on a 3-kg brick to give it an acceleration of 2 m/s^2? If you double this force, what is the brick's acceleration? Explain your answer.
23. Suppose that Earth were moved to a distance of 3.0 AU from the Sun. How much stronger or weaker would the Sun's gravitational pull be on Earth? Explain your answer.
24. In 2006, Mercury was at greatest western elongation on April 8, August 7, and November 25. It was at greatest eastern elongation on February 24, June 20, and October 17. Does Mercury take longer to go from eastern to western elongation, or vice versa? Explain why, using Figure 3-8.
25. The mass of the Moon is 7.35×10^{22} kg, while that of Earth is 5.98×10^{24} kg. The average distance from the center of the Moon to the center of Earth is 384,400 km. What is the size of the gravitational force that Earth exerts on the Moon?
26. What is the size of the gravitational force that the Moon exerts on Earth? How do your answers compare with the force between the Sun and Earth calculated in the text?

Chp 3-Discussion Questions. Analyzing Scales and Motions of the Universe

1. Which planet would you expect to exhibit the greatest variation in apparent brightness as seen from Earth? Which planet would you expect to exhibit the greatest variation in angular diameter? Explain your answers.
2. What do you believe to be Galileo's single most important astronomical observation, and why it was most important?

Chp 3-Collaborative Group Exercises. Analyzing Scales and Motions of the Universe

1. Use two thumbtacks, a loop of string, and a pencil to draw several ellipses. Describe how the shape of an ellipse varies as the distance between the thumbtacks changes.
2. Use data from the appendix to determine how many Martian years old each member of your group would be if they were born on Mars.
3. Considering where your group is sitting right now, how many times dimmer would an imaginary, super-deluxe, ultrabright flashlight be if it were located at the front door of the group member who lives

farthest away as compared to if it were at the front door of the group member who lives closest. Explain your reasoning.

4. Galileo's *Dialogue Concerning the Two World Chief Systems* described fictional conversations between three people. Create a short play using this style, describing Kepler's laws of planetary motion using each person in your group.

5. Astronomers use powers of ten to describe the distances to objects. List an object or place that is located at very roughly each of the following distances from you: 10^{-2} m, 100 m, 10^{1} m, 10^{3} m, 10^{7} m, 10^{10} m, and 10^{20} m.

Chp 4-Review Questions. Exploring Our Evolving Solar System

1. What are the two agreed upon defining characteristics of a planet?
2. Compare the characteristics of a terrestrial planet to that of a Jovian planet.
3. In what ways are the largest moons similar to the terrestrial planets? In what ways are they different? Which moons are largest?
4. What is meant by the average density of a planet? Do all the planets orbit the Sun in the same direction? Are all of the orbits circular?
5. What is an asteroid? What is a trans-Neptunian object? In what ways are these minor members of the solar system like or unlike the planets?
6. What are the asteroid belt, the Kuiper belt, and the Oort cloud? Where are they located? How do the objects found in these three regions compare?
7. In what ways is Pluto similar to a terrestrial planet? In what ways is it different?
8. What is the connection between comets and the Kuiper belt? What is the connection between comets and the Oort cloud?
9. Imagine a trans-Neptunian object with roughly the same mass as Earth but located 50 AU from the Sun. (a) What do you think this object would be made of? Explain your reasoning. (b) On the basis of this speculation, assume a reasonable density for this object and calculate its diameter. How many times bigger or smaller than Earth would it be?
10. What is the nebular hypothesis?
11. What is a protosun? What causes it to shine? Into what does it evolve?
12. What are proplyds? What do they tell us about the plausibility of our model of the solar system's origin?
13. (a) What is meant by accretion? (b) Why are the terrestrial planets denser at their centers than at their surfaces?
14. Explain how our current understanding of the formation of the solar system can account for the following characteristics of the solar system: (a) All planetary orbits lie in nearly the same plane. (b) All planetary orbits are nearly circular. (c) The planets orbit the Sun in the same direction in which the Sun itself rotates.
15. Explain why most of the moons of Jupiter orbit that planet in the same direction that Jupiter rotates.
16. What are the differences between radial velocity and the transit method of extrasolar planet detection?

Chp 4-Discussion Questions. Exploring Our Evolving Solar System

1. Propose an explanation of why the Jovian planets are orbited by terrestrial-like moons.
2. Suppose that a planetary system is now forming around some protostar in the sky. In what ways might this planetary system turn out to be similar to or different from our own solar system? Explain your reasoning.
3. Suppose astronomers discovered a planetary system in which the planets orbit a star along randomly inclined orbits. How might a theory for the formation of that planetary system differ from that for our own?

Chp 4-Collaborative Group Exercises. Exploring Our Evolving Solar System

1. Imagine that scientists are proposing to send a robotic lander to visit Jupiter's Callisto. Create a 100-word written proposal describing why you would most like to send a robotic lander to another one of the Galilean moons. Explain why your group found it to be the most interesting and why the government should allocate the money for your alternative project. In your proposal, be sure to demonstrate your knowledge of Callisto and at least one other moon.
2. Find objects in the room or among your possessions that can be used to create a reasonably accurate scale model of the planets of our solar system. Try finding a small object to represent Mercury first.

