Unit 4:

PATTERNS IN ASTRONOMY STARS

OVERVIEW FOR TEACHERS

Unit Outline

Introduction

...Ptolemy once wrote: 'in studying the convoluted orbits of the stars my feet do not touch the earth, and seated at the table of Zeus himself, I am nurtured with celestial ambrosia.'

– Anthony Aveni, ***Stairways to the Stars : Skywatching in Three Great Ancient Cultures***. p. 193

Nathaniel Bowditch thrived on discovering meaningful patterns in numbers and simplifying complex phenomena for ordinary people. As a young boy in the chandlery, he was well aware that Salem's worldly commerce and wealth were intertwined with the mysterious study of navigation and the science of astronomy. Throughout his career, astronomy was Nathaniel's passion. Like Sir Isaac Newton before him, Nathaniel considered the moving heavens to be a never-ending challenge to arrange, describe, classify, and above all, to mathematically order. In his eyes, the seemingly mechanical movements of the stars and planets could be explained with precision and clarity.

Nathaniel's approach to learning and teaching, as Henry David Thoreau would later subscribe to, was to "Simplify, simply."

Nathaniel Bowditch was inspired early on to study the stars from walks on dark nights with his mother, observing the soothing affect of the heavens:

She (Nathaniel's mother) and Nat went out into the dark, moonless night, and walked down Turner's Lane and out on the wharf. Mother helped Nat find the North Star, and told him how the Big Dipper swung around it, and how to tell time by the Dipper. Then she was silent, standing with her hand on Nat's shoulder, looking up at the stars. Boys don't blubber. He must remember that. Finally Nat said, "It's all right about school, Mother, when times are better, I'll get to go back.." Mother did not answer. She was still gazing up at the sky. After a while she said, "I made up a sort of saying for myself, Nat. I will lift up my eyes unto the stars. Sometimes, if you look at the stars long enough, it helps. It shrinks our day-by-day troubles down to size. (***Carry on Mr. Bowditch***. p. 33.)

The Rev. Alexander Young later eulogized the life of Nathaniel Bowditch and relayed this early story about the moon and a sailor's wife's superstition.

I found the plain two-story house, with but two rooms in it, where he dwelt with his mother; and I saw the chamber window where he said she used to sit and show him 'the new moon with the old moon under her arm,' and with the poetical superstition of a sailor's wife, jingle the silver in her pocket that her husband might have good luck, and she good tidings of him, far off upon the sea. (from Susan Bowditch, 1997, p. 6)

The epitome of Bowditch's passion was the translation and expansion of the brilliant French astronomical text, *Mécanique Celeste*. This privately published American edition, titled ***Translation and Commentary of Mécanique Celeste***, analyzed, corrected, and made readable the difficult scientific content of the original work. Bowditch's English language edition not only complemented the original work, but was considered by some as the best follow-up to Newton's *Principia*. Nathaniel's insistence on simplification and clarity allowed many more scientists the opportunity to understand Newton's laws of motion, particularly the role of gravity on the orbiting moon and planets.

Possibly Bowditch's most interesting talent was his aptness to teach difficult topics such as astronomy and navigation to the sailors on the Salem merchant vessels. Although he never accepted a formal teaching position, his many endeavors benefited from his insistence on clarity of instruction and presentation. For instance, in both his publications, ***The American Practical Navigator*** and ***Translation and Commentary of Mécanique Celeste***, Bowditch added diagrams, text, and tables to clarify and better illustrate these difficult texts. Sailors on any one of his voyages benefited from his instruction and penchant for simplicity, as did scholars on both sides of the Atlantic. (Susan Bowditch)

The following unit, entitled Stars, parallels Nathaniel's lifelong pursuit of the very ancient science of astronomy. Using a planisphere in Lesson 1, students are challenged to find the rhythms in the sky by tracing the nightly movement of several stars and constellations. Circumpolar stars and constellations are then distinguished from seasonal stars and constellations. The movement of the stars along the ecliptic, the zodiac constellations, can also be discerned from the planisphere tracings and activities.

In Lesson 2, students explore myths. Ancient cultures memorized the nightly and seasonal sky patterns. Agricultural societies depended on these sky patterns to accurately predict the appropriate times for planting, harvesting, the season of flooding, etc. Fantastic stories of gods and goddesses in the night sky provided these cultures with effective memory aides to guide these predictions. Through explorations, students will discover that seasonal star groups are related to many Greek myths. In an independent research project, students are asked to adopt a constellation and to create a project describing their constellation and its characteristics.

Finally, in Lesson 3, students are led away from the movements of the stars and constellations to explore a more modern approach to star gazing. Bowditch's lifelong passion for astronomy and his insistence that complex patterns can be simplified is pushed into the twentieth century in an exercise using visible starlight data. In a segué activity to the study of visible light, students examine the light characteristics of our own Sun in relationship to other stars. Students sequentially organize and group data on starlight characteristics, such as temperature, absolute magnitude (brightness), luminosity, spectral type, and color, and then create special bar graphs, called histograms, to better understand these variables. As they compare and analyze this star data, students discover that our Sun is a medium-size, medium-temperature yellow star in a sea of blue, blue-white, white, yellow, and red stars of varying sizes, temperature and brightness.

Students continue to analyze graphs of absolute magnitude, temperature, color, luminosity, and spectral type. In their analyses, students uncover obvious similarities between star temperature and star color. Students also discover similarities between absolute magnitude and luminosity, and between spectral type and color. Finally, in a re-creation of a famous diagram in modern astronomy, the Hertzsprung-Russell diagram, students plot star temperature, absolute magnitude (brightness), and color on a single graph. This diagram, often called the workhorse of astronomy, provides scientists valuable insights into the nature of starlight. In addition to illustrating the important relationships between a star's brightness, heat, and color, the H-R diagram illustrates the natural life cycle or evolution of stars, including our Sun.

With their new appreciation of starlight, students are ready to examine the characteristics of light from our own Sun, using the early prism experiments of Sir Isaac Newton. Thus, our Nathaniel Bowditch theme returns to Nat's early mentor, Sir Isaac Newton, and Newton's development of the particle theory of light. [For more information on the nature of starlight and the creation of the Hertzsprung-Russell diagram, read on].

The Nature of Starlight

Visible starlight data provides astronomers with invaluable information about the life and composition of each star. The feeble amount of light that reaches our Earth-based telescopes is analyzed in a spectroscope. The spectroscope splits light into its characteristic colors, or spectrum. This spectrum represents wavelengths of visible light ranging from violet blue (shortest wavelength) to red (longest wavelength). The resulting spectrogram is a series of black lines across a rainbow of colors, arranged right to left in the familiar mnemonic ROY G. BIV (red, orange, yellow, green blue, indigo, and violet) (Kerrod, 1993, p. 70).

Stars with a similar spectrum are classified into the same spectral classes, designated O, B, A, F, G, K, M, in order of decreasing temperature. The common mnemonic for these spectral classes is "Oh Be A Fine Girl (Guy) Kiss Me ". Each spectral class is associated with a peak color in the star spectrum and a defined range of temperatures:

O	B	A	F	G	K	M
Blue	Blue-White	White	Yellow-White	Yellow	Orange	Red

The classification of stars using spectral groups has an unusual history. Three women astronomers, all at the Harvard College Observatory at the end of the 1800's and early 1900's, played leading roles in developing the modern classification: Williamina Fleming, Antonia Maury, and Annie Jump Cannon. Most importantly, Annie Jump Cannon (1863-1941), a native of Nantucket, analyzed the spectral lines of 1,100 different stars. Her classification was based on rearranging the star spectra due to the presence of helium, nitrogen, and silicon. Her sequence O,B,A,F,G,K, and M had the effect of arranging stars according to color, ranging from blue (O) stars to red (M) stars. Modern astronomers now know that her spectral classes correspond to different star temperatures, with the hottest stars (blue) around 40,000 Kelvins (70,000° F). Her work was an important contribution to the later research of astronomer Ejnar Hertzsprung. (Trefil, 2000, p. 66; Burnham, Dyer, Garfinkle, George, Kanipe, Levy, 1997, p. 163).

Starlight reaching our plant is also measured according to its brightness, or magnitude. An instrument, called a photometer, can accurately measure a star's magnitude accurately to one or two decimals. A star's true brightness, or absolute magnitude, is the magnitude scientists would observe if a star were at a distance of 32.6 light-years. Apparent magnitude is the star's brightness as we see it from Earth, and thus has no relation to its true brightness. The scale for star absolute magnitude or brightness ranges from a -8 for the brightest star, to a +14 for the dimmest star. Our sun's absolute magnitude is 4.8, not a particularly bright star.

The brightness of each star is also termed star luminosity. Luminosity, or the total light energy emitted by a star, is measured either as absolute magnitude or in relation to the luminosity of our own Sun, which has a luminosity of one.

