Lesson Plan: Star Gazing

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Target Grade: 5th

Teacher Prep Time: 10 minutes (1 hour if you need to print and laminate star cards.)

Lesson Time: 3 hours (we recommend doing this lesson over three days.)

- Part 1:
  - 20 min - Beginning Thoughts
  - 45 min - Star Brightness
- Part 2:
  - 30 min - Exploring How Actual Brightness Affects Brightness from Earth
  - 45 min - Exploring How Number of Stars in a System Affects Brightness from Earth
- Part 3:
  - 30 min - Exploring How Distance Affects Brightness from Earth
  - 30 min - Final Analysis

Lesson Overview: In this lesson students will explore why stars appear brighter or dimmer in the sky. They will also learn that a star's brightness can be measured in two different ways: the actual brightness (brightness from a fixed distance) and apparent brightness (brightness from Earth). Through guided inquiry, students will discover that a star's brightness from Earth is a combination of the star's actual brightness and its distance from Earth.

Learning Objective: Students will be able to use data to support the claim that a star's brightness as observed from Earth is a function of both distance and actual brightness.

NGSS: 5-ESS1-1 Support an argument that differences in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth.

- **Science and Engineering Practice**
  - #2 Engaging in Argument from Evidence
    - Engaging in argument from evidence in 3-5 builds on K-2 experience and progresses to critiquing the scientific explanations of solution proposed by peers by citing relevant evidence about the natural and designed world(s).
      - Supporting an argument with evidence, data, or a model.
- **Disciplinary Core Idea**
  - ESS1.A The Universe and its Stars
    - The Sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distances from Earth.
- **Crosscutting Concept**
  - #3 Scale, Proportion, and Quantity
    - Natural objects exist from the very small to the immensely large.

Where This Lesson Fits in: This lesson should be done at the beginning of your space unit. It serves as a way to introduce stars.

Materials Needed: (it is recommended that you have student work in groups of 4 during the activity)

- Star cards (laminated)
- Wet-erase pens (Vis a Vis pens)
- Poster paper (3 pages per group)

- 2 mini LED mag light flashlights (other flashlights can be used but you will need to check the distance that you need to be standing so that they appear to be one light)
- Student worksheets (one copy per student)

Teacher Prep:

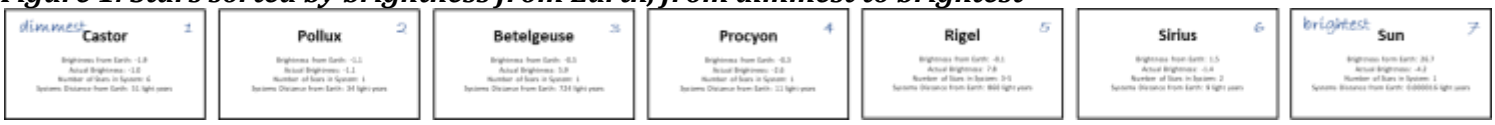
- Print out, cut, and laminate the star cards.
- Make copies of student worksheets.

Lesson Sequence:

Part 1: 20 minutes	**Beginning Thoughts** 1. Pass out *Star Gazing* packet. 2. Students fill out the question: "What do you know about stars?" (page 1) 3. Have students share out key ideas and record them on the board. o ESR (expected student response) ▪ Stars are in the sky ▪ There are many stars ▪ We see stars at night ▪ Stars produce light 4. Discuss that the Sun is a star (revise student ideas if necessary) and make sure students understand that stars are present in the sky during the day, but we just can't see them because the sun is so bright. 5. Have students fill out the questions: "Is the Sun a star?" and "Why do we only see some stars at night?" (page 1)
Part 1: 45 minutes	**Star Brightness** 1. Put the colored picture of the night sky up for student to see. 2. In their groups of 4, have students determine the order of dimmest to brightest stars in the picture and record. (page 1) 3. Have students use the data table on page 2 and write the star's brightness from Earth next to their list from dimmest to brightest. o Most likely students will not put the stars completely in the complete correct order. 4. Discuss with students what they notice about their order and the brightness measurements. 5. Talk to students about how our eyes have a hard time differentiating between small differences in light intensity and that is why we use instruments (photometers) to measure the amount of light a star gives off. o Teacher Note: Brightness measurements are on a logarithmic scale (like earthquakes), therefore, the dimmer the star the smaller the difference between increments and the harder it is for us to distinguish the difference in brightness with our eyes. 6. Have students answer the question "What do you notice about the brightness from Earth's numbers compared to how bright the star is?" (page 2) o ESR ▪ In general, the brighter the star is in the picture, the larger the brightness from Earth number is. 7. Give each student group a set of the 7 star cards. 8. Have them put the cards in order from brightest to dimmest, according to the brightness from Earth. 9. Students should then write, with a wet-erase pen, "brightest" on the star that is brightest (Sun) and "dimmest" on the star that is the dimmest (Castor). In

	addition, have them label the cards from 1 being the dimmest to 7 being the brightest. See figure 1.

