Solution Manual for Stars and Galaxies 9th Edition Seeds 1305120787 9781305120785

C H A P T E R 2

A USER'S GUIDE TO THE SKY

GUIDEPOST

The previous chapter took you on a cosmic zoom through space and time. That quick preview prepared you for the journey to come. In this chapter you can begin your exploration by viewing the sky from Earth; as you do, consider five important questions:

- ► How are stars and constellations named?
- ► How is the brightness of stars measured and compared?
- ► How does the sky appear to change and move in daily and annual cycles?
- ► What causes seasons?
- ► How do astronomical cycles affect Earth's climate?

2-1 STARS AND CONSTELLATIONS

How are stars and constellations named? How is the brightness of stars measured and compared?

- Although the constellations currently used by astronomers originated in Middle Eastern and Greek mythology, the names are Latin. Even modern constellations, added to fill in the spaces between the ancient figures, have Latin names. Named groups of stars such as the Big Dipper or Orion's Belt that are not complete constellations are called asterisms.
- Astronomers now divide the sky into 88 constellations, defined in 1928 by the International Astronomical Union (IAU).
- The names of individual stars usually come from old Arabic, though modern astronomers often refer to a bright star by its constellation plus a Greek letter assigned according to its brightness within the constellation.

- Astronomers describe the brightness of stars using the magnitude scale. First-magnitude stars are brighter than second-magnitude stars, which are brighter than third-magnitude stars, and so on. The magnitude describing what you see when you look at a star in the sky is its apparent visual magnitude, m_V (p. 16), which includes only types of light visible to the human eye and also does not take into account the star's distance from Earth.
- Flux is a measure of light energy striking one square meter per second. The magnitude of a star is related directly to the flux of light received on Earth from that star.

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2-2 THE SKY AND CELESTIAL MOTIONS

How does the sky appear to change and move in daily and annual cycles?

- The celestial sphere is a scientific model of the sky, to which the stars appear to be attached. Because Earth rotates eastward, the celestial sphere appears to rotate westward on its axis.
- The north and south celestial poles are the pivots on which the sky appears to rotate, and they define the four cardinal directions around the horizon: the north, south, east, and west points. The point directly overhead is the zenith, and the point on the sky directly underfoot is the nadir.
- The celestial equator, which is an imaginary line around the sky above Earth's equator, divides the sky into Northern and Southern Hemisphere.
- As the celestial sphere is curved, the distances between the stars "on" the sky are angular, not linear, distances. These angular distances, measured in degrees, arc minutes, and arc seconds, are not directly related to the true distance between the objects measured in units such as kilometers (km) or light-years (ly). The angular distance across an object is its angular diameter.
- What you see of the celestial sphere depends on your latitude. Much of the sky's Southern Hemisphere is not visible from northern latitudes. To see that part of the sky, you would have to travel southward over Earth's surface.
- Circumpolar constellations are those close enough to a celestial pole that they do not appear to rise from the east and set in the west.
- The angular distance from the horizon to the north celestial pole as measured from the north point always equals your latitude. This equality is an important basis for celestial navigation.
- Precession is caused by the gravitational forces of the Moon and Sun acting on the equatorial bulge of the spinning Earth, causing Earth's axis to sweep around in a conical motion like the motion of a wobbling top's axis. Earth's axis precesses with a period of 26,000 years. As a result, the positions of the celestial poles and celestial equator move slowly against the background of the stars.

2-3 SUN AND PLANETS

What causes seasons?

- The rotation of Earth on its axis produces the daily cycle of day and night, and the revolution of Earth around the Sun produces the annual cycle of the seasons.
- Because Earth orbits the Sun, the Sun appears to move eastward along the ecliptic, through the constellations, completing a circuit of the sky in a year. Because the ecliptic is tipped 23.4 degrees to the celestial equator, the Sun spends half the year in each hemisphere's summer, and is above the horizon longer and shines more directly down on the ground. Both effects cause warmer weather in that hemisphere. In each hemisphere's winter, the Sun is above the sky fewer hours and also shines less directly than in summer, so the winter hemisphere has colder weather. When one hemisphere experiences summer, the opposite hemisphere experiences winter. When one hemisphere experiences spring, the opposite hemisphere experiences fall.