The Hertzsprung-Russell Diagram

In 1911, a Dutch astronomer named Ejnar Hertzsprung (1873-1967) compared the spectra or color of stars with their corresponding luminosity. Two years later, unaware of Hertzsprung's work, an American astronomer, Henry Norris Russell (1877-1957) compared star absolute magnitude and spectral class. The spectral class of stars, of course, is based on the color spectrum. Luminosity and absolute magnitude both measure brightness. These two astronomers had independently discovered the same relationships in the stars unaware of each other's work. (Moore, 1986. P. 81).

The final diagram is now known as the Hertzsprung-Russell diagram, a workhorse in astronomy (Trefil, Nov, 2000, p. 67). The vertical axis represents star luminosity (in suns) and the horizontal axis represents star temperature (degrees Kelvin). This amazing diagram illustrates three important groupings of stars: main sequence stars, red giant stars, and white dwarf stars. Main sequence stars represent a broad band on the diagram running from the upper left (hot and bright) to the lower right (cool and dim). These stars, which include our Sun, generate their energy by fusing hydrogen into helium. Red giant stars (cool and bright), are a grouping in the upper right hand corner. The third group, white dwarfs (hot and dim) are in the lower left. These stars are cooling off, no longer producing the hydrogen to helium reaction of the main sequence stars.

The second remarkable feat produced by the H-R diagram is the representation of the life cycle of every star by a trajectory. James Trefil (Nov., 2000. p. 67), renowned science author, lecturer, and physicist, describes this evolutionary process using our sun, a main sequence star, as an example:

"The sun begins on the right [of the H-R diagram] as a cool, contracting cloud of interstellar gas. As it warms up, it moves left toward the main sequence. Finally, when the nuclear fires ignite and the star begins to fuse hydrogen, it sits on the main sequence, staying more or less in one place until all the hydrogen in the core is consumed. The sun will spend about 11 billion years on the main sequence, of which 4.6 billion years have already passed. When the hydrogen in the core is exhausted, more complex nuclear reactions begin. These reactions will cause the sun's surface to cool and swell up, at which point the sun moves to the red giant part of the diagram. Finally, when all nuclear reactions stop, the sun becomes a hot cinder in space and moves down to the white dwarf region."

Massive stars, or stars at their formation with at least six times the mass of our Sun, finish off their life in a different set of events. As they become red giants, massive stars do not continue on as white dwarfs, but continue to heat up fusing the carbon atoms into new heavier elements such as oxygen and nitrogen. The core of the massive star is so hot that fusion continues until the heavy element, iron, forms. At some point, the iron core begins to absorb energy. This energy is eventually released in a tremendous explosion called a supernova. The heat of the star can reach up to 1,000,000,000° C. The iron in the supernova fuse together to form new elements. The resulting gas cloud forms a new nebula, a baby star. The cycle of star birth to star death begins all over again. (Exploring Earth Science, Prentice Hall, 1997, pp. 81-84).

Stars with a beginning mass 1.5 to 4 times that of our sun will end up as a neutron star after a supernova. The mass of only one teaspoon of a neutron star would be about 100,000,000 tons. Pulsars are simply neutron stars that give off radio waves.

Finally, those stars with a mass 10 times that of our sun will end up as a black hole following the supernova explosion. The core of the star that remains after the supernova explosion is so massive and contains so little energy, it is eventually swallowed by its own gravity. Energy and matter are all consumed by the strength of the gravity creating the black hole.

Objectives:

- Students will observe and demonstrate that the patterns of stars, for example, the constellations, stay the same in the night sky, although they appear to move across the sky with time.

- Students will determine that different star patterns can be seen in different seasons, and will use Greek myths to help locate and remember seasonal star arrangements in the sky.
- Students will organize and graph starlight data from the winter sky. Students will analyze and describe visible starlight in terms of star color, brightness, and temperature.
- Students will uncover evidence that the Sun is a medium-sized, main-sequence star as they create and interpret the Hertzprung-Russell diagram, an essential tool of modern astronomers.

Skills:

- Students will learn to use a planisphere of the night sky to discover nightly and seasonal star patterns.
- Students will be able to analyze patterns in the seasonal grouping of stars, and discover that story-telling was a convenient memory device used by many ancient cultures to locate important stars and star patterns in different seasonal skies.
- Students will know how to organize and manipulate starlight data to pro duce graphs (histograms). These histograms will assist their comparison of our own Sun to other stars.
- Students will learn to create and interpret the Hertzsprung-Russell diagram.

Vocabulary:

- planisphere
- constellations
- Histograms
- color
- luminosity
- temperature (Kelvins)
- spectral class
- absolute magnitude
- red giants
- white dwarfs
- main sequence stars
- supernova
- neutron stars
- pulsars
- black holes
- circumpolar stars/constellations
- Andromeda Group
- seasonal stars/constellations
- Hertzsprung-Russell diagram

Frameworks Connections

Science and Technology:

Strand 1: Inquiry

Standard: p. 28
- Note/describe relevant details, patterns and relationships. Describe trends in data even when patterns are not exact.

- Represent data and findings using tables, models, demonstrations and graphs.

Strand 2: Domains of Science

Standard: Physical science, p. 47-48.
-Investigate and describe an understanding of visible electromagnetic radiation, which we generally call l light, with reference to qualities such as color and brightness.

Standard: Earth and space science, p. 77-78
-Observe and demonstrate that the patterns of stars in the sky stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.
-Demonstrate evidence that the Sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars, part of which can be seen as a growing band of light that spans the sky on a very clear night.

Unit 4 Lesson Plans

Lesson 1: Star Patterns

Nathaniel Bowditch loved his children and entertained their visits to his study easily, often rewarding them for good behavior with small constellations drawn in pen on their hands. (Susan Bowditch, 1997)

Objectives

- Students will know how to observe and demonstrate that patterns of stars, for example, the constellations, stay the same in the night sky, although they appear to move across the sky with time.

Skills:

- Students will learn how to use a planisphere of the night sky to discover nightly and seasonal star patterns.

Vocabulary:

- circumpolar stars/constellations
- planisphere
- constellation
- Polaris
- Cepheus
- Ursa Minor
- Ursa Major
- Cassiopeia
- Orion
- seasonal stars/constellations
- zodiac stars/constellations

Materials:

- planisphere (see attached sheet for instructions)
- student worksheet
- pencils
- tracing paper
- notebook
- tape

Procedure:

1. **Planispheres:** Create and distribute classroom set of planispheres (20-30). Each student should have one for his/her own use during class. These can be laminated for durability.

2. Class Challenge:

Whole class activity - Use the board or an overhead projector for responses:

- What is a planisphere (Star Finder)?
- Describe as many features as you can find on the planisphere.
- Why are the **cardinal directions** on the planisphere?
- Lift and then turn the wheel carefully inside of the black envelope. Describe your observations, include changes in daily and seasonal time, movement of the patterns inside of the circle, etc.
- What are these dots and lines called that spin in the circle?
- Find today's date. Place the time at 9PM, and describe what you will expect in the sky.

3. Individual Activity

- Place the planisphere on your desk with the north end facing away from you. Place a small piece of tape on the back to keep the envelope from slipping.
- Spin the white constellation wheel to match today's date at 9 PM.
- Trace the movement of several of the constellations as they complete a yearly cycle. The tracing paper will need a border to match its correct placement each time you remove it to turn the wheel two months forward.
- With the tracing paper covering your planisphere, trace the edges of the right-angled corner of the black planisphere (the title, Pacific Science Center, is in this corner). You now have a guide to guarantee the correct placement of the tracing paper each time you turn the wheel.
- Now, let's follow a few constellations from today's date, through the rest of the year. We will trace the constellation's position every two months to complete an annual cycle. Begin with **Cassiopeia.**
- Your will have to remove your tracing paper each time you move the wheel, so be careful to match the tracing of the black corner to the actual corner.
- What did you discover from your tracing?
- Now let's try **Cepheus** and **Ursa Major (Big Dipper).** What did your tracing produce?

- What constellation seems to be always in the center of these tracings? Why?

- Now trace **Ursa Minor (Little Dipper)**, being careful to tightly replace the wheel each time to get an accurate tracing. What star is at the tip of the handle? Does this star also move throughout the year, or does it appear to stay? Why? What is the name of this star?

4. New Class Challenge:

- Do all of the constellations follow this annual pattern?

- Select several constellations to test your hypothesis. Try some within the double lines, example **Virgo, Leo, Cancer,** etc. Also try constellations on the edge, example **Hydra, Monoceros,Orion**, etc.

5. Analysis

- What different star patterns did your tracings produce?

- Did any of these constellations change throughout the year? What actually changed? Why does this happen?

- If you were to group these constellations, what groups would you make? Why?

- Which constellations (and their stars) would you call Circumpolar constellations? [what does circumpolar mean?] Seasonal constellations? Zodiac constellations? [what does zodiac mean?]

- Summarize your observations of seasonal star/constellation movements.

- Do the same constellations create a pattern each night?

- In the next lesson, we will examine constellation movements during different seasons to compare/contrast the star patterns and relate them to popular Greek myths.

