EXPLORING THE UNIVERSE

A Laboratory Guide for ASTRONOMY

Mike D. Reynolds   Michael E. Bakich

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We are excited to publish *Exploring the Universe: A Laboratory Guide for Astronomy* as the newest addition to the Morton Publishing Company catalog. This book is yet another excellent example of Morton's commitment to publishing high-quality books at reasonable prices. I hope this lab manual will suit the needs of your astronomy course. If you would like to receive a complimentary examination copy, please send in the attached reply card.

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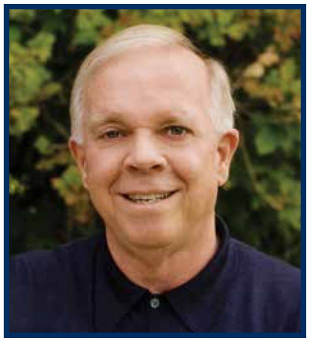

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EXPLORING THE UNIVERSE

A Laboratory Guide for ASTRONOMY

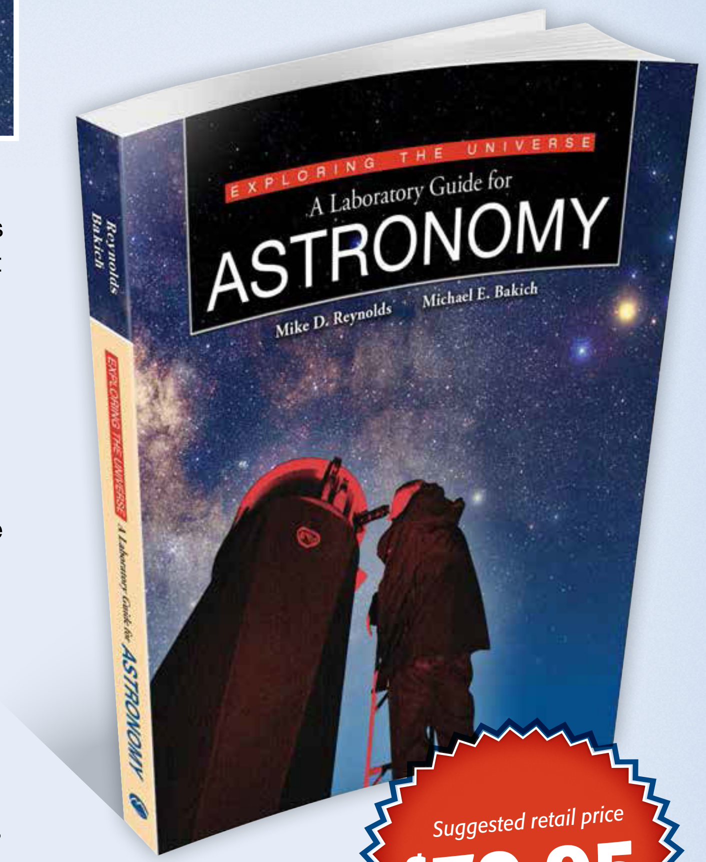
Mike D. Reynolds Michael E. Bakich

Astronomy is a fun and challenging science for students. This manual is intended for one- and two-semester astronomy courses and uses hands-on, engaging activities to get students looking at the sky and developing a lifelong interest in astronomy.

There are many options available for astronomy student lab experiences. Many instructors choose to ask students to perform a variety of digital activities, such as examining spectra and getting to know the night sky through an online planetarium. These experiences are useful for students. However, the authors truly believe that there is no substitute for getting students outside to use binoculars, telescopes, and even the naked eye to see the real thing. Obviously, there are external factors that may prevent you from performing some of these activities: limited time, bad weather, light pollution, etc., so the authors have provided options for those instances. Students should come away from their lab experience with a variety of observational experiences as well as a broad knowledge of various astronomical topics.

The authors wish to instill a sense of wonder and awe in students about the vastness of the universe and the amazing objects that populate it. Wouldn't you want your students to come away from their lab experience with a lifelong interest in astronomy?

The following pages provide a brief walk-through of some of the key features of this full-color lab manual. Thank you for taking the time to evaluate it. If you feel this manual may suit the needs of your course, we will be happy to send you a complimentary examination copy. We hope you find that this manual is the perfect fit for your astronomy laboratory.