Figure 1: Stars sorted by brightness from Earth, from dimmest to brightest



	10. Define the two different brightness measurements, brightness from Earth and actual brightness. ○ **Brightness from Earth** is defined as how bright the star appears viewed from Earth. ○ **Actual Brightness** is how bright the star is from a fixed point of 33 light years away. Explain that light years are a measure of distance when objects in space are very far away. One light year is equal to how far light can travel in one year. Stars are so far away, we use light years when talking about their distances. 11. Define the word "apparent" for students. ○ Apparent: what something seems to be (in this case what the brightness of a star seems to be from someone on Earth) 12. Have students fill out the question: "What is the difference between brightness from Earth and actual brightness?" Make sure that they use the word "apparent" in their answer. (page 2) ○ ESR ▪ The actual brightness is the brightness measured at a fixed distance from the star. The brightness from Earth is the apparent brightness, and is what the brightness appears to be on Earth. 13. If you are splitting the activity over three days, collect the cards and worksheets from students and tell them we will continue our star exploration tomorrow. If you plan to continue in one sitting, this would be a good time for a short brain break.
Part 2: 30 minutes	**Exploring How Actual Brightness Affects Brightness from Earth** 1. Have students order the star cards from dimmest to brightest actual brightness. See figure 2. Note: DO NOT erase numbers from last step.

Figure 2: Stars sorted by actual brightness, from dimmest to brightest

	2. Then have them record the brightness from Earth numbers (numbers they wrote with wet-erase pen) on their worksheets. (page 3) 3. Have students fill out if they agree or disagree with a person who claims that the brighter the absolute brightness, the brighter the star will appear to be in the sky. Make sure that students use evidence (data) to back up their arguments. (page 3) ○ ESR ▪ I disagree with the person because the Sun appears to us as the brightest star (26.7) but the actual brightness of the Sun is the dimmest (-4.2) of the seven stars we looked at.

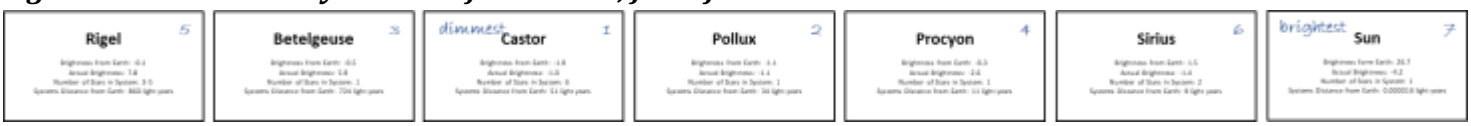
	4. Once students have written down their personal arguments, have them share their ideas with their group. 5. Have the group write the strongest argument on poster paper. o Teacher Note: Strong arguments are arguments that contain data to back up the claim. If desired, you can underline data within students' claims. 6. Tape up all of the posters and read the arguments to students. 7. Have students vote on which argument is the strongest. 8. Discuss why the argument that got the most votes was the strongest.
Part 2: 45 minutes	**Exploring How Number of Stars in System Affects Brightness from Earth** 1. Go outside, standing ~50 ft from students, turn on two flashlights and hold them together (do not let students see that you have two different flashlights). Ask students what they see. o ESR ▪ You are holding a flashlight. 2. Slowly walk towards students while they are making observations. As you get closer to the students, they will notice that what they thought was one flashlight is really is two flashlights. 3. Tell students this phenomenon also happened to early astronomers. They saw a bright spot in the sky and called it a star. As telescopes got better, scientists noticed that some of the objects that they thought were one star actually were star systems made up of multiple stars. 4. Have students answer the question on their worksheet: "How can a "star" be made up of multiple stars?" Also have them draw a picture of what the stars look like from a distance versus what the stars look like up close. 5. Have students order the star cards from least to most stars in the system. See figure 3.