Handouts:

- Planisphere

- Student Sheets: Lesson 1. Star Patterns

UNIT 4 STUDENT HANDOUT

STAR FINDER HOLDER

Used with permission and copyrighted 1994 by the Pacific Science Center

UNIT 4 STUDENT HANDOUT

STAR WHEEL
COMPLEX STAR FIELD

Used with permission and copyrighted 1994 by the Pacific Science Center

UNIT 4 STUDENT HANDOUT

STAR PATTERNS

Answer the following questions as you work with the planisphere:

1. What is a planisphere?

2. Why are the cardinal directions on the planisphere?

3. Describe your observations as you turn the wheel - include daily changes, seasonal changes, movement of the constellations inside the view area, etc .

4. Find today's date. Place the time at 9 PM. Describe what you will see in tonight's sky.

UNIT 4 STUDENT HANDOUT

TRACINGS:

1. What did you discover from your first tracings of Cassiopeia?

2. Describe your next tracings of Cepheus and Ursa Major.

3. What constellation always seems to be in the center of these tracings? Why?

4. Trace Ursa Minor. What star is at the tip of the handle?

4. Does this star also move throughout the year, or does it appear to stay in one place? Why?

5. Why do we call this star Polaris?

UNIT 4 STUDENT HANDOUT

MORE TRACINGS AND ANALYSIS:

1. Do all of the constellations follow the pattern of Polaris and Ursa Minor? Test your hypothesis by tracing several constellations within the double line: Virgo, Leo, Cancer, etc. Also try constellations such as Hydra, Monoceros, Orion, etc.

2. What different star patterns did your tracings produce?

3. Did these constellations disappear any time throughout the year? What actually changed? Why?

4. If you were to group these constellations, what groups would you make? Why?

5. Which constellations and their stars would you call circumpolar constellations? Why?

6. Which constellations would you call seasonal constellations? Why?

7. Which constellations would you call zodiac constellations? Why?

8. Summarize your observations of seasonal star/constellation movements.

Lesson 2: Seasonal Constellations & The Creation of Myths

Objectives:

- Students will analyze patterns in the seasonal grouping of stars, and discover that the art of storytelling created a powerful memory device utilized by many cultures to locate and memorize important stars and star patterns (constellations) in different seasonal skies.

Skills:

- Students will understand how to analyze patterns of stars.
- Students will be able to develop memorization skills through the story narrative.

Vocabulary:

- Andromeda Group
- Cassiopeia
- Cepheus
- Poseidon
- Ethiopia
- Andromeda
- Perseus
- Pegasus
- Medusa
- Cetus
- Pleides

Materials:

- Student worksheet
- planisphere
- notebook
- Seasonal Sky Groups - handout

Procedure:

1. Group Challenge

- Do the constellations remain in the same part of the sky during each season? In your groups of four students, assign each student a different season to investigate. Select four different dates, one each for the four seasons, and trace several different constellations as they move from 7PM to 5AM.
- Compare your tracings. Did any dates contain the same pattern of stars?
- Can you identify the circumpolar constellations? the seasonal constellations? the zodiac constellations?
- Compare/contrast the star patterns you discovered in four different seasons. Can you see any differences, and if so, what might cause these

differences in constellations?

2. Class Activity:

- If the star patterns are changing from one season to the next, how did people who depended on the stars for navigation, remember these changing patterns in the night sky?

  Hint: What is one of the most ancient methods of passing important information from one generation to the next?

The Storyteller

Stories are easy to remember. A good story contains a problem, a conflict, heroes, villains, and a final resolution. The rhythm of the story helps us remember and even learn new information better. The Greeks were one of the greatest storytellers of the ancient world. Let's listen to this myth while you read along, and see if you can find some familiar names:

Andromeda and Perseus

Andromeda was a beautiful princess of Ethiopia. Her mother, the equally beautiful, but very vain Queen Cassiopeia, loved to boast a little too much about her own stunning appearance. This terrible vanity so angered the god, Poseidon, Ruler of the Seas, that he ordered the sea monster, Cetus, to wreck havoc on all coastal towns and villagers. Sailors were never safe as Cetus upset their boats, caused great storms, and put their lives in grave danger. Andromeda's father, King Cepheus, was not at all like his vain, self-centered wife. He became very concerned about the safety of his kingdom and his people, so he sought advice. Advice can come at a terrible price, however. The only solution to the dreadful sea monster's destruction was to sacrifice something of value and beauty. Only the most valued and beautiful girl of his kingdom would be able to calm the raging Posidon, and convince him to remove the monster, Cetus. Cepheus's daughter, Princess Andromeda, was the only choice as the most suitable sacrificial offering. Cepheus was devastated, but had no choice but to allow the offering to be carried out. He led his beautiful daughter down to the rocky coast where he left her chained to an outcropping. Alone she awaited the monster's appearance.

As the great monster approached Perseus suddenly arrived, riding the winged horse, Pegasus. Heroic Perseus had just completed the grim task of killing Medusa, one of the Gorgon sisters. Medusa, like her sisters, was a horrible sight to behold. If anyone even half glanced at her face, they would instantly be turned to stone. Perseus not only slayed Medusa, but placed her hideous head in a bag to prove his deed. Now seeing the beautiful girl's danger, Perseus quickly pulled the grizzly head out from the leather bag, waved it in front of Cetus, and the horrible sea monster was instantly turned into a large mass of rock. Princess Andromeda was quickly rescued from the dangerous rocks and returned to her grieving parents. King Cepheus immediately granted Perseus's request to marry his daughter. As for the vain Queen Cassiopeia, she never again boasted about her beauty.

3. Class Analysis:

- Who were the characters? What roles did they play?

- Now, lets create an hypothesis:

The Greeks were great storytellers, and storytelling is known to be an excellent way to remember past events as well as retain new information. Could there be a group of constellations with names like these in the story? If so, then repeating the story while gazing upwards at the star-filled sky would help someone remember this particular pattern of stars.

- Using your planisphere, look for the story's characters in the constellations.

- Turn the wheel to allow all of these constellation to be showing through your viewing circle. What months are these best seen in?

- When do you think Greek shepherds would most likely hear this story repeated as they gazed at the heavens each night?

- Now, here are some more seasonal constellation groups (see handout). Can you find these on your planisphere?

- Summarize your observations on myths and star patterns, or constellations, in the sky.

Independent Projects:

- Adopt a constellation - Pick any of the constellations you have noticed on your planisphere, and create a colorful poster which contains:

- the myth behind this star grouping

- a tracing of it's yearly sky path, using the planisphere

- the name and characteristics of the brightest stars contained in the constellation

- a picture of this constellation surrounded by its nearest neighbors (seasonal group)

- a colorful picture of the character represented by your constellation.
- your own myth using any seasonal group of stars.
- a myth about the stars that are present on your birthday. Native American star myths are a good model for ideas.

Handouts

- Seasonal Constellations Worksheet
- Seasonal Sky Groups

UNIT 4 STUDENT HANDOUT

SEASONAL CONSTELLATIONS

Group Challenge:

1. Do the constellations remain in the same part of the sky during each season? In your group of four students, assign each student a different season to investigate. Select four different dates, one each for the four seasons, and trace several different constellations as they move from 7PM to 5AM.

2. Compare your tracings. Did any dates contain the same pattern of stars?

3. For your assigned season:

   Can you identify the circumpolar constellations?

   Can you identify the seasonal constellations?

   Can you identify the zodiac constellations?

4. Compare/contrast the constellations you discovered in four different seasons.

5. What might cause these differences in constellations?

Class Activity:

1. If the star patterns are changing from one season to the next, how did people who depended on the stars for navigation, for planting times, etc. remember these changing patterns in the night sky?

(Hint: What is one of the most ancient methods of passing on important information from one generation to the next?)

2. The Storyteller - Stories are easy to remember. A good story contains a problem, a conflict, heroes, villains, and a final resolution. The rhythm of the story helps us remember and even learn new information better. The Greeks were one of the greatest storytellers of the ancient world. Let's listen to this myth while you read along, and see if you can find some familiar names:

UNIT 4 STUDENT HANDOUT

ANDROMEDA AND PERSEUS

Andromeda was a beautiful princess of Ethiopia. Her mother, the equally beautiful, but very vain Queen Cassiopeia, loved to boast a little too much about her own stunning appearance. This terrible vanity so angered the god, Poseidon, Ruler of the Seas, that he ordered the sea monster, Cetus, to wreck havoc on all coastal towns and villagers. Sailors were never safe as Cetus upset their boats, caused great storms, and put their lives in grave danger. Andromeda's father, King Cepheus, was not at all like his vain, self-centered wife. He became very concerned about the safety of his kingdom and his people, so he sought advice. Advice can come at a terrible price, however. The only solution to the dreadful sea monster's destruction was to sacrifice something of value and beauty. Only the most valued and beautiful girl of his kingdom would be able to calm the raging Poseidon, and convince him to remove the monster, Cetus. Cepheus's daughter, Princess Andromeda, was the only choice as the most suitable sacrificial offering. Cepheus was devastated, but had no choice but to allow the offering to be carried out. He led his beautiful daughter down to the rocky coast where he left her chained to an outcropping. Alone she awaited the monster's appearance.