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Michael E. Bakich
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Explore like Copernicus

Objectives set learning goals to prepare students for what they are expected to know after completing the lab and also aid in the review of material.

Tools of the Trade

Telescopes

4

LEARNING OBJECTIVES

Upon completion of this chapter, you should be able to:

1. Describe the three main types of telescopes and important names and dates associated with their invention.
2. Describe the function of a telescope mount and its importance in the whole system.
3. Identify the most important telescope accessories and describe the use of each.
4. Calculate the magnification of any telescope/eyepiece combination.
5. Examine telescopes and determine characteristics such as optical type, mount, focal length, and focal ratio.
6. Identify different types of eyepieces by size and focal length.
7. Determine how an object moves through the field of view when a telescope is moved in various directions.
8. Define all glossary terms.

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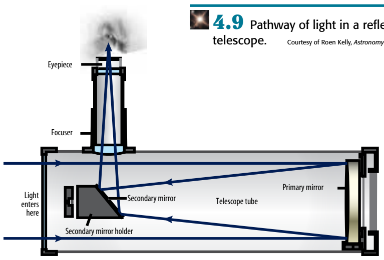
Looking Up elements provide students with information about important figures in astronomy and their contributions. Other fun facts are also provided to capture students' interests.



4.9 Pathway of light in a reflecting telescope. Courtesy of Roen Kelly, Astronomy magazine

Looking Up

In the eighteenth century German-born British astronomer William Herschel (1738–1822) constructed a number of reflecting telescopes. Herschel discovered Uranus with his most famous, a "7-foot" (2.1 m focal length) reflector. This telescope had a mirror 165 mm in diameter.

4

In 1835 German chemist Justus von Leibig (1803–1873) developed a process for depositing a thick layer of silver on glass. This was a major step forward, because when the silver tarnished it could be chemically removed and a new layer redeposited without altering the mirror's curve.

Apart from tarnishing, silver is not the ideal reflective surface for a telescope mirror. Aluminum, for example, reflects 50 percent more light. John Donovan Strong (1905–1992), a physicist at the California Institute of Technology, was one of the first to coat a mirror with aluminum. The first mirror he aluminized, in 1932, is the earliest known example of a telescope mirror coated by this technique. Now all reflectors have aluminized mirrors.

Looking Up

Speculum-mirror reflectors reached their height in the mid-nineteenth century with the 1.8 m mirror in the telescope of William Parsons, Third Earl of Rosse (1800–1867), at Birr Castle in Parsonstown, Ireland.

Construction of Large Reflecting Telescopes

Small telescopes can do only so much. Bigger telescopes collect more light and reveal finer detail. The technology needed to build larger telescopes advanced slowly, however. American astronomer George Ellery Hale (1868–1938) oversaw construction of the first 100-inch (2.5 meters) telescope in 1917. That telescope still stands on Mount Wilson in California, overlooking Los Angeles.

The next record came in 1948 with another Hale project, the 200-inch (5 meters) Hale Telescope on California's Palomar Mountain (Fig. 4.10). By the late twentieth and early twenty-first centuries, big telescopes were popping up around the world, mostly on isolated mountaintops where the skies are clear and steady.

Larger reflecting telescopes are being planned and built. The Giant Magellan Telescope (Fig. 4.11A) is well on its way from concept to completion. The University of Arizona's ... irror Lab has cast two of the tele- ... irrors and nearly finished polishing ... orkers expect to break ground for ... anas Observatory in Chile in 2020. ... rrently in the planning stage are the ... and the European Extremely Large ... l C). The Thirty Meter Telescope will

4.10 Palomar Observatory 200-inch Hale reflector, the world's largest telescope from 1948 to 1976. Courtesy of Palomar Observatory/California Institute of Technology

10.3 Full Moon. Courtesy of John Chumack

10.4 First quarter Moon. Courtesy of John Chumack

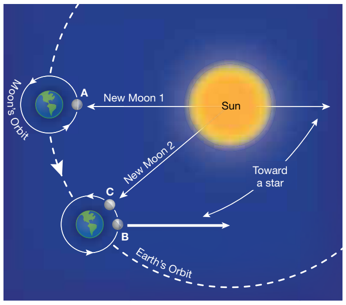
10.5 Earthshine is the light reflected from Earth onto the dark part of the lunar surface. This allows us to see that part of the Moon. Courtesy of John Chumack

10.6 Last quarter Moon. Courtesy of John Chumack

From new Moon, our lone natural satellite progresses through **waxing crescent** until **first quarter** (Fig. 10.4). When the Moon is a thin crescent, sunlight reflected off Earth falls on its dark part. This subtle illumination is known as **earthshine** (Fig. 10.5). After first quarter, the Moon continues through **waxing gibbous** until it is a full Moon. Then it progresses through **waning gibbous** until **last quarter** (Fig. 10.6). It continues through **waning crescent** until it is back to new Moon to begin another lunar month.