Figure 3: Stars sorted by number of stars, from least to most

	6. Then have them record the brightness from Earth numbers on their worksheets and circle systems that have the same number of stars in their system. For example, you would circle all of the following because they have 1 star in their system: Sun 7, Procyon 4, Pollux 2, and Betelgeuse 3). (page 3) 7. Have students fill out if they agree or disagree with a person who claims that the more stars that make up the system, the brighter the star will appear to be in the sky. Make sure that students use evidence (data) to back up their arguments. (page 3) o ESR ▪ I disagree with the person because the Sun appears to be the brightest star (26.7) and is made up of 1 star and Pollux is the second dimmest star (-1.1) and is also made up of 1 star. 8. Once students have written down their personal arguments, have them share their ideas with their group. 9. Have the group write the strongest argument on a new poster paper. 10. Tape up all of the posters and read the arguments to students. 11. Have students vote on which argument is the strongest. 12. Discuss why the argument that got the most votes was the strongest.

	13. If you are splitting the activity over three days, collect the cards and worksheets from students and tell them we will continue our star exploration tomorrow. If you plan to continue in one sitting, this would be a good time for a short brain break.
Part 3: 30 minutes	**Exploring How Distance Affects Star Brightness** 1. Have students order the star cards from farthest to closest to Earth. See figure 4.

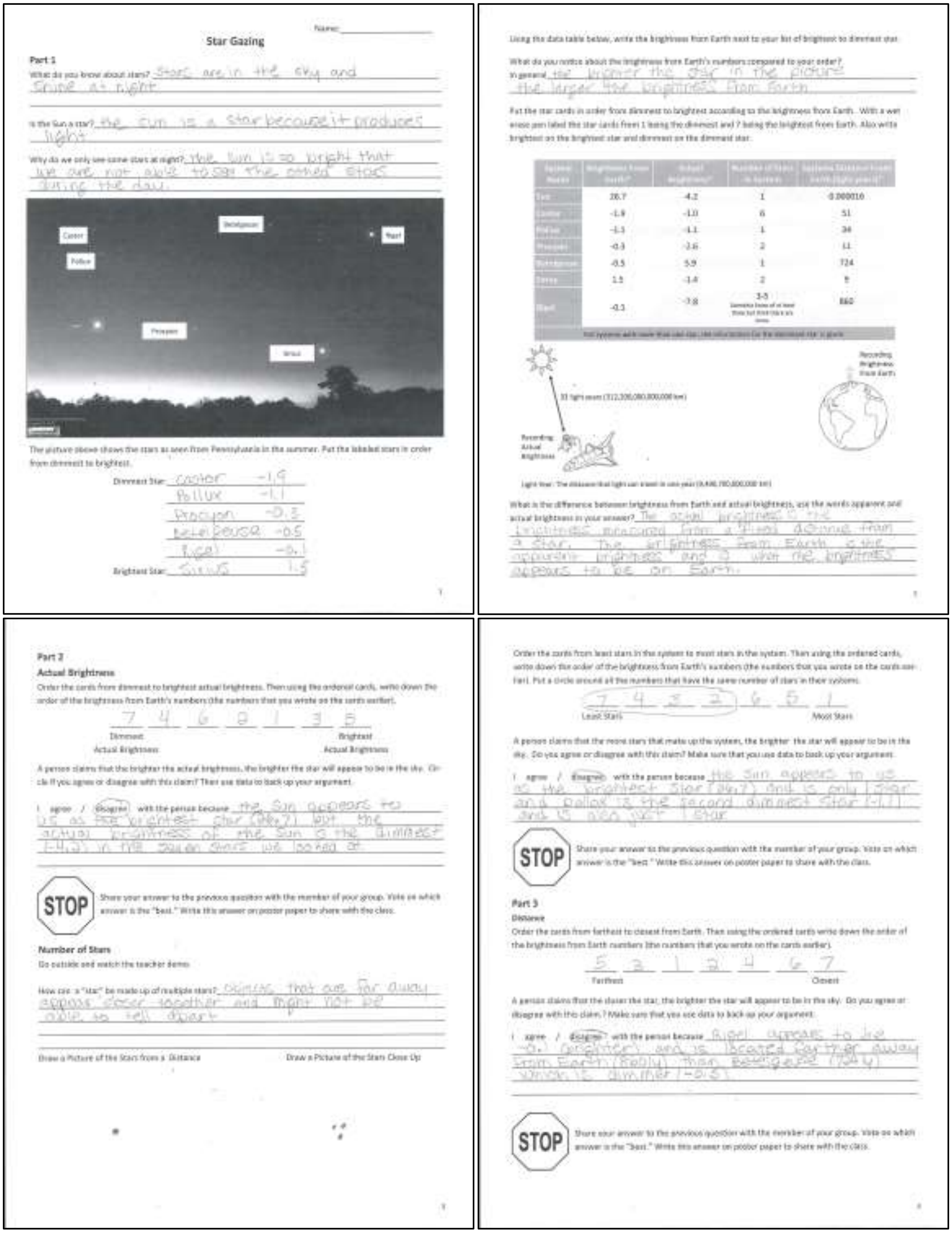
Figure 4: Stars sorted by distance from Earth, from farthest to closest