As the great monster approached, Perseus suddenly arrived, riding the winged horse, Pegasus. Heroic Perseus had just completed the grim task of killing Medusa, one of the Gorgon sisters. Medusa, like her sisters, was a horrible sight to behold. If anyone even half glanced at her face, they would instantly be turned to stone. Perseus not only slayed Medusa, but placed her hideous head in a bag to prove his deed. Now seeing the beautiful girl's danger, Perseus quickly pulled the grizzly head out from the leather bag, waved it in front of Cetus, and the horrible sea monster was instantly turned into a large mass of rock. Princess Andromeda was quickly rescued from the dangerous rocks and returned to her grieving parents. King Cepheus immediately granted Perseus's request to marry his daughter. As for the vain Queen Cassiopeia, she never again boasted about her beauty.

Class Analysis:

- Who were the characters? What roles did they play?

- Now, lets create a hypothesis:

The Greeks were great storytellers, and storytelling is known to be an excellent way to remember past events as well as retain new information. Could there be a group of constellations with the same names like those in the story? If so, then, a reasonable hypothesis would be that repeating the story while gazing upwards at the star-filled sky would help someone remember this particular pattern of stars.

- Using your planisphere, look for the story's characters in the constellations.

- Turn the wheel to allow all of these constellation to be showing through your viewing circle. What months are these best seen in?

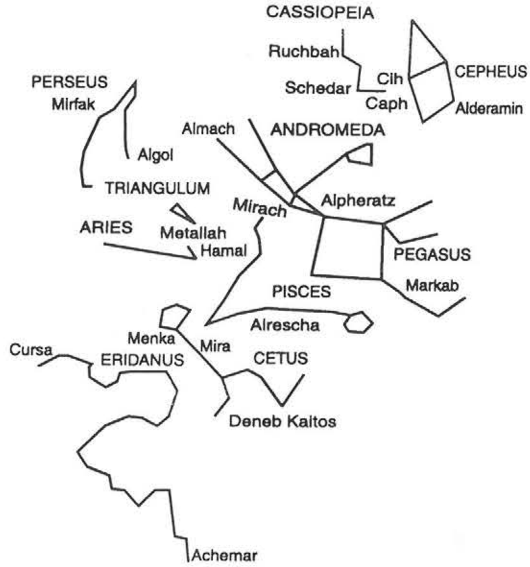
- When do you think Greek shepherds would most likely hear this story repeated as they gazed at the heavens each night?

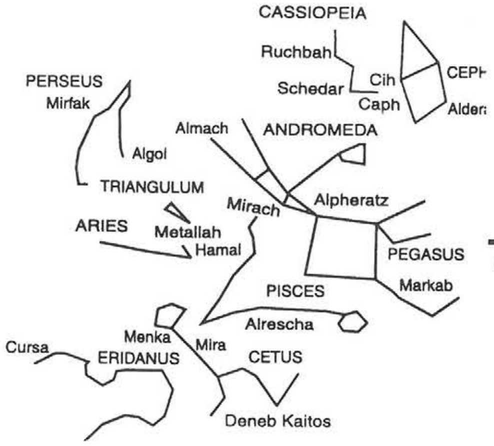
- Now, here are some more seasonal constellation groups (see handout). Can you find these on your planisphere?

- Summarize your observations and conclusions on myths and star patterns (constellations), in the sky.

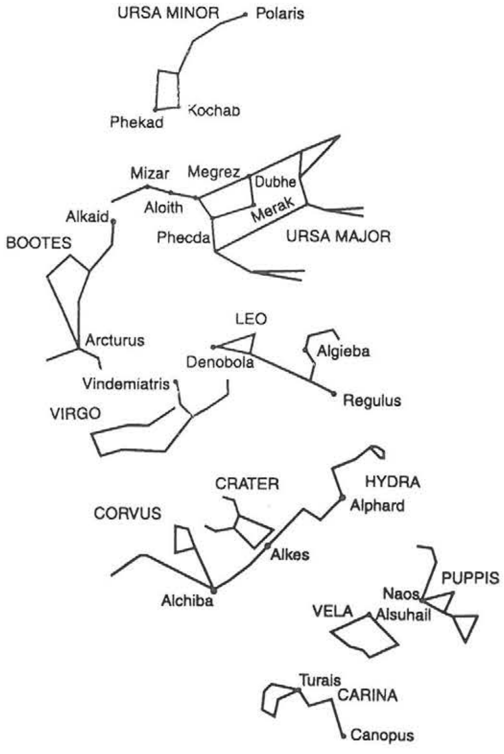
UNIT 4 STUDENT HANDOUT

The Andromeda Group

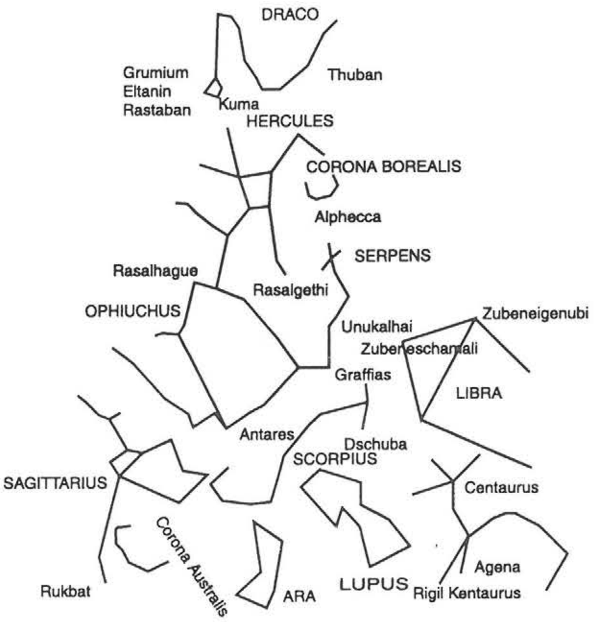




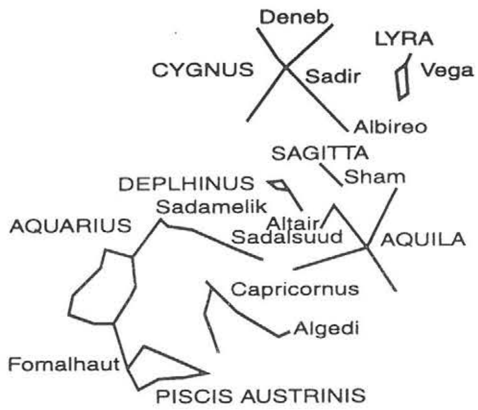
The Osiris Group



The Harnessing & Harvesting Group



The Hero and Healer Group



The Birds and Sea Group

Lesson 3: The Nature of Starlight

Objectives:

- Students will compare/contrast our Sun's visible light characteristics with other stars by organizing and graphing star color, absolute magnitude, temperature, spectral type, luminosity, and diameter.

Skills:

- Students will know how to organize and manipulate star data.
- Students will be able to produce and interpret histograms.
- Students will learn to compare and contrast quantitative data,

Vocabulary:

- Histograms
- peak color in spectrum
- diameter in Suns
- apparent magnitude
- absolute magnitude
- distance in light-years
- luminosity class
- luminosity in Suns
- temperature in Kelvins (°K)
- spectral type

Materials:

- What is Starlight? - handout
- Questions for Starlight Jeopardy - handout
- Among the Stars of Winter Database - handout
- Definitions of Star Terms - handout
- Organizing the Star Data - handout
- Creating Histograms for Starlight Data - handout
- notebook
- metric ruler
- centimeter graph paper
- colored pencils

Procedure:

Class Challenge (on board or overhead):

- Brainstorm: What is starlight? How do we describe it?
- After some discussion, reveal a list of all of the vocabulary words above, except for histograms.

- Challenge the students to try to define these words and then, explain how they relate to the question, What is starlight? Provide textbooks, dictionaries, etc. to encourage self-discovery.
- If needed for further discussion and clarification, distribute copies of the definitions provided in the handout.

Class Activity:

- Play Starlight Jeopardy (10 minutes):
- Divide the class into groups of 4 to 6 students.
- Assign jobs - Recorder, Team Captains.
- Hand out the sheet, Among the Stars of Winter database.
- Read out loud a selected level of question, calling on the first person who raised his/her hand.
- If the answer is correct, assign the student's team the correct points. If incorrect, delete a point.
- Team captains must keep their group concentrating and working on each question as quickly as possible. If the groups become too noisy, they lose one point.
- The group with the highest score after ten minutes wins the game.

Next Class Challenge (on board or overhead):

- How can we organize all of these numbers in the star database? (use board or overhead)
- Example: Look at the data column called Distance in Light-Years. How would you rearrange this long column to create a logical pattern?
- [after class brainstorming] You can organize it by resorting the data from the smallest number to the largest number.
- You can create groups of similar number.
- Hand out the student worksheet - Organizing the Star Data.

Group Activity:

- Use the worksheets provided to begin organizing your new data.
- Do these special types of bar graphs, called histograms, help you understand your data better? How?