Periods

The Moon orbits Earth once every 27 days, 7 hours, and 43.7 minutes. This is known as an **orbital period**. The Moon also has a **synodic period**, which takes 29 days, 12 hours, and 44.1 minutes to complete (Fig. 10.7). The synodic period is the time it takes for an object to reappear at the same place relative to two other objects. In this case, the two other objects are Earth and the Sun, and because Earth revolves around the Sun, it takes the Moon just a little bit longer to get to the same place.



10.7 The Moon's orbital period (from A to B) is more than two days shorter than its synodic period (from A to C). The difference is due to Earth's motion around the Sun.

GLOSSARY TERMS

Waxing growing; for the Moon, this means the illuminated portion is getting larger from night to night

Crescent phase between either quarter Moon and new Moon

First quarter lunar phase that occurs when the Moon lies 90° east of the Sun; the first quarter Moon rises at midday and sets at midnight

Earthshine light reflected from Earth onto the dark part of the lunar surface, allowing us to see that part of the Moon

Gibbous major phase between either quarter Moon and the full Moon

Waning shrinking; for the Moon, this means the illuminated portion is getting smaller from night to night

Last quarter lunar phase that occurs when the Moon is located 90° west of the Sun; the first quarter Moon rises at midnight and sets at midday

Orbital period time it takes the Moon to orbit Earth once; 27 days, 7 hours, and 43.7 minutes; also Sidereal period

Synodic period time it takes the Moon to go from any phase to the same phase; 29 days, 12 hours, 44.1 minutes

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Glossary Terms listed in boxes in the margins of the text give students an easy reference.

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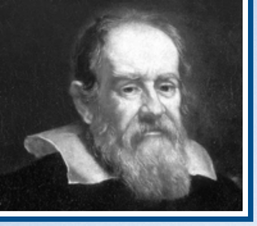
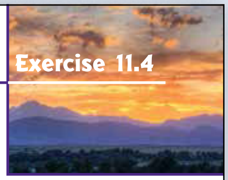


Observe like Galileo

Outdoor observational labs require that students look up at the sky with the naked eye, binoculars, or a telescope. This book is intended to build interest and get students excited about astronomy. Students are encouraged to explore, observe, analyze, and record their findings.

Classifying Sunspots



Since telescopic solar observing began, astronomers have counted sunspots. They also have divided sunspots into types. Astronomers have used several classification systems for sunspots over the years. One of the easiest to use is the McIntosh classification system (Table 11.4), which debuted in 1966. This three-letter system will classify any type of sunspot. The first letter indicates the overall group structure, the second letter indicates the appearance of the penumbra of the largest spot in the group, and the third letter indicates the distribution of the spots within the group. For example, the McIntosh system would designate the simplest sunspot with no penumbra as Axx.

The dark, inner part of a sunspot is its umbra, and the lighter outer region is the penumbra. Degree measurements relate to the Sun's disk diameter as 180°, so a sunspot 10° across would span one-eighteenth of the Sun's disk.

Remember to always use an approved solar filter to observe the Sun. Don't take a chance where your eyes are concerned.

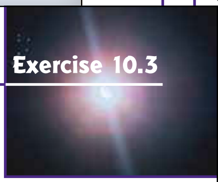
TABLE **11.4** McIntosh System of Sunspot Classification

First Letter		
A	Individual spot or group of spots without a penumbra or bipolar structure	
B	Group of sunspots without a penumbra in a bipolar arrangement	
C	Bipolar sunspot group where the principal spot is surrounded by a penumbra	
D	Bipolar group where the principal spots have a penumbra; at least one of the two principal spots has a simple structure; length of the group is less than 10°	
E	Large, bipolar group in which the two principal spots, which are surrounded by penumbrae, generally exhibit a complex structure; numerous smaller spots occur between the principal spots; length of the group lies between10° and 15°	
F	Very large bipolar or complex sunspot group with penumbrae on spots at both ends and whose length is at least 15°	
H	Unipolar (single) group with penumbra	
...ter		
	...penumbra	

(Continues)

11

Unaided Viewing of the Moon



The goal of this exercise is to introduce you to observing the Moon. This observation is done entirely naked eye—that is, no binoculars or telescope. If you wear eyeglasses for distance (you are nearsighted), wear your glasses when making this observation. This exercise will begin teaching you how to recognize lunar features.