	2. Then have them record the brightness from Earth numbers on their worksheets. (page 4) 3. Have students fill out if they agree or disagree with a person who claims that the closer the star, the brighter the star will appear to be in the sky. Make sure that students use evidence (data) to back up their arguments. (page 4) o ESR ▪ I disagree with the person because Rigel appears to be -0.1 (brighter) and is located farther away from Earth (860 ly) than Betelgeuse (724 ly), which is -0.5 (dimmer). 4. Once students have written down their personal arguments, have them share their ideas with their group. 5. Have the group write the strongest argument on a new poster paper. 6. Tape up all of the posters and read the arguments to students. 7. Have students vote on which argument is the strongest. 8. Discuss why the argument that got the most votes was the strongest.
Part 3: 30 minutes	**Final Analysis** 1. Have students look at their data. Ask them if any of the ways that we arranged the stars: actual brightness, distance from Earth or number of stars, match the brightness from Earth? 2. Students should notice that none of them did. Tell them that this means that the brightness from Earth must not depend on just one of these factors, but a combination of them. 3. Ask students if there is a way that they can tell if any of these things plays a role in the star's brightness from Earth. o Students should generate the following ideas: ▪ Look for star systems with the same distance and actual brightness but different numbers of stars in the system. ▪ Look for star systems that have the same number of stars and the same actual brightness but are different distances from Earth. ▪ Look for star systems that have the same number of stars and are the same distance from Earth but have different actual brightness. 4. Explain that astronomers are a little different than other scientists. They cannot design their experiments by telling stars where to go in the sky. Instead, they have to think about which data they can analyze in order to answer their questions.

	5. Tell students scientists found that the number of stars did not affect brightness from Earth if they looked at systems that were the same distance from Earth and had the same actual brightness. Therefore, when analyzing the data we will not need to look at the number of stars in a system. 6. Tell students we want to find out how **actual brightness** affects the brightness of a star as seen from Earth. 7. Ask students what we need to look for in our data. o ESR ▪ We need to find stars that are at the approximately the same distance from Earth but have different actual brightness. 8. Have students find the two stars that are closest together, determine the difference in distance between the two stars and answer the questions: "Do you think that actual brightness affects how bright the star appears to be from Earth and why?" and "As the actual brightness increases, the brightness from Earth _____." (page 5) 9. Discuss the answers as a class. 10. Tell students we want to find out how **distance from Earth** affects the brightness of a star as seen from Earth. 11. Ask students what we need to look for in our data. o ESR ▪ We need to find stars that have the same actual brightness but are different distances from Earth. 12. Have students find the two stars that are closest in actual brightness, determine the difference in actual brightness between the two stars and answer the questions: "Do you think that distance from Earth affects how bright the star appears to be from Earth and why?" and "As the distance from Earth increase, the brightness from Earth _____." (page 5) 13. Discuss the answers as a class. 14. Discuss and have students answer the question: "What is the biggest factor that explains why the Sun appears so much brighter than any other star from Earth?" o ESR ▪ The biggest factor in the Sun's brightness is the distance between the Sun and the Earth. The Sun has a relatively low actual brightness (-4.2) but since it is closer than any other star it appears to be the brightest star.

Example Student Work:



Star Gazing

Part 1

What do you know about stars? Stars are in the sky and shine at night

Is the Sun a star? the sun is a star because it produces light

Why do we only see some stars at night? the sun is so bright that we are not able to see the other stars during the day.

Dimmest Star: Castor -1.9

Pollux -1.1

Procyon -0.3

Betelgeuse -0.5

Rigel -0.1

Brightest Star: Sirius 1.5

Part 2

Actual Brightness

7 4 6 2 1 3 5

STOP

Number of Stars

STOP

Part 3

Distance

5 3 1 2 4 6 7

STOP

Final Analysis

As a class discuss the following:

- Is the brightness from Earth solely dependent on actual brightness, number of stars, or distance from Earth?
- What data would you need to get to show how each of these factors affect the brightness from Earth?

Scientific Finding: The number of stars only a small effect on the brightness of a star as seen from Earth. Therefore, we will assume this factor does not affect the brightness from Earth.

*Does **actual brightness** affect the brightness from Earth?*

To study this what must be true of the distance and number of stars?
The distance must be as close as possible to each other the number of stars does not matter because it does not affect brightness from Earth

Find the two stars that have the most similar distance from the Earth.