Chp 5-Review Questions. Uncovering Earth's System

1. How does water falling as snow atop a mountain eventually become a cloud?
2. What is unique about the behavior of water compared to other common substances?
3. How does the greenhouse effect influence the temperature of the atmosphere? Which properties of greenhouse gases in the atmosphere cause this effect?
4. How do we know that Earth was once entirely molten?
5. What are the different types of seismic waves? Why are seismic waves useful for probing Earth's interior structure?
6. Describe the interior structure of Earth.
7. The deepest wells and mines go down only a few kilometers. What, then, is the evidence that iron is abundant in Earth's core? That Earth's outer core is molten but the inner core is solid?
8. Describe the process of plate tectonics. Give specific examples of geographic features created by plate tectonics.
9. Explain how convection in Earth's interior drives the process of plate tectonics.
10. Describe the various ways in which Earth's surface is reshaped over time.
11. Describe Earth's magnetosphere. If Earth did not have a magnetic field, do you think aurorae would be more common or less common than they are today?
12. Ozone and carbon dioxide each make up only a fraction of a percent of our atmosphere. Why, then, should we be concerned about small increases or decreases in the atmospheric abundance of these gases?
13. What is the difference between ozone depletion and global warming?

Chp 5-Discussion Questions. Uncovering Earth's Systems

1. The human population on Earth is currently doubling about every 30 years. Describe the various pressures placed on Earth by uncontrolled human population growth. Can such growth continue indefinitely? If not, what natural and human controls might arise to curb this growth? It has been suggested that overpopulation problems could be solved by colonizing the Moon or Mars. Do you think this is a reasonable solution? Explain your answer.
2. In order to alleviate global warming, it will be necessary to dramatically reduce the amount of carbon dioxide that we release into the atmosphere by burning petroleum. What changes in technology and society do you think will be needed to bring this about?

Chp 5-Collaborative Group Exercises. Uncovering Earth's Systems

1. Using a ruler and self-stick or tape-on labels, create a scale model of Earth on the shortest member of your group. Use the group member's height in inches divided by Earth's diameter (12,800 km) as the scale factor. For example, if the selected group member is 65 in. tall then the 50-km maximum depth of Earth's crust is (65 in. ÷ 12,800 km) × (50-km) = 0.25 in. from the top of the head and 0.25 in. from the bottom of the feet.

Chp 6-Review Questions. Exploring Terrestrial Surface Processes and Atmospheres

1. Describe the kinds of features that can be seen on the Moon with a small telescope.
2. Are impact craters on the Moon the same shape as the meteoroids that made the impact? Explain your answer.
3. Why is Earth geologically active while the Moon is not?
4. Rocks found on the Moon are between 3.1 and 4.47 billion years old. By contrast, the majority of Earth's surface is made of oceanic crust that is less than 200 million years old, and the very oldest Earth rocks are about 4 billion years old. If Earth and the Moon are essentially the same age, why is there such a disparity in the ages of rocks on the two worlds?
5. What kind of surface features are found on Mercury? How do they compare to surface features on the Moon? Why are they probably much older than most surface features on Earth?
6. If Mercury is the closest planet to the Sun and has such a high average surface temperature, how is it possible that ice might exist on its surface?
7. What is flake tectonics? Why does Venus exhibit flake tectonics rather than plate tectonics?
8. How was water most recently discovered on Mars?
9. How was water most recently discovered on Earth's Moon?
10. Why do ice rafts indicate the existence of a subsurface ocean on Europa?

Chp 6-Discussion Questions. Exploring Terrestrial Surface Processes and Atmospheres

1. NASA is planning a new series of manned missions to the Moon. Compare the advantages and disadvantages of exploring the Moon with astronauts as opposed to using mobile, unmanned instrument packages.
2. Describe how you would empirically test the idea that human behavior is related to the phases of the Moon. What problems are inherent in such testing?
3. Imagine that you are planning a lunar landing mission. What type of landing site would you select? Where might you land to search for evidence of recent volcanic activity?
4. If you were planning a new mission to Mercury, what features and observations would be of particular interest to you?
5. The total cost of the Mars Global Surveyor mission was about $154 million. (To put this number in perspective, in 2000 the U.S. Mint spent about $40 million to advertise its new $1 coin, which failed to be accepted by the public. Several recent Hollywood movies have had larger budgets than the Mars Global Surveyor.) Does this expenditure seem reasonable to you? Why or why not?
6. Is it worthwhile for scientists to actively search for water on planets and satellites?

Chp 6-Collaborative Group Exercises. Exploring Terrestrial Surface Processes and Atmospheres

1. The image of the Moon in Figure 6-2 reveals numerous craters. Using the idea that the Moon's landscape can only be changed by impacts, make a rough sketch showing 10 of the largest craters and label them from oldest (those that showed up first) to youngest (the most recent ones). Explain your reasoning and any uncertainties.
2. Consider the image of Mars in Figure 6-1. Draw a circle on your paper roughly 5 cm in diameter and, taking turns, have each person in your group sketch a different region of Mars. How is your collaborative sketch different from the other images of Mars found throughout the book?