- The beginning of spring, summer, winter, and fall are marked by the vernal equinox, the summer solstice, the autumnal equinox, and the winter solstice.
- In its orbit around the Sun, Earth is slightly closer to the Sun at perihelion in January and slightly farther away from the Sun at aphelion in July. This change in distance to the Sun has almost no effect on Earth's seasons.
- The planets appear to move generally eastward along the ecliptic. They appear like bright, non-twinkling stars with the exception of Uranus and Neptune, which are too faint to be visible to the unaided eye. Mercury and Venus are never seen far from the Sun and are therefore seen either in the evening sky after sunset or in the dawn sky before sunrise.
- Planets visible in the sky at sunset are traditionally called evening stars, and planets visible in the dawn sky are called morning stars even though they are not actually stars.
- The locations of the Sun and planets along the zodiac are diagramed in a horoscope, which is the basis for the ancient pseudoscience (or false science), known as astrology.

2-4 ASTRONOMICAL INFLUENCES ON EARTH'S CLIMATE

How do astronomical cycles affect Earth's climate?

- According to the Milankovitch hypothesis, slow changes in the shape of Earth's orbit, the angle of axis tilt, and axis orientation can alter the planet's heat balance and cause the cycle of ice advances and retreats during an ice age. Evidence found in seafloor samples and other locations support the hypothesis, and the hypothesis is widely accepted today.
- Scientists routinely test their own ideas by organizing theory and evidence into a scientific argument.

CHAPTER OUTLINE

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KEY TERMS

angular diameter
angular distance
aphelion
apparent visual magnitude (m_v)
arc minutes arc
seconds asterisms
autumnal equinox
celestial equator
circumpolar constellations
constellations
ecliptic
evening star
flux
horizon
horoscope
International Astronomical Union (IAU)
magnitude scale
Milankovitch hypothesis
morning star
nadir
north celestial pole
north, south, east, and west points
perihelion
precession
pseudoscience
revolution
rotation
scientific argument
scientific model
south celestial pole
summer solstice
vernal equinox
winter solstice
zenith
zodiac

RESOURCES AND TIPS

Stellarium is an open-source planetarium program available for download. The program can be downloaded at: http://www.stellarium.org. Once you have gone to this site, click on the icons that corresponds to your platform (e.g. Mac OS X, Windows, or Linux) located along the top of the page. The *Stellarium* installation package will download to your computer. There is also a button to download a User's Manual (which is rather technical). Many other resources about Stellarium are available on this site.

For Windows installation: Double click on the stellarium-0.10.2.exe file to run the installer. Follow the on-screen instructions.

Starting Stellarium in Windows: The Stellarium installer creates an item in the Start Menu in the Programs section, from which Stellarium can be run. If you cannot find it, type stellarium in the "Search" box and hit return. You will then get the series of Setup boxes. Stellarium will then appear as an item in the Start Menu and as a desk-top icon. Use this icon to start the program in the future.

Other internet sites related to this material:

Current observational events: http://www.space.com/skywatching/
Night sky events for the week: http://www.nightskyinfo.com/

Related smart phone apps (free):
Sky Guide – virtual star chart from current or manual location
Star Chart – virtual star chart from current or manual location
Night Sky 2 - virtual star chart from current or manual location

ANSWERS TO REVIEW QUESTIONS

1. Our current scientific culture has been greatly influenced by Western Civilization, and the modern constellations came about as Europeans began to explore the world during the 15th to the 17th centuries. The southern sky was unknown by the ancient Greeks and hence uncharted until the age of exploration began. European explorers created constellations in the southern hemisphere that depicted various devices of their time. Europeans also created a few northern hemisphere constellations. Because most of the bright stars were already part of ancient constellations, these newly created northern hemisphere constellations were developed using faint stars.
2. The brightest stars in each constellation are named by a Greek letter followed by the possessive form of the Latin constellation name. The constellation name describes the star's location in the sky and the Greek letter indicates its brightness relative to the other stars in the constellation. The brighter stars have Greek letters nearer the beginning of the Greek alphabet.
3. Which is the asterism and which is the constellation: Orion and Orion's belt? Name another asterism/constellation combination. Orion is the constellations as it defines a region of the sky and Orion's belt is an asterism since it is a grouping of stars within a constellation. The Big Dipper is an example of an asterism found within the constellation Ursa Major.
4. a) α Ursa Majoris is the brighter of the two because it has a Greek letter designation that suggests that it is the brightest star in the constellation of Ursa Majoris.