Star Name:	Procyon	Sirius
Distance:	11 ly	9 ly
Actual Brightness:	2.6	-1.4

What is the difference in distance from Earth between these two stars? 11 ly - 9 ly = 2 ly

Do you think that actual brightness affects how bright the star appears to be from Earth and why?
yes because Sirius has an actual brightness that is more (-1.4) than procion (2.6) and Sirius appears brighter from Earth (-1.5) than procion (0.4)

As the actual brightness increases, the brightness from Earth increases / decreases

How actual brightness affects the brightness from Earth and how you know this.

*Does **distance** affect the brightness from Earth?*

To study this what must be true of the actual brightness and number of stars?
The actual brightness must be as close as possible to each other the number of stars does not matter because it does not affect brightness from Earth

Star Name:	Castor	Pollux
Distance:	51 ly	34 ly
Actual Brightness:	-1.0	-1.1

What is the difference in actual brightness between these two stars? -1.0 - -1.1 = 0.1

Do you think that distance from Earth affects how bright the star appears to be from Earth and why?
yes because Castor is farther from Earth (51 ly) than Pollux (34 ly) and Castor appears dimmer (-1.0) than Pollux (-1.1) from Earth

As the distance from Earth increases, the brightness from Earth increases / decreases

How distance affects the brightness from Earth and how you know this.

What is the biggest factor that explains why the Sun appears so much brighter than any other star from Earth? Even though the Sun's actual brightness is low (-4.7) the Sun is close to Earth than any other star and therefore, appears bright to us

Content Notes for Teachers:

Teacher Slide Not For Students

Apparent Magnitude

Apparent Magnitude (m): A measure of the brightness of a celestial object as seen by someone on Earth.

- Apparent Magnitudes were first measured by a Greek astronomer Hipparchus in ~150 BC. He set the scale for the brightest stars to be 0 and the dimmest starts to be 6. Therefore, the brighter the star the lower the apparent magnitude.
- Hipparchus though Vega was the brightest star so he set that to 0. There are brighter stars than Vega so some stars have negative apparent magnitude.
- Apparent magnitude is calculated with: $m_x - m_{x,0} = -2.5log\left(\frac{F_x}{F_{x,0}}\right)$
  - m is the apparent magnitude
  - F is the flux density (energy (power of radiation) per unit area) this can be measured
  - $m_{x,0}$ is the apparent magnitude of the reference object, Vega, $(m_{x,0} = 0)$
  - $F_{x,0}$ is the reference flux. You find this by pointing your photometer at Vega with the appropriate filter and making your measurement
- Apparent Magnitude is on a logarithmic scale, like earthquakes (see table).
- Apparent magnitude can be done in the ultraviolet, visible, or infrared wavelengths.

For the Activity the Brightness from Earth is Negative of the Apparent Magnitude

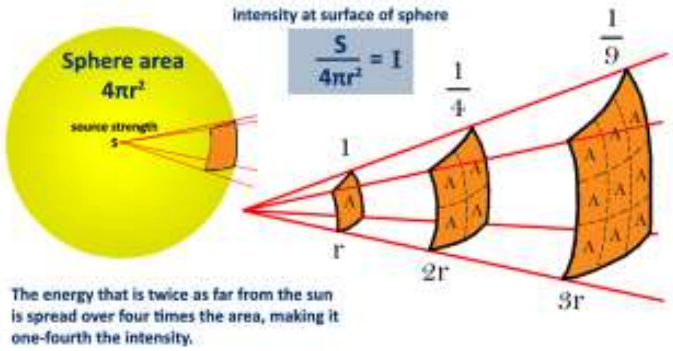
m_2-m_1	How much brighter the brighter star will be
1	2.51
2	$(2.51)^2 = 6.31$
3	$(2.51)^3 = 15.85$
4	$(2.51)^4 = 39.82$
5	$(2.51)^2 = 100$

Teacher Slide Not For Students

Absolute Magnitude

Absolute Magnitude (M): A measure of the brightness of a celestial object 32.6 ly (10 parsecs) from the object, the brighter an object is the lower the absolute magnitude.

- If you know the distance of the object and the apparent magnitude you can calculate the absolute magnitude because we know how flux changes with distance.
  - $M = m - 2.5log\left(\frac{d}{10\ pc}\right)^2$
    - d is distance (must be in parsecs), m is apparent magnitude, and M is absolute magnitude
    - For Procyon $M = 0.3 - 2.5log\left(\frac{3.4\ pc}{10\ pc}\right)^2 = 2.6$



For the Activity the Actual Brightness is Negative of the Absolute Magnitude