Chp 7-Review Questions. Observing the Dynamic Giant Planets

1. In what ways are the motions of Jupiter's atmosphere like the motion of water stirred in a pot (see Figure 7-2b)? In what ways are they different?
2. How do the swirling atmospheres of Jupiter and Saturn compare?
3. What would happen if you tried to land a spacecraft on the surface of Jupiter?
4. What are the belts and zones in the atmospheres of Jupiter and Saturn? Is the Great Red Spot more like a belt or a zone? Explain your answer.
5. Describe the internal structures of Jupiter and Saturn, and compare them with the internal structure of Earth.
6. Briefly describe the evidence supporting the idea that Uranus was struck by a large planet-like object several billion years ago.
7. Describe the seasons on Uranus. In what ways are the Uranian seasons different from those on Earth?
8. Why are Uranus and Neptune distinctly greenish-blue in color, while Jupiter and Saturn are not?
9. How many rings encircle Saturn? Draw a sketch.
10. If Saturn's rings are not solid, why do they look solid when viewed through a telescope?
11. Compare the rings that surround Jupiter, Saturn, Uranus, and Neptune. Briefly discuss their similarities and differences.

Chp 7-Discussion Questions. Observing the Dynamic Giant Planets

1. The classic science fiction films *2001: A Space Odyssey* and *2010: The Year We Make Contact* both involve manned spacecraft in orbit around Jupiter. What kinds of observations could humans make on such a mission that cannot be made by robotic spacecraft? What would be the risks associated with such a mission? Do you think that a manned Jupiter mission would be as worthwhile as a manned mission to Mars? Explain your answers.
2. Suppose that Saturn were somehow moved to an orbit around the Sun with semimajor axis 1 AU, the same as Earth's. Discuss what long-term effects this would have on the planet and its rings.
3. Sir William Herschel, a British astronomer, discovered Uranus in 1781 and named it Georgium Sidus (Latin for "Georgian Star"), after the reigning monarch, George III. What name might Uranus have been given in 1781 if an astronomer in your country had discovered it? Why? What if it had been discovered in your country in 1881? In 1991?

Chp 7-Collaborative Group Exercises. Observing the Dynamic Giant Planets

1. Using a ruler with millimeter markings on the first image of Jupiter in the text (Figure 7-1a), determine the ratio of the longest width of the Great Red Spot to the full diameter of Jupiter. Each group member should measure the image and all values should be averaged.
2. The text provides different years that spacecraft have flown by Jupiter and Saturn. List these dates and create a time line by listing one important event that was occurring on Earth during each of those years.
3. If the largest circle you can draw on a piece of paper represents the largest diameter of Saturn's rings, about how large would Saturn be if scaled appropriately? Which item in a group member's backpack is closest to this size?

Chp 8-Review Questions. Looking for Life beyond Earth

1. Why are extreme life-forms on Earth, such as those shown in the photograph that opens this chapter, of interest to astrobiologists?
2. What is meant by "life as we know it"? Why do astrobiologists suspect that extraterrestrial life is likely to be of this form?
3. How have astronomers discovered organic molecules in interstellar space? Does this discovery mean that life of some sort exists in the space between the stars?
4. Mercury and Venus are both considered unlikely places to find life. Suggest why this should be.
5. Many science-fiction stories and movies—including *The War of the Worlds*, *Invaders from Mars*, *Mars Attacks!,* and *Martians, Go Home*—involve invasions of Earth by intelligent beings from Mars. Why Mars rather than any of the other planets?
6. Describe how the Viking Landers looked for evidence of life on Mars.
7. Explain which variable in the Drake equation is the most difficult to estimate and suggest why this would be.
8. Suppose someone brought you a rock that he claimed was a Martian meteorite. What scientific tests would you recommend be done to test this claim?
9. Why are most searches for extraterrestrial intelligence made using radio telescopes? Why are most of these carried out at frequencies between 10^3 MHz and 10^4 MHz?
10. Explain why planet-hunting infrared telescopes need to be placed in space.

Chp 8-Discussion Questions. Looking for Life beyond Earth

1. Suppose someone told you that the Viking Landers failed to detect life on Mars simply because the tests were designed to detect terrestrial life-forms, not Martian life-forms. How would you respond?
2. Science-fiction television shows and movies often depict aliens as looking very much like humans. Discuss the likelihood that intelligent creatures from another world would have (a) a biochemistry similar to our own, (b) two legs and two arms, and (c) about the same dimensions as a human.
3. The late, great science-fiction editor John W. Campbell exhorted his authors to write stories about organisms that think as well as humans but not like humans. Discuss the possibility that an intelligent being from another world might be so alien in its thought processes that we could not communicate with it.
4. If a planet always kept the same face toward its star, just as the Moon always keeps the same face toward Earth, most of the planet's surface would be uninhabitable. Discuss why.
5. How do you think our society would respond to the discovery of intelligent messages coming from a civilization on a planet orbiting another star? Explain your reasoning.
6. What do you think will set the limit on the lifetime of our technological civilization? Explain your reasoning.

7. The first of all Earth spacecraft to venture into interstellar space were *Pioneer 10* and *Pioneer 11*, which were launched in 1972 and 1973, respectively. Their missions took them past Jupiter and Saturn and eventually beyond the solar system. Both spacecraft carry a metal plaque with artwork (reproduced below) that shows where the spacecraft is from and what sort of creatures designed it. If an alien civilization were someday to find one of these spacecraft, which of the features on the plaque do you think would be easily understandable to them? Explain.