Procedure

Materials
- Flashlight (if needed, for answering questions and drawing in a dark location)
- Sketching pencils
- Eraser
- Clipboard (to hold your papers)

1. In the circle below, make a sketch of the Moon as you see it with the naked eye. Perfect details are not necessary in this drawing. Later you will go back and identify features you have drawn from the Moon chart. Look for light and dark patches, craters, lines, markings, etc.
2. Use a pencil to make your drawing. You can also use the pencil to shade areas. This drawing is best made around the time of the full Moon.

10

Sketch areas are provided for students to draw their observations and label their findings.

Sunset over the Rockies.

Courtesy of Vikki Granger, Insight 360 Media

GLOSSARY TERMS

Analemma plot, or graph, of the Sun's position in the sky at a certain time of day (such as noon) at one location measured throughout the year; has the shape of a figure 8

Photosphere surface of a star, including the Sun, which is the layer emitting visible light, about 500 kilometers deep.

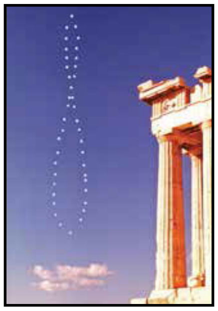
Granulation mottled (alternating light and dark) appearance of the photosphere of the Sun caused by the convection of gas cells, which are rising and falling

Facula (*pl.* = faculae) bright region of the Sun's photosphere associated with sunspots; seen most easily when near the Sun's limb

Limb darkening phenomenon whereby the edge of the solar disk appears darker than the center due to the light rays from the edge having to move through more of the solar atmosphere to reach us than light rays near the center of the disk

Chromosphere region of the atmosphere of a star (such as the Sun) between the star's photosphere and its corona

11



11.1 These 41 solar exposures, plus one foreground image showing the Parthenon in Athens, Greece, were taken at the same time of day starting January 12 and ending December 21, 2002.

Courtesy of Anthony Ayiomamitis

CAUTION

DO NOT look at the Sun through your telescope without a proper solar filter! An example of the danger: Ron Lambert of El Paso, Texas, had his Tele Vue eyepiece capped when he accidentally moved the Sun into the field of view of his telescope for less than one second. The heat caused the eyecap to melt. Note also that sunglasses, even with UV protection, are NOT adequate eye protection for viewing the Sun.

The center of our solar system, and our closest star, is the Sun. It is about 300,000 times closer than the next closest star, Proxima Centauri. Because it is the sky's brightest object, the Sun also is the easiest to observe. We can clearly see its surface features, examine its characteristics in a variety of wavelengths, and glean insight into the nuclear mechanisms of not only the Sun, but also of other stars.

During this lab, you will construct a safe pinhole solar viewer and use it to sketch the positions of sunspots during a clear day. You also will track the Sun in a variety of ways, and construct and use a sundial to track the Sun's movement and tell time.

By tracking the Sun over a period of time, we can better understand the orbital relationship between it and Earth, as well as some of Earth's particular mechanics. Observing the Sun's motion on a daily basis, as well as over the course of a year, will demonstrate Earth's rotational motion and its revolution around the Sun. The location of the observer and the time of year will change where the observer sees the Sun in the local sky. For example, Figure 11.1 captures the apparent track the Sun makes in the local sky from the same place looking in the same direction at the same time every day, usually around noon. The figure-eight visible in the exposures is known as an **analemma**.