- What can you now conclude about the various stars in this data base and their distance in light-years from Earth?

Group Activity:

- Astronomers like to find patterns in their starlight data. For instance, the chart below suggests that stars have different colors, and the color of a star has something to do with how hot it is. It also suggests that the lifetime of a star is related to star temperature and color.

Spectral Type	Temperature	Peak Color In	Lifetime
O	Over 25,000	Blue	10 million years
B	11,000-25,000	Blue-White	40 million years
A	7,500-11,000	White	100 million years
F	6,000-7,500	Yellow-White	5 billion years
G (Sun)	5,000-6,000	Yellow	10 billion years
K	3,500-5,000	Orange	50 billion years
M	less than 3,500	Red	100 billion years

- Let's analyze this chart.
- Your new challenge is to create another set of histograms from your star data - temperature, peak color, and spectral type.
- Use the student worksheet, Creating Histograms for Starlight Data, to organize your data.
- In your group, graph these 3 histograms, assigning different graphs to each of your group members.

Final Group Activity

- Create your own histograms of absolute magnitude, luminosity, luminosity class, and diameter in suns.
- Answer the questions under Analysis.

Handouts:

- What is Starlight?
- Definitions of Starlight Variables
- Among the Stars of Winter Database
- The Meaning of Star Names
- Starlight Jeopardy Questions
- Organizing the Star Data
- Creating Histograms for Starlight Data.

Starlight Jeopardy Answers

Each of the questions below is worth 1, 2 or 3 points, according to the difficulty of the question (1=easy, 2=moderate, 3=difficult). Ask each team to select the level of difficulty they would like to attempt. To keep it simple, continue on to the next group after one group has either attempted to answer the question, or answered it correctly. Students may use the Stars of Winter Database, the definition sheet and their notes. The correct answer is in parentheses. This short game is only a memory builder to introduce new vocabulary.

1 POINT QUESTIONS:

1. Distance in space is measured in ____________________ (light-years).

2. Starlight is studied by ________________ (spectroscopy).

3. The surface temperature in stars is measured in the ________________(Kelvin) scale.

4. Star class is called the ____________ (luminosity) class by astronomers.

5. The diameter of a star is the width of the star compared to the ____________ (sun).

6. ________________ (Luminosity) is the total light energy emitted by the star, as compared to the sun.

7. The true brightness of a star measures the stars as if they were all the same distance away (32.6 light-years). ________________ (absolute magnitude).

8. O,B,A,F,G,K, and M are called ________________ (spectral) classifications.

2 POINT QUESTIONS:

1. Describe the logarithmic magnitude scale.

2. The temperature of Sirius is 9,700 K. What is this in Celsius?

3. What is the name of the apparently brightest star in the database?

4. The star that is truly the brightest in our database is ___________?

5. The star, Almaaz, has a diameter how many times greater than our Sum?

6. The hottest star in the database is _____________?

7. Explain the spectral type classification for the star, Capella.

8. The furthest star from our Sun is ___________.

9. The star with the greatest total light energy emitted is ____________.

10. Our Sun's luminosity class, or star's class, is ________________.

3 POINT QUESTIONS:

1. Explain the classification of stars according spectral type.

2. Explain the scale measuring the absolute magnitude of stars.

3. Betelgeuse has a luminosity value of 5,000. What does this mean?

4. The star, Wezen, has a diameter value of 365, and Sirius has a diameter value of 2. What do these numbers mean?

5. The spectral type for our Sun is G2 V. What does this mean?

6. Describe the stages, or luminosity classes, of stars.

7. Describe the Kelvin scale for measuring temperature of stars.

8. How far (in kilometers) does light travel from Sirius to our Earth?

9. What star name means "camels quenching their thirst"?

10. Which star is often called the "dog star"?

UNIT 4 STUDENT HANDOUT

WHAT IS STARLIGHT?

1. Brainstorm ideas to the question, What Is Starlight?

2. Define these vocabulary words provided by your teacher. Use text books, dictionaries, Internet resources, etc. to discover the definitions.

- Distance in light-years
- Peak color in spectrum
- Luminosity class
- Temperature in Kelvins (K)
- Diameter in Suns
- Luminosity in Suns
- Apparent magnitude
- Absolute magnitude
- Spectral type

Definitions of Starlight Variables

1. **Distance:** Distance in space is measured in light-years. One light-year is the distance light travels in a year, or about 9.5 trillion kilometers in one year, or about 6 trillion miles in one year.

2. **Peak Color in Spectrum:** Starlight is studied by spectroscopy (using diffraction to break light into its component colors). Depending on how hot a star is, the light emitted from the star shines brightest in certain wavelengths. Stars whose spectra peak in the red are cooler than stars whose spectra peak in the blue.

3. **Temperature (Kelvins):** The surface temperature of the star. When the stars are arranged by surface temperature and by peak color, the relationship between the two is easily seen.

4. **Star's Luminosity Class:** This represents the stage of the star's life cycle. For instance, most stars spend most of their existence in the main sequence phase. Later, stars enlarge dramatically to become giant or supergiant stars. Finally, most stars shrink to become white, red, or black dwarfs. Some stars explode as supernovae while their cores collapse into extremely dense neutron stars or even black holes.

5. **Diameter in Suns:** The width of the star, as compared to our Sun.

6. **Luminosity:** The total light energy emitted by the star, as compared to our Sun.

7. **Absolute Magnitude:** The true brightness of a star; this scale measures the stars as if they were all the same distance away (about 32.6 light years). The smaller numbers indicate brighter stars; zero and negative numbers indicate still greater brightness.

8. **Spectral Type:** Spectral classifications are O, B, A, F, G, K, and M. O stars are the hottest and M stars are the coolest. Luminosity class is indicated by Roman numerals. I is a supergiant; II is bright giant; III is giant; IV is subgiant; and VI main sequence. Spectral and luminosity classes are further subdivided with numbers and letters.

UNIT 4 STUDENT HANDOUT

THE STARS OF WINTER DATABASE

Star Name	Navigation Star ☆	Distance in Light-Years	Peak Color in Spectrum	Star's Luminosity Class	Temperature in Kelvins (K)	Diameter in Suns	Luminosity in Suns	Abosolute Magnitude	Spectral Type
Capella	☆	44	yellow	giant	5100	11	72	0.9	GB III
Menkalinin		80	blue-white	subgiant	9000	2	45	0.6	A2 IV
Almaaz		6500	white	supergiant	7200	365	200000	-8.5	F0 Ia
Hoedus II		310	blue	main sequence	21000	3	377	-1.7	B3 V
Hassaleh		330	orange	bright giant	4200	73	655	-2.3	K3 II
Theta Auriga		150	blue-white	peculiar	10000	2	146	-0.7	A0 pec
Hoedus I		530	orange	bright giant	4300	53	655	-2.3	K4 II
Sirius	☆	9	blue-white	main sequence	9700	2	21	1.42	A1 V
Mirzam		740	blue	bright giant	26000	4	6500	-4.8	B1 II
Wezen		3100	white	supergiant	6000	365	125000	-8	F8 Ia
Adhara	☆	490	blue	bright giant	20000	5	4500	-4.4	B2 II
Muliphen		1000	blue	bright giant	14000	5	1803	-3.4	B8 II
Aludra		2500	blue	supergiant	14500	37	50000	-7	B5 Ia
Furud		290	blue	main sequence	18000	2	377	-1.7	B2.5 V
Procyon	☆	11	white	subgiant	6700	2	7	2.64	F5 IV
Gomeisa		140	blue	main sequence	13000	2	95	-0.2	B8 Ve
Castor		47	blue-white	main sequence	9300	2	28	1.14	A1 V
Pollux	☆	35	orange	giant	4900	9	32	0.98	KO IIIb
Wasat		53	white	subgiant	7000	2	8	2.46	F2 IV
Mebsuta		190	yellow	supergiant	5000	33	175	-0.9	G8 Ib
Alhena		88	blue-white	subgiant	9800	3	79	0	A0 IV
Propus		190	red	giant	3100	34	125	-0.5	M3 III
Tejat Posterior		160	red	giant	2900	35	125	-0.5	M3 IIIa
Alzirr		59	white	giant	6600	2	11	2.1	F5 III
Mekbuda		1500	yellow	supergiant	5700	86	5000	-4.5	G0 Ib
Sun	☆	8.3 light-minutes	yellow	main sequence	5800	1	1	4.75	G2 V