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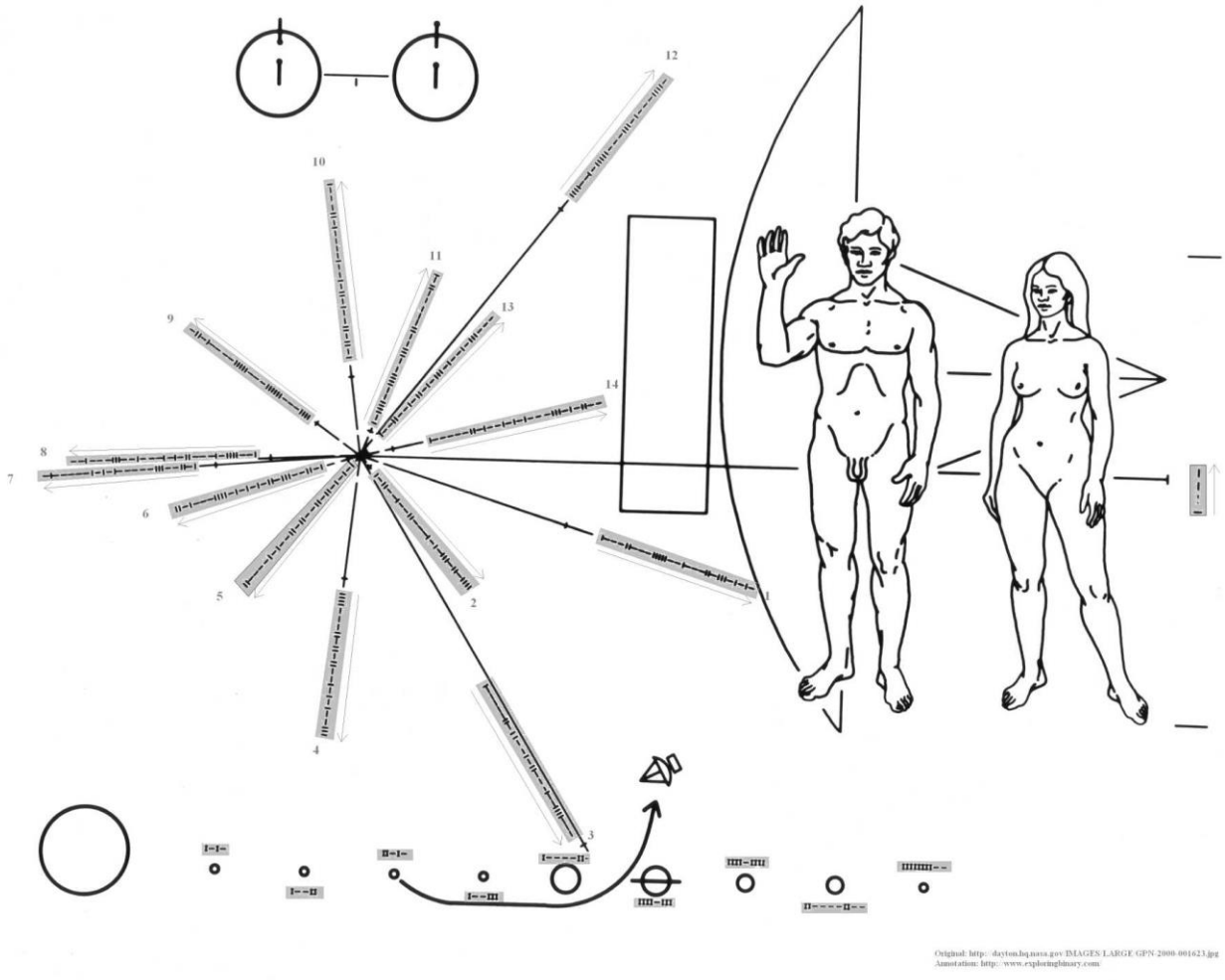
Middle left is position of the Sun relative to 14 reference stars (pulsars) and the center of the Galaxy
Top left is Hydrogen emitting radiation at a wavelength of 21 cm
Far right is the mathematical Binary equivalent of the decimal number 8



Across bottom are planets of the solar system and their relative distances from the Sun (shown in binary code)

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Chp 8-Collaborative Group Exercises. Looking for Life beyond Earth

1. Any living creatures in the subsurface ocean of Europa would have to survive without sunlight. Instead, they might obtain energy from Europa's inner heat. Search the Internet for information about "black smokers," which are associated with high-temperature vents at the bottom of Earth's oceans. What kind of life is found around black smokers? How do these life-forms differ from the more familiar organisms found in the upper levels of the ocean?
2. Like other popular media, the Internet is full of claims of the existence of "extraterrestrial intelligence," namely, UFO sightings and alien abductions. (a) Choose a Web site of this kind and analyze its content using the idea of Occam's razor, the principle that if there is more than one viable explanation for a phenomenon, one should choose the simplest explanation that fits all the observed facts.
(b) Read what a skeptical Web site has to say about UFO sightings. A good example is the Web site of the Committee for the Scientific Investigation of Claims of the Paranormal, or CSICOP. After considering what you have read on both sides of the UFO debate, discuss your opinions about whether aliens really have landed on Earth.
3. Imagine that astronomers have discovered intelligent life in a nearby star system. Your group is submitting a proposal for who on Earth should speak for the planet and what 50-word message should be conveyed. Prepare a maximum one-page proposal that states (a) who should speak for Earth and why; (b) what this person should say in 50 words; and (c) why this message is the most important compared to other things that could be said.