   b) It is difficult to determine which is brighter; one might guess that α Pegasi should be brighter than ε Scorpii. Both constellations are bright constellations, and α is the brightest star in Pegasus, while ε would be one of the moderately bright stars in Scorpius. As it turns out, ε Scorpii is slightly brighter than α Pegasi.

   c) α Orionis should be much brighter than α Telescopii. Orion is a very bright constellation with several stars brighter than second magnitude. On the other hand, Telescopium is a faint constellation with no stars brighter than third magnitude.
5. Astronomers measure the brightness of stars using the magnitude scale, attributed in its original form to the Greek astronomer Hipparchus (about 190–120 BC). Ancient astronomers divided the stars into six classes: the brightest were called first magnitude and the faintest were called sixth magnitude. Modern astronomers can measure magnitude to high precision and have extended the scale to larger numbers for even fainter stars, and to zero and negative numbers for the brightest stars. The magnitude scale is confusing because it is an inverse scale, meaning that bright objects have smaller magnitudes than fainter objects.
6. In the term *apparent visual magnitude*, the word *apparent* means that the magnitude describes how bright the star appears to us, observing from Earth.

7. In the term *apparent visual magnitude*, the word *visual* means that the magnitude includes only light that is visible to the human eye.
8. The apparent visual magnitude (m_V) indicates how bright a star looks to the human eyes as seen from Earth. It does not take into account how far the star is from Earth and therefore does not indicate the actual light output by the star.
9. No, the apparent visual magnitude numbers of two stars only take into account the apparent brightness at Earth, not the size of the star. A small, nearby star could appear brighter than a faraway, large star.
10. Yes, the apparent visual magnitude numbers of two stars tells us which star appears brighter (or shines more light) than the other star when observed from Earth. This quantity is a constant that is independent of time and therefore should apply to any time interval during which the stars are observed.
11. Why doesn't a magnitude difference of one mean that the corresponding flux ratio is also one? To make modern flux measurements agree with ancient system that had five orders of magnitude, astronomers defined the modern magnitude scale so that the five magnitudes have a flux ratio of 100.

$$\frac{F_{Æ}}{F_B} = 100 = 2.51^5 = 2.51^{(N_B - N_A)}$$

Therefore, with only a magnitude difference of 1 $F_A/F_B = (2.51)^1 = 2.51$.
12. Earth receives more flux from star B, which has a negative apparent visual magnitude. On the modern magnitude scale, the smaller the number, the brighter the star and a few stars are so bright that the scale had to be extended to negative values. The apparent brightness does not define how much light is emitted at the surface of the star, only how much light reaches the Earth.
13. Although modern astronomers know that the stars are scattered through space at different distances, it is still convenient to describe the sky as the celestial sphere: a great sphere enclosing the Earth with the stars stuck on the inside like thumbtacks in a ceiling This is an example of a simple scientific model: it describes what we see as the sky appears to turn above us, and enables us to predict correctly the future positions of the stars at various times of the night and throughout the year.
14. A scientific model is a carefully derived idea of how something works to help scientists think about some aspect of nature. Figure 2-7 shows a spinning top (a) that has an axis of rotation precessing around the normal vector to the floor. This is similar to the motion observed for Earth's north pole among the stars (b) and therefore is a scientific model that helps scientist to think about how Earth's axis precesses around the normal to its orbit, causing the north pole to move slowly against the background of the stars (c). The model holds true in terms of predicting the overall rotation of the axis, but differs in that while gravity tends to make a top fall over, the Earth's axis is twisted upright relative to its orbit instead. This has to do with the bulge that forms equatorially due to rotation and the pull of the Sun and Moon on this bulge.
15. If the Earth did not turn on its axis with respect to the stars, then we would not be able to define the celestial poles or equator.
16. For the celestial equator to be near the horizon, I would need to go to the Earth's north or south pole.
17. If you were on the Earth's equator, the north celestial pole would be on your northern horizon and the south celestial pole would be on your southern horizon.