UNIT 4 STUDENT HANDOUT

THE STARS OF WINTER DATABASE 2

Star Name	Navigation Star ☆	Distance in Light-Years	Peak Color in Spectrum	Star's Luminosity Class	Temperature in Kelvins (K)	Diameter in Suns	Luminosity in Suns	Apparent Magnitude	Spectral Type
Ameb		930	white	supergiant	7400	32	6000	-4.7	FO 1b
Nihal		320	yellow	bright giant	5600	30	545	-2.1	G5 II
Betelgeuse	☆	325	red	supergiant	3400	265	5000	-4.5	M1 lab
Rigel	☆	910	blue	supergiant	13000	58	55000	-7.1	B8 lac
Mintaka		2300	blue	giant	24000	13	50000	-7	BO III
Ainilam	☆	1200	blue	supergiant	23000	16	25000	-6.2	BO lae
Bellatrix	☆	360	blue	giant	23000	3	2168	-3.6	B2 III
Algiebba		770	blue	main sequence	19000	8	1977	-3.5	B1 V
Nair Al Saif		1900	blue	giant	28000	6	20000	-6	09 III
Saiph		215	blue	supergiant	22000	4	525	-2.1	BO.5 la
Meissa		470	blue	not identified	35000	3	552	-2.2	08 e
Alnitak		1600	blue	supergiant	28000	80	34000	-6.6	09.5 lb
Aldebaran	☆	65	orange	giant	4000	34	137	-0.6	K5 III
El Nath	☆	150	blue	giant	14000	2	344	-1.6	B7 III
Ainilam		150	yellow	giant	5000	13	65	0.2	G9.5 III
Al Hecka		520	blue	giant	18000	4	1247	-3	B4 III
Alcyone		260	blue	giant	15000	3	344	-1.6	B7 III
Sun	☆	8.3 light-minutes	yellow	main sequence	5800	1	1	4.75	G2 V

UNIT 4 STUDENT HANDOUT

THE MEANINGS OF STAR NAMES

Constellation Name	Star Name	Meaning of Star Name
Auriga, the Chariteer	Capella	little she-goat, goat star, rainy goat star
Auriga, the Chariteer	Menkalinan	shoulder of the rein holder
Auriga, the Chariteer	Almaaz	he-goat; western goat str; signal for close of navigation; also called Al Anz
Auriga, the Chariteer	Hoedus II	one of kid goats, rising before Sun, marks stormy season
Auriga, the Chariteer	Hasseleh	marks back of charioteer's knee
Auriga, the Chariteer	Theta Auriga	marks wrist of charioteer
Auriga, the Chariteer	Hoedus I	one of kid goats; rising before Sun, marks stormy season; also called Sadatoni
Canis Major, the Great Dog	Sirius	sparkling; dog star; scorching one; rising before Sun on hottest days of summer
Canis Major, the Great Dog	Mirzam	roarer or announcer (of Sirius)
Canis Major, the Great Dog	Wezen	weight; also called Wesen
Canis Major, the Great Dog	Adhara	maiden, attendant of Suhail who married Orion
Canis Major, the Great Dog	Muliphen	marks the top of the dog's head
Canis Major, the Great Dog	Aludra	maiden, attendant of Suhall who married Orion
Canis Major, the Great Dog	Furud	male apes, also called Phurud
Canis Minor, Small Dog	Procyon	before the dog (rising before Sirius), water dog (near Milky Way)
Canis Minor, Small Dog	Gomeisa	watery eyed (near Milky Way), also called Mirzam
Gemini, The Twins	Castor	horseman, mortal twin
Gemini, The Twins	Pollux	boxer, immortal twin
Gemini, The Twins	Wasat	middle of the sky (near the ecliptic)
Gemini, The Twins	Mebsuta	outstretched paw of the lion
Gemini, The Twins	Alhena	brand mark
Gemini, The Twins	Propus	the projecting foot; also called Tejat Prior
Gemini, The Twins	Tejat Posterior	heel
Gemini, The Twins	Alzirr	button
Gemini, The Twins	Mekbuda	folded paw of the lion

UNIT 4 STUDENT HANDOUT

THE MEANINGS OF STAR NAMES PAGE 2

Lepus, The Hare	Arneb	the hare
Lepus, The Hare	Nihal	camels quenching their thirst
Orion, The Hunter	Betelgeuse	arm of central one; armpit of white belted sheep
Orion, The Hunter	Rigel	left leg of giant, Orion's left foot
Orion, The Hunter	Mintaka	belt
Orion, The Hunter	Ainilam	string of pearls
Orion, The Hunter	Bellatrix	Amazon female warrior
Orion, The Hunter	Algiebba	handle of the sword
Orion, The Hunter	Nair al Saif	bright one of the sword
Orion, The Hunter	Saiph	sword of powerful one
Orion, The Hunter	Meissa	glittering star
Orion, The Hunter	Alnitak	girdle
Taurus, The Bull	Aldebaran	follower (of the Pleides)
Taurus, The Bull	El Nath	the one butting with horns
Taurus, The Bull	Ain	eye
Taurus, The Bull	Al Hecka	white one
Taurus, The Bull	Alcyone	brightest one of the Pleiades (Seven Sisters)

STARLIGHT JEOPARDY

Each of the questions below is worth 1, 2 or 3 points, according to the difficulty of the question (1=easy, 2=moderate, 3=difficult). Ask each team to select the level of difficulty they would like to attempt. To keep it simple, continue on to the next group after one group has either attempted to answer the question, or answered it correctly. Students may use the Stars of Winter Database, the definition sheet and their notes. The correct answer is in parentheses. This short game is only a memory builder to introduce new vocabulary.

1 POINT QUESTIONS:

1. Distance in space is measured in ____________________ .
2. Starlight is studied by ________________ .
3. The surface temperature in stars is measured in the ________________scale.
4. Star class is called the _____________ class by astronomers.
5. The diameter of a star is the width of the star compared to the _____________ .
6. ________________ is the total light energy emitted by the star, as compared to the sun.
7. The true brightness of a star measures the stars as if they were all the same distance away (32.6 light-years). ________________ .
8. O,B,A,F,G,K, and M are called ________________ classifications.

2 POINT QUESTIONS:

1. Describe the logarithmic magnitude scale.
2. The temperature of Sirius is 9,700 K. What is this in Celsius?
3. What is the name of the apparently brightest star in the database?
4. The star that is truly the brightest in our database is ___________?
5. The star, Almaaz, has a diameter how many times greater than our Sum?
6. The hottest star in the database is _____________?

7. Explain the spectral type classification for the star, Capella.

8. The furthest star from our Sun is ___________.

9. The star with the greatest total light energy emitted is ____________.

10. Our Sun's luminosity class, or star's class, is ________________.

3 POINT QUESTIONS:

1. Explain the classification of stars according spectral type.

2. Explain the scale measuring the absolute magnitude of stars.

3. Betelgeuse has a luminosity value of 5,000. What does this mean?

4. The star, Wezen, has a diameter value of 365, and Sirius has a diameter value of 2. What do these numbers mean?

5. The spectral type for our Sun is G2 V. What does this mean?

6. Describe the stages, or luminosity classes, of stars.

7. Describe the Kelvin scale for measuring temperature of stars.

8. How far (in kilometers) does light travel from Sirius to our Earth?

9. What star name means "camels quenching their thirst"?

10. Which star is often called the "dog star"?

UNIT 4 STUDENT HANDOUT

ORGANIZING THE STAR DATA

How can we organize and make sense of all of the numbers in the Stars of Winter Database?

Begin with one variable. For example, *Distance in light-years.*

a. Rearrange your data by sorting it from the smallest number to the largest number.

Star Name	Distance in Light Years

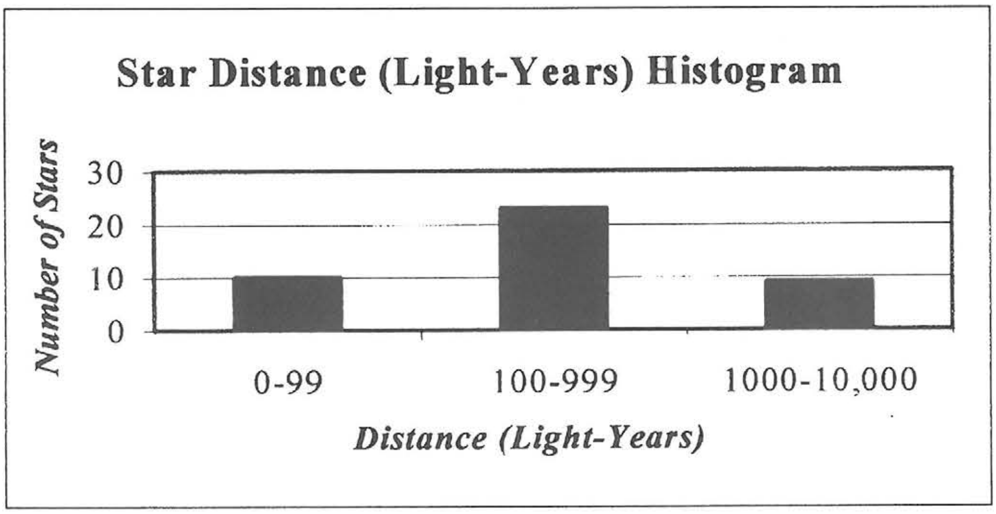
Star Name	Distance in Light Years

2. Next, create groups of similar numbers:

For example, the *Distance in light-years* data is easily grouped into three sections: 0 to 99, 100 to 999, and 1,000 to 10,000. Tally the number of stars in each group below:

0 to 99 light years	100 to 999 light-years	1000 to 100,000 light years

Your final bar graph, or histogram, is now very simple. Place the number of stars tally on the vertical axis and the three groups of stars on the horizontal axis:



3. What can you conclude about star distance from your histogram?

UNIT 4 STUDENT HANDOUT

CREATING HISTOGRAMS FOR STARLIGHT DATA

Introduction

Astronomers like to find patterns in starlight data. The chart below suggests that stars can be organized by spectral type, temperature, and color. The column, lifetime, appears to be related to the other three variables as well.