Chp 9-Review Questions. Probing the Dynamic Sun

1. What is meant by the luminosity of the Sun?
2. What is thermonuclear fusion? Why is this fusion fundamentally unlike the burning of a log in a fireplace?
3. Why do thermonuclear reactions occur only in the Sun's core, not in its outer regions?
4. If thermonuclear fusion in the Sun were suddenly to stop, what would eventually happen to the overall radius of the Sun? Justify your answer using the ideas of hydrostatic equilibrium and thermal equilibrium.
5. Give some everyday examples of conduction, convection, and radiative diffusion.
6. What is a neutrino? Why is it useful to study neutrinos coming from the Sun? What do they tell us that cannot be learned from other avenues of research?
7. Briefly describe the three layers that make up the Sun's atmosphere. In what ways do they differ from each other?
8. How do astronomers know when the next sunspot maximum and sunspot minimum will occur?
9. Why do astronomers say that the solar cycle is 22 years long, even though the number of sunspots varies over an 11-year period?
10. Explain how the magnetic-dynamo model accounts for the solar cycle.
11. Why should solar flares and coronal mass ejections be a concern for businesses that use telecommunication satellites?

Chp 9-Discussion Questions. Probing the Dynamic Sun

1. Discuss the extent to which cultures around the world have worshiped the Sun as a deity throughout history. Why do you suppose there has been such widespread veneration?
2. In the movie *Star Trek IV: The Voyage Home*, the starship Enterprise flies on a trajectory that passes close to the Sun's surface. What features should a real spaceship have to survive such a flight? Why?
3. Discuss some of the difficulties in correlating solar activity with changes in Earth's climate.
4. Describe some of the advantages and disadvantages of observing the Sun (a) from space and (b) from Earth's south pole. What kinds of phenomena and issues might solar astronomers want to explore from these locations?

Chp 9-Collaborative Group Exercises. Probing the Dynamic Sun

1. Figure 9-16 shows variations in the average latitude of sunspots. Estimate the average latitude of sunspots in the year you were born and estimate the average latitude on your twenty-first birthday. Make rough sketches of the Sun during those years to illustrate your answers.
2. Create a diagram showing a sketch of how limb darkening on the Sun would look different if the Sun had either a thicker or thinner photosphere. Be sure to include a caption explaining your diagram.
3. Solar granules, shown in Figure 9-6, are about 600 miles (1000 km) across. What city is about that distance away from where you are right now? What city is that distance from the birthplace of each group member?
4. Magnetic arches in the corona are shown in Figure 9-20. How many Earths high are these arches, and how many Earths could fit inside one arch?

Chp 10-Review Questions. Observing Properties of Distant Stars

1. Explain the difference between a star's apparent brightness and its luminosity.
2. Why does it take at least six months to make a measurement of a star's parallax?
3. What is the inverse-square law? Use it to explain why an ordinary lightbulb can appear brighter than a star, even though the lightbulb emits far less light energy per second.
4. Why is the magnitude scale called a "backward" scale? What is the difference between apparent magnitude and absolute magnitude?
5. The star Zubenelgenubi (from the Arabic for "scorpion's southern claw") has apparent magnitude 2.75, while the star Sulafat (Arabic for "tortoise") has apparent magnitude 3.25. Which star appears brighter? From this information alone, what can you conclude about the luminosities of these stars? Explain your answer.
6. Menkalinan (Arabic for "shoulder of the rein-holder") is an A2 star in the constellation Auriga (the Charioteer). What is its spectral class? What is its spectral type? Which gives a more precise description of the spectrum of Menkalinan?
7. If a red star and a blue star both have the same radius and both are the same distance from Earth, which one looks brighter in the night sky? Explain why.
8. If a red star and a blue star both appear equally bright and both are the same distance from Earth, which one has the larger radius? Explain why.
9. Sketch a Hertzsprung-Russell diagram. Indicate the regions on your diagram occupied by (a) main-sequence stars, (b) red giants, (c)supergiants, (d) white dwarfs, and (e) Sun.
10. What information about stars do astronomers learn from binary systems that cannot be learned in any other way? What measurements do they make of binary systems to garner this information?
11. Which is more massive, a red main-sequence star or a blue main- sequence star? Which has the greater radius? Explain your answers.

Chp 10-Discussion Questions. Observing Properties of Distant Stars

1. In its orbit around Earth, the *Hipparcos* satellite could measure stellar parallax angles with acceptable accuracy only if the angles were larger than about 0.002 arcsec. Discuss the advantages or disadvantages of making parallax measurements from a satellite in a large solar orbit, say at the distance of Jupiter from the Sun. If this satellite can also measure parallax angles of 0.002 arcsec, what is the distance of the most remote stars that can be accurately determined? How much bigger a volume of space would be covered compared to Earth-based observations? How many more stars would you expect to be contained in that volume?
2. As seen from the starship *Enterprise* in the *Star Trek* television series and movies, stars appear to move across the sky due to the starship's motion. How fast would the *Enterprise* have to move in order for a star 1 pc away to appear to move 1° per second?
(*Hint: The speed of the star as seen from the Enterprise is the same as the speed of the Enterprise relative to the star.)* How does this compare with the speed of light? Do you think the stars appear to move as seen from an orbiting space shuttle, which moves at about 8 km/s?