18. I am lying on the ground, either prone or supine, with my head pointing to the east and my feet pointing to the west. If lying prone, my outstretched arms point to the north (right) and south (left). If lying supine, my outstretched arms point south (right) and north (left).
19. As the Earth rotates on its axis, all of the stars appear to rotate westward, in big circles, around the north and south celestial poles. Circumpolar stars are those at a given latitude that never rise or set. From a latitude close to a celestial pole, such as Norway or Tierra del Fuego, you would have many more circumpolar constellations than at a latitude closer to the equator, such as Hawaii. At the celestial poles, all of the constellations in the sky are circumpolar; at the equator, none of the constellations are circumpolar.
20. During the winter, light from the sun hits Earth at a more oblique angle than it does during the summer. Further, the length of time that the sun is above the horizon is noticeably shorter during the winter than during the summer.
21. The seasons are reversed. The season when the sun is highest in the sky at noon in the southern hemisphere is the season when the sun is lowest in the sky at noon in the northern hemisphere.
22. On the first day of spring in my hemisphere, it would be the first day of fall in the opposite hemisphere.
23. The summer solstice marks the beginning of summer and is the day with the longest period of sunlight. After the summer solstice, the day lit hours start to get shorter so the Sun will be in the sky for slightly less time tomorrow than it was today.
24. The first day of fall in the northern hemisphere occurs on the northern autumnal equinox; this is the same day as the southern vernal equinox (aka first day of spring for the southern hemisphere). At the equinox, the tilt of the Earth's axis is not inclined relative to the Sun so both hemispheres are equally illuminated. So, for two points in either hemisphere located at the same latitude relative to the equator (e.g., 40ºN and 40ºS), those two places will receive equal flux at noon on the equinox.
25. Due to the eccentricity of the Earth's orbit, with perihelion occurring in early January, the northern hemisphere winters should be slightly warmer than the southern hemisphere winters. In the southern hemisphere, winter coincides with the time, in July, when Earth reaches aphelion, its most distant point from the sun.
26. How Do We Know? – A scientific model can be technically inaccurate but still be useful in understanding the basic behavior or nature of a system. Some realistic details of the system, for example the distance to stars on the celestial sphere, are simply unimportant when trying to understand the behavior of the system. For the case of the celestial sphere, how stars move on a daily or yearly basis doesn't depend on their distance from the Earth, so those details can be left out.
27. How Do We Know? – Astrology is a set of theories that purport the belief that the motion of the stars and planets and other celestial events control the events in our lives. These ideas have no scientific basis and have repeatedly been tested for accuracy and have repeatedly failed. Such methods or theories with no scientific basis are therefore classified under pseudoscience.
28. How Do We Know? – Evidence is reality, and scientists constantly check their ideas against reality. It is a characteristic of scientific knowledge that it is supported by evidence. A scientific statement is more

than an opinion or a speculation because it has been tested objectively against reality. Every scientific theory needs to be supported by evidence in the form of observations and/or experiments.

29. How Do We Know? – Evidence from experiments and observation is the foundation of science. Evidence is reality, and scientists must constantly check their ideas against reality. In order to understand nature, scientists must be objective and not ignore any known evidence.