Observing the Sun

Solar Features

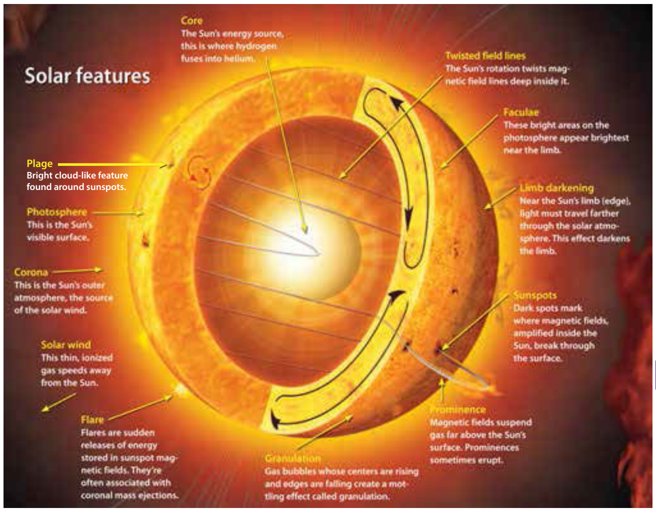
With proper eye protection, you can see a multitude of features on our Sun (Fig. 11.2). The **photosphere** is the Sun's visible surface and is the lowest observable layer of solar atmosphere. If the seeing (atmospheric steadiness) is good you will spot **granulation** on the photosphere, which observers describe as mottled (having alternating light and dark areas). Vast gas bubbles, whose centers are rising and whose edges are sinking, create the granules.

Faculae, Latin for "little torch," are bright areas visible on the photosphere. Faculae appear all over the solar disk, but observers most often see them near the solar limb where the contrast between the faculae and the darkened limb is highest.

Finally, look for a phenomenon called **limb darkening**. We ob darkening because the Sun is a sphere. Near what is seen as the e solar disk, the light must travel farther through the solar atmosp causes the limb to be dimmer than the rest of the disk.

The **chromosphere** (Fig. 11.3), or "sphere of color," lies just photosphere. Here, hydrogen atoms emit energy called hydrogen-a radiation. Hα is reddish-colored light with a wavelength of 656.28 ters (nm). Although your eyes can detect the red light of the chrom

Caution boxes are posted where applicable to make students aware of potential risks when performing certain activities.



11.2 Features of the Sun.

Courtesy of Roen Kelly, *Astronomy* magazine

11

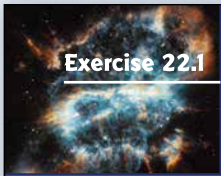
11.3 Chromosphere.

Courtesy of Craig and Tammy Temple

An extensive, full-color art and photography program includes hundreds of labeled diagrams, star charts, and procedural images to ensure that students have accurate visual representations of what they will see in the lab.

Record like Messier

Traditional labs require students to calculate, analyze, and master difficult concepts such as Kepler's laws, geometrical optics, and spectroscopy.



Exercise 22.1

Measuring Radioactivity

Procedure

Materials

- Geiger counter equipped with a Geiger-Müller tube
- Radioactive source (supplied by your laboratory instructor)
- Potential radiation blocking materials: paper, aluminum foil, plastic wrap, cardboard, lead foil, glass (supplied by your laboratory instructor)
- Graph paper

CAUTION
Use radioactive source materials with caution and as directed by your laboratory instructor.

1 Obtain the Geiger counter and radioactive source from your instructor. Be certain to follow all directions for handling the radioactive source. Inspect the Geiger counter and radioactive source. Your instructor will provide specific directions for operating the Geiger counter you will use in this procedure.

2 Using your radioactive source as directed, bring your Geiger counter near it. Note the clicks and/or the indicator; this is a count of ionization events by the radioactive source.

3 Collect counts for three 60-second periods at distances of 0, 2, 4, 6, 8, and 10 cm, and record your results in Table 22.2 on the data sheet, page 423. Record your data as counts per minute (cpm or c/m). Determine the average for the three counts.

4 Next, test the ability of various supplied materials to block radiation from the source. Place the material between the radioactive source and the Geiger counter, or as directed by your instructor. Again, collect counts for three 60-second periods at the distances of 0, 2, 4, 6, 8, and 10 cm, and record your data in Table 22.3 on the data sheet, page 424. As before, record your data as counts per minute (cpm or c/m). Determine the average for the three counts.

Unit 6 Classifying Celestial Objects

DATA SHEET 22.1

Name ______ Section ______ Date ______

Ionization Events Count

TABLE 22.2 Count of Ionization Events by Radioactive Source

Radioactive Source:

Distance	Count 1	Count 2	Count 3	Average for the 3 Counts
0 cm				
2 cm				
4 cm				
6 cm				
8 cm				
10 cm				

1 Graph your results; average counts per minute (cpm) versus distance.

2 Based on your graph and data, what is the pattern that describes the change in counts per minute (ΔCPM) with distance? Consider: no change, linear decline, exponential decline, or some other pattern?

