Chapter 2: The Nature of Stars

Summary

Chapter 2 introduces the basic physical properties of stars which affect their appearance: apparent brightness, distance, temperature (seen as color), and the relationships among these properties by utilizing slides, photographs, colored filters and/or the night sky. Students will investigate differences among the stars.

Terminology

absolute magnitude	clusters	light-year
actual brightness	globular cluster	nebulae
apparent brightness	interstellar medium	spiral galaxy
apparent magnitude	Kelvin	supercluster

Common Misconceptions About Stars

1. *All stars are the same color.*
2. *The North Star is the brightest star in the night sky.*
3. *All stars are the same distance from the Earth.*

SUGGESTIONS FOR THE POSTER PAGES, INVESTIGATIONS, AND ACTIVITIES

Investigation 2.1: The Properties of Stars

Show one of the HOA slides to the students. Have them list the differences they see, and think about what properties of stars could cause these differences. Size may be a common answer to this question, and size is indeed important. The greater the surface area of a star, the greater the amount of light or energy it emits. Since the area varies as the square of the radius, a star which has 3 times the radius of another star would emit 3 2 or 9 times the total light.

Size is only one variable that determines the actual brightness of a star; temperature is another. If your students have used a Bunsen burner, they already know that a yellow flame will deposit carbon on the bottom of a test tube because the flame is not hot enough for complete combustion of the gas. If a yellow flame is cool, a blue flame must be hotter, since it does not deposit carbon on the tube. So a yellow flame is cooler than blue, and blue is hotter than yellow. Similarly, when an electric stove element is first turned on, it is black. After a few minutes the element starts turning dark red, then at maximum high it is orange-red. The brighter the color, the hotter the burner. Stars have a similar temperature/ color relationship. Red stars are cooler (surface temperatures of ~ 3,000 K), yellow stars are hotter (surface temperatures of ~6,000 K), while white or blue-white stars are even hotter (surface temperatures up to ~50,000 K). The important concept for students to acquire is that color is associated with temperature.

Core Activity 2.2: Understanding the Temperature Scales

The following math conversion exercises are meant to help students understand the differences among the three temperature scales, Fahrenheit, Celsius, and Kelvin. It is likely that only students who have had chemistry or thermal physics will have been introduced to the Kelvin scale. Others may have encountered the Celsius scale, but are more comfortable with the Fahrenheit scale, especially if they have not completely grasped what Celsius temperatures mean relative to the Fahrenheit scale. The Kelvin scale is important in physical science; it is the only scale that is not arbitrary and is used for stellar temperatures. This activity is not necessary for students already familiar with the Kelvin scale.

Answers to the Exercises on Temperature Scales

1. T_c = (5/9) (98.6 – 32) = 37^{o}C; T_k = 37 + 273 = **310K**

2. (Answers will vary)

3. 100^{o}C + 273 = 373K; T_f = (9/5)(100) + 32 = **212^{o}F**

   –173^{o}C + 273 = 100K; T_f = (9/5) (–173) + 32 = **–279^{o}F**

4. a) T_c = 5,770K – 273 = 5,497; T_f = (9/5 (5,497) + 32 = 9,927^{o}F

   b) 12,000 – 5,770 = 6,230K; T_c = 6,230 – 273 = 5,957

   T_f = (9/5) (5,957) + 32 = **10,755 ^{o}F hotter.** Its surface temperature is **20,682^{o}F**

5. a) **30,273K – 60,273K (a 30,000K range),**

   T_f = (9/5) (30,000) + 32 = **54,032 ^{o}F range**

   b) T_k = 3,250 + 273 = **3,523K**; T_f = (9/5) (3523) + 32 = **6,373 ^{o}F**

6. $T_c = 3K – 273 =$ **–270°C,** $T_f = (9/5)(–270) + 32 =$ **–454°F**

7. 4,500K – 2,400K = 2,100K – 273 = 1,827°C;

   $T_f = (9/5)(1,827) + 32 =$ **3,321°F**

8. There are various reasons. From the perspective of astronomy, the Kelvin scale is a thermodynamic temperature scale (absolute temperature scale)—that is, a temperature scale in which the temperature is a function of the energy possessed by matter. It is a measure of the total energy or power emitted by a star. When we read an outdoor thermometer, we are concerned with how "hot" or "cold" it is outside. When we take our temperature when our body is fighting an infection, we are concerned with whether our body is producing more "heat." Have your students calculate what the Kelvin scale would be for an outdoor or internal thermometer. Is it a convenient scale? Why or why not?

Investigation 2.3: How Bright Is It?

You may choose to do this activity with the drawing provided, followed by the slide, or by observation of the night sky.

Core Activity 2.4: The Apparent Colors of Stars in the Night Sky

Choose one of the HOA slides for this activity. Have pieces of red, blue, and yellow transparencies—such as the filters used in photography or in theatrical lighting, or colored cellophane. You will want to experiment with several slides to see which ones contain the colors that work best with your filters. The stars on the slides are small, and the difference the filters make may not be obvious to your students. You may want to start by using pieces of colored construction paper before using the slides, so that they can see how the filters change the appearance of red, blue, and yellow colors. Then the students can use the filters with the slide(s) you have selected.

This activity demonstrates the varying effects of red, blue, and yellow filters when viewing starlight. The apparent brightness of a star depends upon which part of the visible spectrum we are observing. Consider a blue and a red star, each of the same apparent brightness. If the two stars are observed through a red filter, the red star will appear brighter than the blue one. If they are both viewed through a blue filter, the blue star will appear brighter. Yellow filters match the strongest part of the visible spectrum and approximate normal vision. A standard set of filters is used in the analysis of starlight: the UBV set of filters (U for ultraviolet, B for blue, and V for visual, or yellow). The use of these filters gives two types of information: (1) the total magnitude of light from all spectral ranges, and (2) the color index which is used to calculate temperature.

Poster Page: The Man Who Colors the Stars (David Malin)

"The Man Who Colors Stars" is a video showcasing the impressive blend of photography and science that amateur astronomer and artist David Malin has created based on his work at the Anglo-Australian telescope. (See Resource List for details.) Another person who contributes simultaneously to art and science is William Hartmann. A well-respected astrophysicist, he has merged his science expertise with his artistic skill, and produces scientifically correct space art. Dana Berry is a graphic artist for the Wright Center for Science Education at Tufts University. Dana uses his artistic talent to explain and illustrate the world of science. He now produces science animations for *Nova, Discovery*, planetariums, and the Jet Propulsion Lab in California. Fred Hoyle is an astronomer who writes science fiction. Isaac Asimov, a hugely popular science fiction writer, had a degree in chemistry and wrote textbooks for chemistry, physics, astronomy, and biology. There are dozens of examples of people using their scientific knowledge to create and enhance art, and their artistic ability to portray science.

RESOURCE