ANSWERS TO DISCUSSION QUESTIONS

1. Fromearliest times, we humans have tried to make sense of the universe, seeking to understand nature and our place within it. Especially in ancient cultures without today's light pollution, it was a natural impulse to find patterns in the stars and connect them with history, myths, and legends.
2. Like all stars, Polaris appears to trace a circular path around the north celestial pole as the Earth rotates on its axis. Polaris is so close to the true pole that this apparent motion is very small; nonetheless, to find your exact latitude from the position of Polaris, you would need to know the date and time in order to figure out Polaris's location relative to the pole at that moment.
3. The apparent path of the sun across the Earth's sky is called the ecliptic. Planets orbiting other stars would also have such an ecliptic. If their axes of rotation are tilted, or if they have extremely eccentric orbits, they will also have seasons. The source of the seasons would be the variability in the angle at which the light hits the surface of the planet (more direct during some seasons and more oblique during others) and in the length of time that light hits the surface (longer daylight and shorter daylight periods).
4. (Answers may vary.) No, because relabeling the star would change the Greek letter assigned to it and many other stars within the Orion constellation and all star charts would have to be updated to reflect that change.
5. Ancient astronomers only estimate magnitudes by eye and classified the stars into six classes based on brightness. Modern astronomers use scientific instruments to measure the brightness of stars to a much higher precision, requiring the magnitude to be redefined to a broader scale that could be extended beyond 1-6. Therefore, the change in magnitude only represents higher precision in the measurement and scale, not a change in the apparent brightness of Sirius.

ANSWERS TO PROBLEMS

1. Star C is brightest. Stars C and B are visible to the unaided eye, but Star A is not. Please see Table 2.1 to see magnitude differences and flux ratios.
2. Approximately 2 magnitudes brighter

   $m_B - m_A = 2.5 \times \log(FA/FB) = 2.5 \times \log(7.3) = 2.2$
3. Approximately 6 magnitudes brighter

   $m_B - m_A = 2.5 \times \log(FA/FB) = 2.5 \times \log(251) = 6.0$
4. The apparent magnitude difference would be 0.8 and star A is the brighter star.
5. The apparent magnitude difference would -1.2 and star B is the brighter star.
6. If in the previous problem Star A has an apparent visual magnitude of 5; apparent visual magnitude of Star B is 3.8. Both Star A and Star B would be visible using just the human eye.

7. 1575 (1580 using Table 2-1)
8. 173
9. A is brighter than B by a factor of 2736
10. The Moon is 1,575 times brighter than the Venus at its brightest.
11. 90°; 66.6°;
12. If you are at a latitude of 40° north of Earth's equator, that angle is also the angular distance from your northern horizon up to the north celestial pole. From the north celestial pole, it is an additional 50° up to your zenith and another 40° (south) to the celestial equator; your southern horizon is therefore 50° below the celestial equator, and the south celestial pole (which is 90° from the celestial equator) is thus 90°– 50° = 40° below your southern horizon.
13. If you are at a latitude of 30° north of Earth's equator, the angular distance between the north celestial pole to the zenith is 60°. The north celestial pole is 30° above the horizon and nadir is another 90° below the horizon and thus 30° + 90° = 120° between nadir and the north celestial pole.
14. There are ~2 precession periods per nodding period and ~4 precession periods per eccentricity periods. In figure 2-11a, there are ~0.6 precessions, ~0.4 precessions, and ~0.2 eccentricity changes during the 15,000 years represented. Because precessions undergo the largest fraction of change, it is likely that this would have the most effect on the changes shown in Figure 2-11.

ANSWERS TO LEARNING TO LOOK

1. As the caption says, the star Polaris, which is at the end of the handle of the Big Dipper, appears to not move at all. The remaining stars of the Big Dipper rotate around Polaris forming the innermost six star trails.
2. The next to pictures would be located at Latitude -60º and -90 º. In the -60º picture, the celestial south pole would be 60º above the southern horizon and 30º from the zenith. In the -90º picture, the celestial south pole would be 90º above the southern horizon and at the zenith. At this latitude, my zenith would be 180º from the same as a person located at latitude +90º or at their nadir location.
3. The size of the average star is ~1/4 the width of the Moon, therefore the angular diameter of the average star would (1/4) × 1/2° = 1/8º.
4. Ursa Major in the looking north cartoon is the circumpolar constellations.
5. Since the view shows the Earth, it must represent a daytime image. However, the brightness of the Sun has been decreased so that stars can be seen during the day for illustration purposes. The constellation shown in the March 1 view is an asterism in the constellation Aquarius.
6. Your zodiac constellation would be Gemini.

ANSWERS TO DOING SCIENCE

1. The temperatures determined from calcite deposits in Devil's Hole may reflect only local climate changes in that specific location. Ocean floor samples on the other hand reflect global climate conditions.