Chp 10-Collaborative Group Exercises. Observing Properties of Distant Stars

1. Considering where your group is sitting right now, how many times dimmer would an imaginary, super-deluxe, ultrabright flashlight be if it were located at the front door of the group member who lives

farthest away as compared to if it were at the front door of the group member who lives closest. Explain your reasoning.

2. As a group, select any two of the stars in a text appendix listing of the sky's brightest stars and compare the apparent visual magnitudes to determine how many times brighter one is than the other.

Chp 11-Review Questions. Inferring Patterns in Star Life Cycles

1. If no one has ever seen a star go through the complete formation process, how are we able to understand how stars form?
2. If an interstellar medium fills the space between the stars, how is that we are able to see the stars at all?
3. In Figure 11-2, what makes the nebula dark? What makes the Orion nebula glow?
4. Describe the energy source that causes a protostar to shine. How does this source differ from the energy source inside a main-sequence star?
5. In what ways is the internal structure of a 1-$M_\odot$ main-sequence star different from that of a 5-$M_\odot$ main-sequence star? How is it different from a 0.5-$M_\odot$ main-sequence star? What features are common to all these stars?
6. How does the chemical composition of the present-day Sun's core compare to the core's composition when our Sun formed? What caused the change?
7. On what grounds are astronomers able to say that the Sun has about 5.4×10^9 years remaining in its main-sequence stage?
8. Explain how it is possible for the core of a red giant to contract at the same time that its outer layers expand.
9. Why does helium fusion require much higher temperatures than hydrogen fusion?
10. What does it mean when an astronomer says that a star "moves" from one place to another on an H-R diagram?
11. Explain how and why the turnoff point on the H-R diagram of a cluster is related to the cluster's age.
12. What is the difference between Population I and Population II stars? In what sense can the stars of one population be regarded as the "children" of the other population?
13. What are thermal pulses in AGB stars? What causes them? What effect do they have on the luminosity of the star?
14. How can an astronomer tell the difference between a planetary nebula and a planet?
15. What is a white dwarf? Does it produce light in the same way as a star like the Sun?

Chp 11-Discussion Questions. Inferring Patterns in Star Life Cycles

1. Some science-fiction movies show stars suddenly becoming dramatically brighter when they are "born" (that is, when thermonuclear fusion reactions begin in their cores). Discuss whether or not this is a reasonable depiction.
2. Eventually the Sun's luminosity will increase to the point where Earth can no longer sustain life. Discuss what measures a future civilization might take to preserve itself from such a calamity.

Chp 11-Collaborative Group Exercises. Inferring Patterns in Star Life Cycles

1. Imagine that your group walks into a store that specializes in selling antique clothing. Prepare a list of observable characteristics that you would look for to distinguish which items were from the early, middle, and late twentieth century. Also, write a paragraph that specifically describes how this task is similar to how astronomers understand the evolution of stars.
2. Consider advertisement signs visible at night in your community and provide specific examples of ones that are examples of the three different types of nebulae that astronomers observe and study. If

an example does not exist in your community, creatively design an advertisement sign that could serve as an example.

3. The inverse relationship between a star's mass and its main-sequence lifetime is sometimes likened to automobiles in that the more massive vehicles, such as commercial semi–tractor-trailer trucks, need to consume significantly more fuel to travel at highway speeds than more lightweight and economical vehicles. As a group, create a table called "Maximum Vehicle Driving Distances," much like Table 11-1: Approximate Main-Sequence Lifetimes, by making estimates for any five vehicles of your group's choosing. The table's column headings should be (1) vehicle make and model; (2) estimated gas tank size; (3) cost to fill tank; (4) estimated mileage (in miles per gallon); and (5) number of miles driven on a single fill-up.

Chp 12-Review Questions. Predicting the Violent End of the Largest Stars

1. What are the important thermonuclear reactions leading up to the formation of iron?
2. Describe the steps leading up to a core-collapse supernova.
3. How do neutron stars form?
4. What are the differences between degenerate-electron pressure and degenerate-neutron pressure?
5. How is a neutron star similar to a coastal lighthouse?
6. What determines if a core-collapse supernova will form a neutron star or a black hole?
7. What is the difference between a black hole's event horizon and its Schwarzschild radius?
8. When we say that the Moon has a radius of 1080 miles (1737 km), we mean that this is the smallest radius that encloses all of the Moon's material. In this sense, is it correct to think of the Schwarzschild radius as the radius of a black hole? Why or why not?
9. Astronomers cannot actually see the black hole candidates in close binary systems. How, then, do they know that these candidates are not white dwarfs or neutron stars?
10. What are the differences between a Type Ia and a Type II supernova?
11. What are the similarities between a nova and a Type Ia supernova? What are the differences?
12. What is the similarity between a nova and an X-ray burster? How are they different?