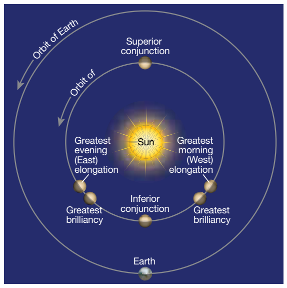
3 What would account for the pattern you graphed based on your data? Detail your explanation.

Radioactivity CHAPTER 22 423

Observational tables ask students to record their observations in a meaningful format.

Check Your Understanding exercises conclude each introductory section and ask thought-provoking questions in order to measure student progress throughout the chapter.

14.5 Venus setting September 16, 1986, in Tucson, Arizona.



14.6 Highlights of Venus' orbit around the Sun.

Courtesy of Holley Y. Bakich

continuous state of mixing, and any patterns observed quickly dissipate. Features in Venus' atmosphere range from dusty shadings to bright spots. You may be able to spot its most famous feature through a violet filter. This filter doesn't allow in much light, so you will need at least an 8-inch telescope. Look for an immense C or Y-shaped feature centered on the planet's **equator**.

GLOSSARY TERMS

Equator imaginary line that divides the northern half of a body from its southern half

14

Check Your Understanding

3.1 When Venus is at greatest elongation, does it appear closer to the Sun or farther from it than Mercury does when that planet is at greatest elongation?

3.2 How many times larger is Venus when it is nearest Earth compared to when it lies farthest from our planet?

3.3 Who was the first person to observe the phases of Venus?

3.4 Why don't astronomers see long-lasting features as they view Venus?

(1879–1963), a professor at the University of Tokyo who published his results in 1917. This test consists of 38 colored plates. Another test is the Pseudoisochromatic Plate Ishihara Compatible (PIPIC) Color Vision Test, consisting of 24 plates. The PIPIC Color Vision Test can determine all color deficiencies.

1

Procedure

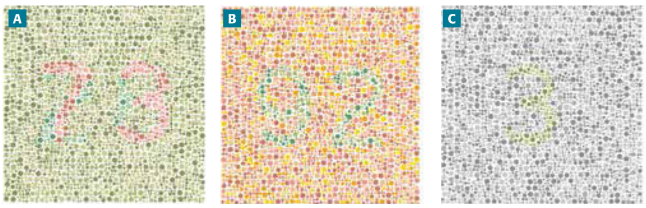
Materials

- Figure 1.11

1. Before beginning this procedure, answer the following questions:
   - a. Which nerve cells in the retina respond to color?
   - b. Which colors of cones (red, green, blue) must combine to allow us to see yellow light?
   - c. Which sex (male or female) suffers most from color blindness?
2. Write down the number you see within each square in Figure 1.11.
   - a.
   - b.
   - c.
3. Does the test indicate that you have any form of color blindness? If yes, describe it in the space provided below.

Note

This simple test is just a demonstration. For a diagnosis, you should visit a vision care professional.



1.11 Color-blindness tests.

Courtesy of Good-Lite Co.

Note boxes help students understand the details of the procedures.