Spectral	Type Temperature (°K)	Peak Color in Spectrum	Lifetime
O	Over 25,000	Blue	10 million years
B	11,000-25,000	Blue-white	40 million years
A	7,500-11,000	White	100 million years
F	6,000-7,500	Yellow-white	5 billion years
G (Sun)	5,000-6000	Yellow	10 billion years
K	3,500-5000	Orange	50 billion years
M	less than 3,500	Red	100 billion years

1. Let's use these relationships to analyze our Stars of Winter database. We can create histograms to place our stars into like groups. First, sort the data in ascending order (smallest to largest). This has already been done for you below for temperature:

Star Name	Temperature in Kelvins (K)	Spectral Type	Peak Color in Spectrum
Tejat Posterior	2900	M3 IIIa	red
Propus	3100	M3 III	red
Betelgeuse	3400	M1 lab	red
Aldebaran	4000	K5 III	orange
Hassaleh	4200	K3 II	orange
Hoedus I	4300	K4 II	orange
Pollux	4900	KO IIIb	orange
Mebsuta	5000	G8 Ib	yellow
Ainilam	5000	G9.5 III	yellow
Capella	5100	GB III	yellow
Nihal	5600	G5 II	yellow
Mekbuda	5700	G0 Ib	yellow
Sun	5800	G2 V	yellow

Star Name	Temperature in Kelvins (K)	Spectral Type	Peak Color in Spectrum
Wezen	6000	F8 Ia	yellow-white
Alzirr	6600	F5 III	yellow-white
Procyon	6700	F5 IV	yellow-white
Wasat	7000	F2 IV	yellow-white
Almaaz	7200	F0 Ia	yellow-white
Ameb	7400	FO 1b	yellow-white
Menkalinin	9000	A2 IV	white
Castor	9300	A1 V	white
Sirius	9700	A1 V	white
Alhena	9800	A0 IV	white
Theta Auriga	10000	A0 pec	white
Gomeisa	13000	B8 Ve	blue-white
Rigel	13000	B8 lac	blue-white
Muliphen	14000	B8 II	blue-white
El Nath	14000	B7 III	blue-white
Aludra	14500	B5 Ia	blue-white
Alcyone	15000	B7 III	blue-white
Furud	18000	B2.5 V	blue-white
Al Hecka	18000	B4 III	blue-white
Algiebba	19000	B1 V	blue-white
Adhara	20000	B2 II	blue-white
Hoedus II	21000	B3 V	blue-white
Saiph	22000	BO.5 la	blue-white
Ainilam	23000	BO lae	blue-white
Bellatrix	23000	B2 III	blue-white
Mintaka	24000	BO III	blue-white
Mirzam	26000	B1 II	blue
Nair Al Saif	28000	O9 III	blue
Alnitak	28000	O9.5 Ib	blue
Meissa	35000	O8 e	blue

2. Now, organize your large data set into groups of similar numbers.

• For example, using the chart at the beginning of this worksheet, spectral type groups (O,B,A,F,G,K,M), temperature groups (over 25, 000; 11,000-25,000 etc), and peak color in spectrum groups (blue, blue-white, etc) provide logical arrangements of the data.

Simple tally the number of stars in each group:

Spectral Type

O	B	A	F	G	K	M

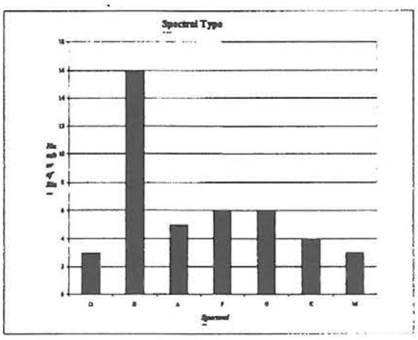
Temperature (K)

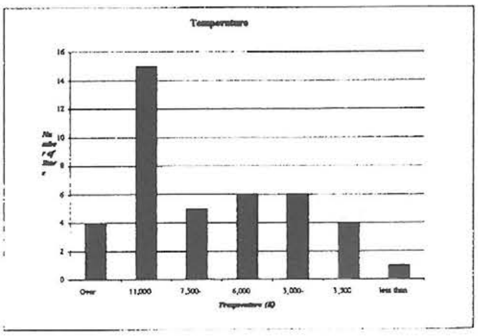
Over 25,000	11,000 -25,000	7,500 -11.000	6,000 -7,500	5,000 -6,000	3,500 -5,000	Less than 3,500

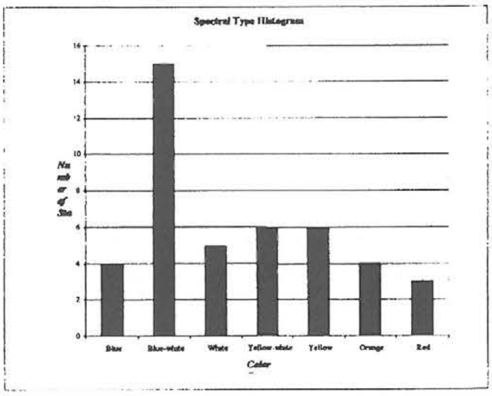
Peak Color in Spectrum

Blue	Blue -white	White	Yellow -white	Yellow	Orange	Red

Create 3 histograms, one for each variable above. Organize your graph with the vertical axis defined as the number of stars (your tally) in a group, and the horizontal axis as the group definition. Example:







3. Now you need to create your final set of histograms for absolute magnitude, luminosity (in suns), star luminosity class, and diameter (in suns). The data is provided below, sorted from the brightest star to the dimmest star in the Stars of Winter Database.

Star Name	Absolute Magnitude	Luminosity in Suns	Star's Luminosity Class	Diameter in Suns
Almaaz	-8.5	200000	supergiant	365
Wezen	-8	125000	supergiant	365
Rigel	-7.1	55000	supergiant	58
Aludra	-7	50000	supergiant	37
Mintaka	-7	50000	giant	13
Alnitak	-6.6	34000	supergiant	80
Ainilam	-6.2	25000	supergiant	16
Nair Al Saif	-6	20000	giant	6
Mirzam	-4.8	6500	bright giant	4
Ameb	-4.7	6000	supergiant	32
Mekbuda	-4.5	5000	supergiant	86
Betelgeuse	-4.5	5000	supergiant	265
Adhara	-4.4	4500	bright giant	5
Bellatrix	-3.6	2168	giant	3
Algiebba	-3.5	1977	main sequence	8
Muliphen	-3.4	1803	bright giant	5
Al Hecka	-3	1247	giant	4
Hassaleh	-2.3	655	bright giant	73
Hoedus I	-2.3	655	bright giant	53
Meissa	-2.2	552	not identified	3
Nihal	-2.1	545	bright giant	30
Saiph	-2.1	525	supergiant	4
Hoedus II	-1.7	377	main sequence	3
Furud	-1.7	377	main sequence	2
El Nath	-1.6	344	giant	2
Alcyone	-1.6	344	giant	3
Mebsuta	-0.9	175	supergiant	33
Theta Auriga	-0.7	146	peculiar	2
Aldebaran	-0.6	137	giant	34
Propus	-0.5	125	giant	3
Tejat Posterior	-0.5	125	giant	35
Gomeisa	-0.2	95	main sequence	2
Alhena	0	79	subgiant	3
Ainilam	0.2	65	giant	13
Menkalinin	0.6	45	subgiant	2
Capella	0.9	72	giant	11
Pollux	0.98	32	giant	9
Castor	1.14	28	main sequence	2
Sirius	1.42	21	main sequence	2
Alzirr	2.1	11	giant	2
Wasat	2.46	8	subgiant	2
Procyon	2.64	7	subgiant	2
Sun	4.75	1	main sequence	1

4. Again, the data must be grouped in some meaningful way. A scale that increases each time by a factor of ten is useful when dealing with very large numbers. This is called a log scale.

5. We will use a log scale to group luminosity, and repeat these divisions for absolute value (also a measure of brightness). Luminosity class will be grouped by class name. Diameter (in suns) will also use a log scale to distinguish groups of stars.

6. The different groupings are provided in tables below to help you create your histograms:

Luminosity (in suns)

Over 100,000	10,000 -100,000	1,000 -10,000	100 -1,000	10 -100	0 -10

Absolute Magnitude

Less than -7.9	-7.9 to -5.9	-5.9 to -2.9	-2.9 to -0.49	-0.49 to 2.1	2.1 to 4.65

Star Luminosity Class

Super Giant	Giant	Bright Giant	Sub Giant	Main Sequence	Peculiar	Not Identified

Diameter (in suns)

1-10	10-100	100-1000

7. Using graph paper, create your histograms for the four variables above. Use the histograms for peak color, temperature, and spectral type as models

Analysis Questions:

- How is a histogram different from a line graph?