Chp 12-Discussion Questions. Predicting the Violent End of the Largest Stars

1. Imagine that our Sun was somehow replaced by a 1-$M_\odot$ white-dwarf star and that Earth continued in an orbit of semimajor axis 1 AU around this star. Discuss what effects this would have on our planet. What would the white dwarf look like as seen from Earth? Could you look at it safely with the unaided eye? Would Earth's surface temperature remain the same as it is now?
2. The similar names white dwarf, red dwarf, and brown dwarf describe three very different kinds of objects. Suggest better names for these three kinds of objects, and describe how your names more accurately describe the objects' properties.
3. Describe the kinds of observations you might make in order to locate and identify black holes.

Chp 12-Collaborative Group Exercises. Predicting the Violent End of the Largest Stars

1. Imagine that a supernova originating from a close binary star system, both of whose stars have less than 4 solar masses, began (as seen from Earth) on the most recent birthday of the youngest person in your group. Using the light curves in Figure 12-18, what would its new luminosity be today and how bright would it appear in the sky (apparent magnitude) if it were located 32.6 light-years away? How would your answers change if you were to discover that the supernova actually originated from an isolated star with a mass 15 times greater than our Sun?
2. Consider the graph showing a recording of a pulsar in Figure 12-9. Sketch and label similar graphs that your group estimates for: (1) a rapidly spinning, professional ice skater holding a flashlight; (2) an emergency signal on an ambulance; and (3) a rotating beacon at an airport.
3. As stars go, pulsars are tiny, only about 12 miles (20 km) across. Name three specific things or places that have a size or a separation of about 12 miles.

Chp 13-Review Questions. Exploring Our Galaxy

1. Why do the stars of the Galaxy appear to form a bright band that extends around the sky?
2. How did observations of globular clusters help astronomers determine our location in the Galaxy?
3. Why are infrared telescopes useful for exploring the structure of the Galaxy? Why is it important to make observations at both near- infrared and far-infrared wavelengths?
4. The galactic halo is dominated by Population II stars, whereas the galactic disk contains predominantly Population I stars. In which of these parts of the Galaxy has star formation taken place recently? Explain your answer.
5. Most interstellar hydrogen atoms emit only radio waves at a wavelength of 21 cm, but some hydrogen clouds emit profuse amounts of visible light (see, for example, Figure 11-1). What causes this difference?
6. The Milky Way map taken at radio wavelengths, shown back in Figure 2-26b, has a large gap on the side of the Galaxy opposite to ours. Why is this?
7. In a spiral galaxy, are stars in general concentrated in the spiral arms? Why are spiral arms so prominent in visible-light images of spiral galaxies?
8. How do astronomers determine how fast the Sun moves in its orbit around the Galaxy? How does this speed tell us about the amount of mass inside the Sun's orbit? Does this speed tell us about the amount of mass outside the Sun's orbit?
9. How do astronomers conclude that vast quantities of dark matter surround our Galaxy? How is this dark matter distributed in space?
10. Another student tells you that the Milky Way Galaxy is made up "mostly of stars." Is this statement accurate? Why or why not?
11. What proposals have been made to explain the nature of dark matter?
12. In our Galaxy, why are stars of spectral classes O and B only found in or near the spiral arms? Is the same true for stars of other spectral classes? Explain why or why not.
13. What is the evidence that there is a supermassive black hole at the center of our Galaxy

Chp 13-Discussion Questions. Exploring Our Galaxy

1. From what you know about stellar evolution, the interstellar medium, and the density-wave theory, explain the appearance and structure of the spiral arms of grand-design spiral galaxies.
2. What observations would you make to determine the nature of the dark matter in our Galaxy's halo?
3. Describe how the appearance of the night sky might change if dark matter were visible to our eyes.
4. Discuss how a supermassive black hole could have formed at the center of our Galaxy.

Chp 13-Collaborative Group Exercises. Exploring Our Galaxy

1. Student book bags often contain a wide collection of odd-shaped objects. Each person in your group should rummage through her or his own book bag and find one object that is most similar to the Milky Way Galaxy in shape. List the items from each group member's belongings and describe what about the items is similar to the shape of our Galaxy and what about the items is not similar, then indicate which of the items is the closest match.

2. One strategy for identifying a central location is called triangulation. In triangulation, a central position can be pinpointed by knowing the distance from each of three different places. First, on a piece of paper, create a rough map showing where each person in your group lives. Second, create a circle around each person's home that has a radius equal to the distance that each home is from your classroom. Label the place where the circles intersect as your classroom. Why can you not identify the position of the classroom with only two people's circles?

Chp 14-Review Questions. Investigating Other Galaxies

1. Why did many nineteenth-century astronomers think that the "spiral nebulae" are part of the Milky Way?
2. What was the Shapley-Curtis "debate" all about? Was a winner declared at the end of the "debate"? Whose ideas turned out to be correct?
3. How did Edwin Hubble prove that the Andromeda "Nebula" is not a nebula within our Milky Way Galaxy?
4. What is the Hubble classification scheme? Which category includes the largest galaxies? Which includes the smallest? Which category of galaxy is the most common?
5. Which is more likely to have a blue color, a spiral galaxy or an elliptical galaxy? Explain why.
6. Why are Type Ia supernovae useful for finding the distances to very remote galaxies? Can they be used to find the distance to any galaxy you might choose? Explain your answers.
7. What is the Tully-Fisher relation? How is it used for measuring distances? Can it be used for galaxies of all kinds? Why or why not?
8. Some galaxies in the Local Group exhibit blueshifted spectral lines. Why aren't these blueshifts violations of the Hubble law?
9. What is the difference between a cluster and a supercluster? Are both clusters and superclusters held together by their gravity?
10. What are starburst galaxies? How can they be produced by collisions between galaxies?
11. What evidence is there for the existence of dark matter in clusters of galaxies?
12. What is gravitational lensing? Why don't we notice the gravitational lensing of light by ordinary objects on Earth?
13. When quasi-stellar radio sources were first discovered and named, why were they called "quasi-stellar"?