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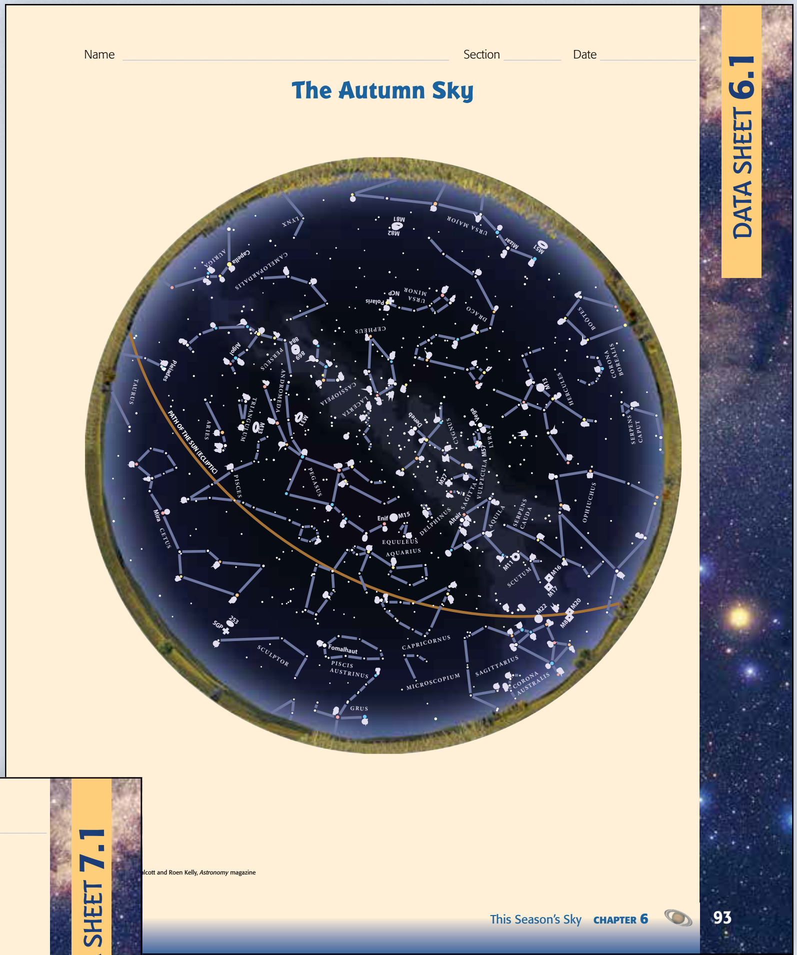
Investigate like Kepler

Star maps give students a visual representation of the night sky and what they should see when they conduct their observations.



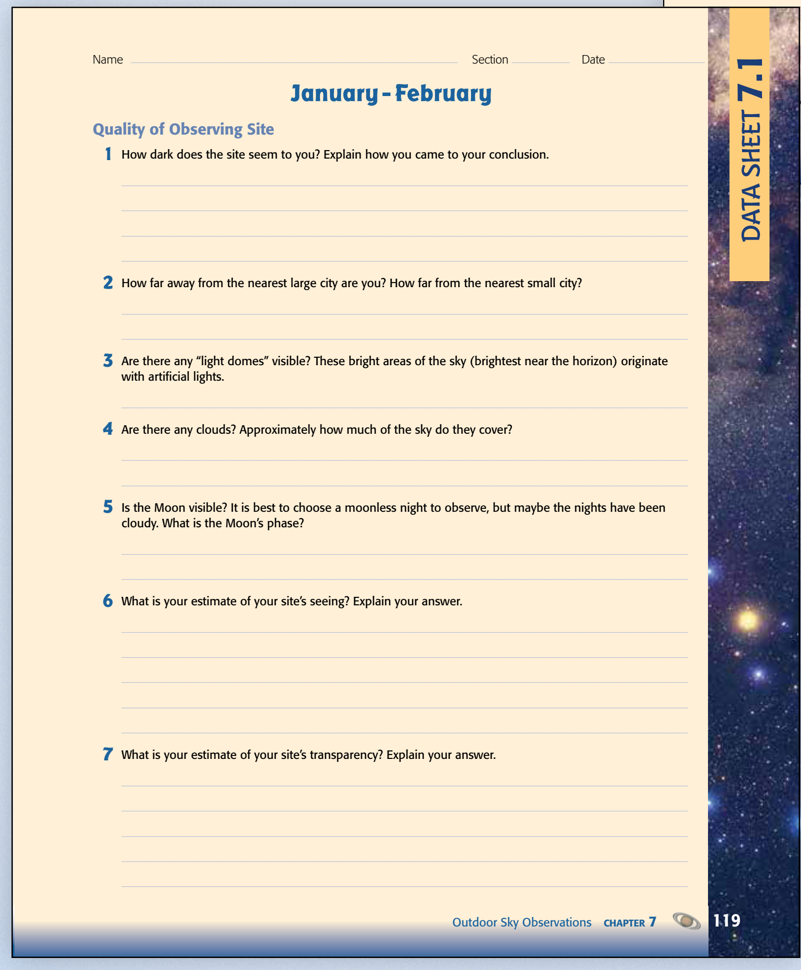
Name ______ Section ______ Date ______

DATA SHEET 6.1

The Autumn Sky

...lcott and Roen Kelly, *Astronomy* magazine

This Season's Sky CHAPTER 6 93



Name ______ Section ______ Date ______

DATA SHEET 7.1

January - February

Quality of Observing Site

1 How dark does the site seem to you? Explain how you came to your conclusion.

2 How far away from the nearest large city are you? How far from the nearest small city?

3 Are there any "light domes" visible? These bright areas of the sky (brightest near the horizon) originate with artificial lights.