- When analyzing large databases, explain why histograms are a useful first step in identifying meaningful patterns.

- Compare and contrast your results from graphing star temperature, peak color in the spectrum, and spectral type.

- Compare and contrast our Sun's temperature, color, and spectral type to the other stars in the database.

- Compare and contrast our Sun's luminosity and absolute magnitude to the other stars in the database.

- What is our Sun's luminosity class?

- Write a paragraph describing our Sun according to the results of your analysis of the Stars of Winter Database. What kind of star is our Sun?

Lesson 4: The Hertzsprung-Russell Diagram (H-R Diagram)

Objectives:

- Students will uncover further evidence that the Sun is a medium-sized, main-sequence star as they create and interpret the Hertzprung-Russell diagram, an essential tool of modern astronomers.

Skills:

- Students will understand how to graph star data
- Students will be able to organize numerical data into meaningful groups
- Students will learn to analyze the significance of their results

Vocabulary:

- Hertzsprung-Russell diagram
- Main sequence stars
- Red Giants
- White Dwarfs
- Neutron Stars
- Supernova
- Black Holes
- Star Life Cycle or Evolution

Materials:

- Hertzsprung-Russell Diagram - handout
- Star Data for Creating the H-R Diagram
- centimeter graph paper
- metric ruler
- notebook
- colored pencils, markers, etc.

Procedure:

Class Challenge:

You are now ready to create the single most important diagram astronomers use today, the Hertzsprung-Russell (H-R) diagram.

After you create your diagram, we will spend time analyzing the important star patterns it contains, and research how this diagram explains the natural life cycle, or birth, death, and re-birth of stars.

Individual Activity:

- You will be creating your own graph using the Star Data for Creating the H-R Diagram.
- On graph paper, create a horizontal scale (x-axis) for Temperature (K). Your data will begin with the hottest stars at the origin, and decrease in temperature from left to right. Your data will range from 23,000 K to 2,000 K.
- Create your vertical scale (y-axis) for Absolute Magnitude. Your data will begin with the most positive numbers at the origin (+15.0) to the most negative numbers at the top of the vertical axis (-8.0).
- Plot each star point for absolute magnitude and temperature. Do not connect the data points.
- Write the name of each star next to its dot on the diagram.
- Find the chart in this handout that contains information on spectral type, temperature, and color. Lightly shade in the color of each spectral type where it corresponds to a range of temperatures.

Class Activity: The Life Cycle or Evolution of Stars

But...how do we create a meaningful pattern from this scattering of data?

We go back to the drawing board!

- The creation of a scatter plot of different stars according to their absolute magnitude and temperature, as well as an overlay of star color, was a major discovery in modern astronomy. The interpretation was improved even further when the star's luminosity class was identified. This natural grouping of the data led two scientists in the early 1900s, Danish astronomer Ejnar Hertzsprung and American astronomer Henry Norris Russell to create what is now known as the Hertzsprung-Russell (H-R) diagram.

- What is the relationship between star color and star temperature? Between star absolute magnitude and luminosity?

- Now for a little group research:

  In your groups, define these terms and explain how they relate to a star's life cycle:

  - a main sequence star?
  - a red giant?
  - a white dwarf?
  - a supernova?
  - a neutron star?
  - a black hole?

- What kind of star is our Sun?

- Use the chart below to determine the oldest stars and the youngest stars in your Hertzsprung-Russell diagram:

Spectral	Type Temperature (°K)	Peak Color in Spectrum	Lifetime
O	Over 25,000	Blue	10 million years
B	11,000-25,000	Blue-white	40 million years
A	7,500-11,000	White	100 million years
F	6,000-7,500	Yellow-white	5 billion years
G (Sun)	5,000-6000	Yellow	10 billion years
K	3,500-5000	Orange	50 billion years
M	less than 3,500	Red	100 billion years

Oldest Stars

Youngest Stars

Analysis:

- Using either your H-R diagram, or a more complete H-R diagram you may have found during your research, summarize the natural evolution of stars from birth to death to rebirth. Include your understanding of the changes in absolute magnitude, temperature, and color as a star progresses through this cycle.

Handouts

- Creating the Hertzsprung-Russell Diagram
- Data for the Hertzsprung-Russell Diagram

UNIT 4 STUDENT HANDOUT

CREATING THE HERTZSPRUNG-RUSSELL DIAGRAM

Class Challenge:

1. You are now ready to create the single most important diagram astronomers use today, the Hertzsprung-Russell (H-R) diagram.

   After you create your diagram, we will spend time analyzing the important star patterns it contains, and research how this diagram explains the natural life cycle, or birth, death, and re-birth, of stars.

Individual Activity:

2. You will be creating your own graph using the Star Data for Creating the H-R Diagram.

3. On graph paper, create a horizontal scale (x-axis) for Temperature (K). Your data will begin with the hottest stars at the origin, and decrease in temperature from left to right. Your data will range from 23,000 K to 2,000 K.

4. Create your vertical scale (y-axis) for Absolute Magnitude. Your data will begin with the most positive numbers at the origin (+15.0) to the most negative numbers at the top of the vertical axis (-8.0).

5. Plot each star point for absolute magnitude and temperature. Do not connect the data points.

6. Write the name of each star next to its dot on the diagram.

7. Find the chart in this handout that contains information on spectral type, temperature, and color. Lightly shade in the color of each spectral type where it corresponds to a range of temperatures.

CLASS ACTIVITY: THE LIFE CYCLE OF STARS

UNIT 4 STUDENT HANDOUT

1. But…how do we create a meaningful pattern from this scattering of data?

   We go back to the drawing board!

2. The creation of a scatter plot of different stars according to their absolute magnitude and temperature, as well as an overlay of star color, was a major discovery in modern astronomy. This discovery was further improved when the star's luminosity class was included. This natural grouping of the data led two scientists in the early 1900s, Danish astronomer Ejnar Hertzsprung and American astronomer Henry Norris Russell to create what is now known as the Hertzsprung-Russell (H-R) diagram.

3. What does the H-R diagram suggest about the relationship between absolute magnitude and star temperature?

4. What does the H-R diagram suggest about the relationship between star spectral type and temperature?

5. Now for a little group research:

In your groups,

- Research and define the following terms.
- Explain how they are related to a star's life cycle.

a main sequence star?

a red giant?

a white dwarf?

a supernova?

a neutron star?

a black hole?

6. Can you identify any of these star types in your graph? For instance, where would you expect to find the main sequence stars?

-the red giants and supergiants?

-the white dwarves?

7. What kind of star is our Sun?

8. Use the chart below to determine the oldest stars and the youngest stars in your Hertzsprung-Russell diagram:

Spectral	Type Temperature (°K)	Peak Color in Spectrum	Lifetime
O	Over 25,000	Blue	10 million years
B	11,000-25,000	Blue-white	40 million years
A	7,500-11,000	White	100 million years
F	6,000-7,500	Yellow-white	5 billion years
G (Sun)	5,000-6000	Yellow	10 billion years
K	3,500-5000	Orange	50 billion years
M	less than 3,500	Red	100 billion years

Oldest Stars

Youngest Stars

Analysis:

Use either your H-R diagram, or even better, a more complete H-R diagram you may have found during your research, to summarize the natural evolution of stars from birth to death to rebirth. Include your understanding of the changes in absolute magnitude, temperature, and color as a star progresses through this cycle.

Data for the Hertzsprung-Russell Diagram

(modified from Richard Moeschl, Exploring the Night Sky, p. 326)

Star Name	Spectral Type	Absolute Magnitude	Temperature (K)
Sirius	A1	1.4	9,500
Procyon	F5	2.8	6,500
Sun	G2	5.0	5,000
Barnard's Star	M5	13.2	2,600
Vega	A0	0.5	9.700
Van Maanen's Star	F0	14.2	5,800
Canopus	F0	-4.6	6,400
Deneb	A2	-7.1	9,400
Pollux	K0	1.0	4,100
Mintaka	O9.5	-5.1	21,000
Altair	A5	2.4	7,700
Regulus	B8	-0.7	13,000
Luyten 745-6	F0	14.3	5,900
Antares	M1	-3.0	2,700
Rigel	B8	-6.2	11,000
Betelgeuse	M2	-5.6	2,700
Aldebaron	K5	-0.5	3,500
Capella	G0	-0.5	5,000
Arcturus	K1	-0.0	3,900
Spica	B1.5	-2.2	19,500
Acrux	B1	-2.7	19,000
Formalhaut	A3	2.1	8,900
Rigel Kentaurus	G0	-0.5	5,800
Alnitak	O9.5	-5.9	23,000
Wolf 424 A	M6	14.4	2,500

UNIT 4 STUDENT HANDOUT

HERTZSPRUNG-RUSSELL DIAGRAM