Chp 14-Discussion Questions. Investigating Other Galaxies

1. Earth is composed principally of heavy elements, such as silicon, nickel, and iron. Would you be likely to find such planets orbiting stars in the disk of a spiral galaxy? In the nucleus of a spiral galaxy? In an elliptical galaxy? In an irregular galaxy? Explain your answers.
2. Discuss the advantages and disadvantages of using the various standard candle distance indicators to obtain extragalactic distances.
3. Describe what sorts of observations you might make to search for as-yet-undiscovered galaxies in our Local Group. How is it possible that such galaxies might still remain to be discovered? In what part of the sky would these galaxies be located? What sorts of observations might reveal these galaxies?

Chp 14-Collaborative Group Exercises. Investigating Other Galaxies

1. In the early twentieth century, there was considerable debate about the nature of spiral nebulae and their distance from us, but the debate was resolved by improvements in technology. As a group, list three issues that we, as a culture, did not understand in the past but understand today, and explain why we now have that understanding.
2. Even though there are billions of galaxies, there are not billions of different kinds. In fact, galaxies are classified according to their appearance. As a group, dig into your book bags and put all of the writing implements you have (pens, pencils, highlighters, and so on) in a central pile. Remember

which ones are yours! Determine a classification scheme that sorts the writing implements into at least three to six piles.

3. Write down the scheme from Exercise 2 and the number of items in each pile. Ask the group next to you to use your scheme and sort your materials. Correct any ambiguities before submitting your classification scheme.

4. Imagine your company, Astronomical Artistry, has been contracted by the local marching band to create a football halftime show about spiral galaxies. How exactly would you design the positions of the band members on the field to represent the different spiral galaxies of classes Sa, Sb, and Sc? Create two columns on your paper by drawing a line from top to bottom, drawing sketches in the left-hand column, and writing a description of each sketch in the right-hand column. Also include what the band's opening formation and final formation should be.

Chp 15-Review Questions. Observing the Evolution of the Universe

1. What is Olbers's paradox? How can it be resolved?
2. What does it mean when astronomers say that we live in an expanding universe? What is actually expanding?
3. Describe how the expansion of the universe explains Hubble's law.
4. If a galaxy was discovered to be the most distant ever observed, what would astronomers notice about its spectra and speed?
5. What does it mean to say that the universe is homogeneous? That it is isotropic?
6. How is the expanding universe similar to a baking chocolate chip cake?
7. Where is the center of the universe?
8. Imagine an astronomer living in a galaxy more than a billion light-years away from our own. Is the observable universe for that astronomer the same as for an astronomer on Earth? Why or why not?
9. What is the cosmic microwave background?
10. What was the era of recombination? What significant events occurred in the universe during this era? Was the universe matter- dominated or radiation-dominated during this era?
11. What is dark energy? Describe two ways that we can infer its presence.

Chp 15-Discussion Questions. Observing the Evolution of the Universe

1. How can astronomers be certain that the cosmic microwave background fills the entire cosmos, not just the vicinity of Earth?
2. How does the evidence for the Big Bang confirm or conflict with religious or spiritual views of the beginning of time?
3. Some GUTs predict that the proton is unstable, although with a half-life far longer than the present age of the universe. What would it be like to live at a time when protons were decaying in large numbers?

Chp 15-Collaborative Group Exercises. Observing the Evolution of the Universe

2. Imagine your firm, *Creative Cosmologists Coalition*, has been hired to create a three-panel, folded brochure describing the principal observations that astronomers use to infer the existence of a Big Bang. Create this brochure on an 8½ × 11 piece of paper. Be sure each member of your group supervises the development of a different portion of the brochure and that the small print acknowledges who in your group was primarily responsible for which portion.
3. The three potential geometries of the universe are shown in Figure 15-17. To demonstrate this, ask one member of your group to hold a piece of paper in one of the positions while another member draws two parallel lines that never change in one geometry, eventually cross in another geometry, and eventually diverge in another.
4. The four fundamental forces of nature are the strong force, the weak force, the gravitational force, and the electromagnetic force. List four things at your school that rely on one of these fundamental forces, and explain how each thing is dependent on one of the fundamental forces.
5. Consider the following hypothetical scenario adapted from a daytime cable television talk show. Chris states that Pat borrowed Chris's telescope without permission. Tyler purchased balloons and a new telescope eyepiece without telling Chris. Sawyer borrowed star maps from the library, with the library's permission, but without telling Pat. Eventually, when the four met on Sunday evening, Chris was crying and speechless. Can you create a "grand unified theory" that explains this entire situation?