4 Are there any clouds? Approximately how much of the sky do they cover?

5 Is the Moon visible? It is best to choose a moonless night to observe, but maybe the nights have been cloudy. What is the Moon's phase?

6 What is your estimate of your site's seeing? Explain your answer.

7 What is your estimate of your site's transparency? Explain your answer.

Outdoor Sky Observations CHAPTER 7 119

Data Sheets are provided for students to record required information for each lab activity. These sheets are intended to be submitted upon completion of the lab activity.

Why Study Astronomy?

The study of astronomy has its roots in observation and human exploration. Advancements in technology have allowed for dramatic gains in the study of astronomy, but curiosity and observation are still at its core, allowing us to build on the knowledge of those who preceded us.

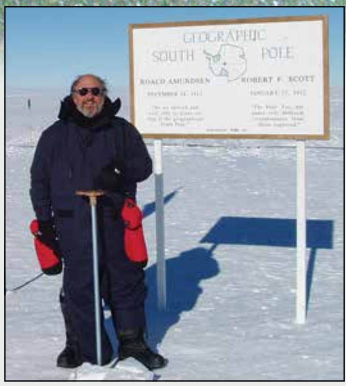
Shackleton

So how has the study of astronomy benefited us? Besides allowing us to understand our origin and place in the cosmos, it has also helped save lives! In 1914, arctic explorer Ernest Shackleton, ship captain Frank Worsley, and a team of 26 men set sail on the vessel *Endurance* from England to Antarctica. Before reaching land, their ship became entrapped and destroyed by sea ice, stranding the men on the coast of Antarctica for more than a year.

In a desperate effort to seek help, Shackleton, Worsley, and a hand-picked crew of four loaded into a small lifeboat and embarked on a dangerous journey to a whaling station on South Georgia Island, 800 nautical miles to the north across the treacherous Southern Ocean. Using dead reckoning, a nautical almanac, and celestial navigation, the men made their way to safety, ultimately rescuing the entire crew of the *Endurance*.

Explorers like Shackleton and Worsley have used their familiarity with the sky and knowledge of astronomy to navigate the globe for centuries. Their story is a testament to the human spirit and the power of educating ourselves about the cosmos. Today, we use satellites to navigate, but a sense of exploration still drives us, as we hope it will drive you and your students in the study of astronomy.

The Authors Remind You to Keep Looking Up!



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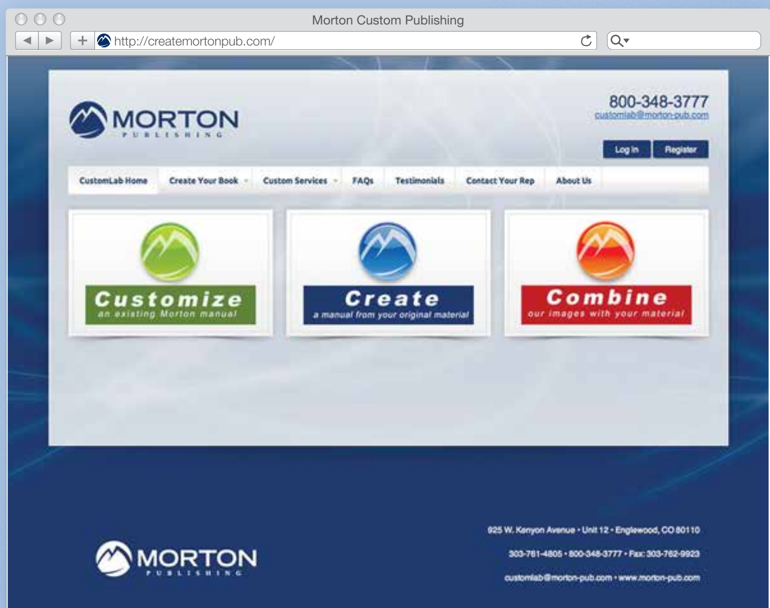

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