



Discovering Planet “X”

Overview: An activity exploring parallax and then simulating the discovery of Pluto with a Blink Comparator via an online interactive.

Target Grade Level: 3-5

Estimated Duration: 1 class period or about 45 minutes

Learning Goals: Students will be able to...

- relate the blinking of the Planet between pictures to its movement over time.
- describe why Pluto appears to move between the two pictures, whereas the stars do not.
- demonstrate parallax with a hands-on activity.

Standards Addressed:

Benchmarks (AAAS, 1993)

The Physical Setting, 4A: The Universe, 4B: The Earth

National Science Education Standards (NRC, 1996)

Physical Science, Standard B: Position and motion of objects

Earth & Space Science, Standard D: Objects in the sky, Changes in earth and sky

Principles and Standards for School Mathematics (NCTM, 2000)

Geometry Standard: Specify locations and describe spatial relationships using coordinate geometry and other representational systems, Use visualization, spatial reasoning, and geometric modeling to solve problems

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Background:

The search for the planet that would become known as Pluto began in 1906, after calculations appeared to show that the orbit of Uranus was affected by the gravitational pull of a planet lying beyond Neptune. The sought-for object became known as “Planet X”. An advocate of its existence was the astronomer Percival Lowell, who in 1894 had established an observatory (the Lowell Observatory, still in operation) in Flagstaff, AZ, with the most modern equipment available.

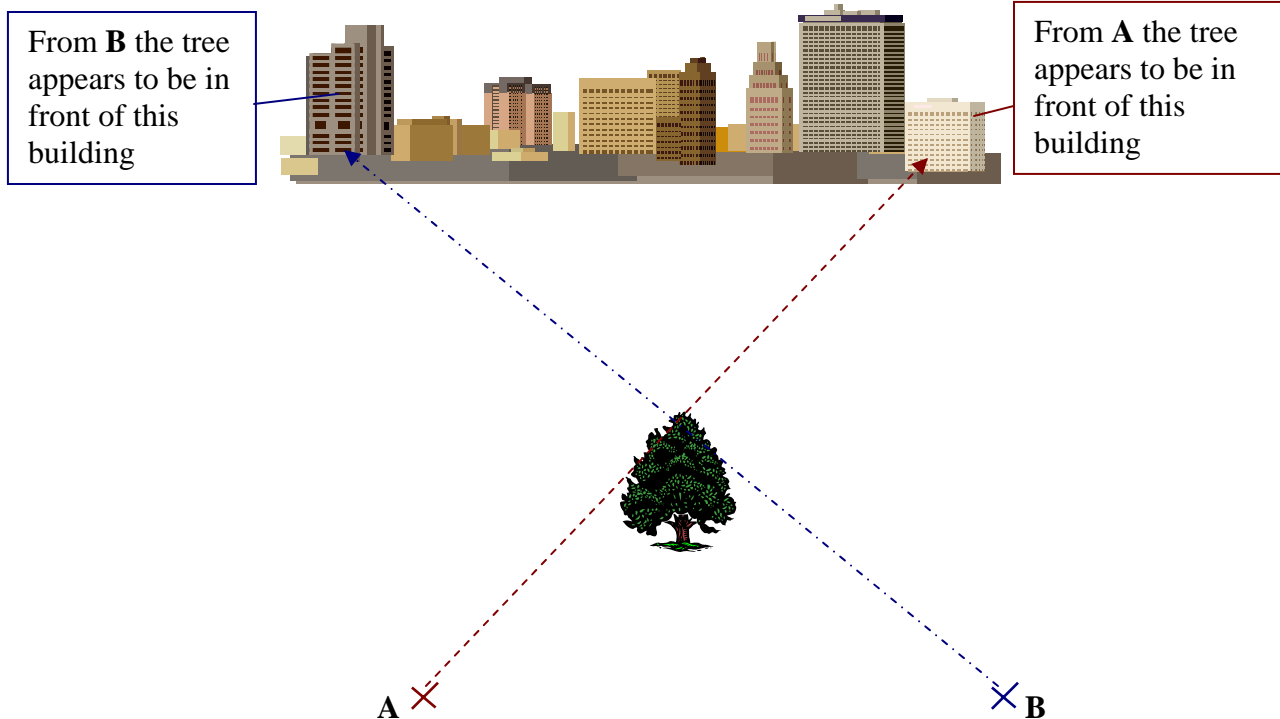
Guided by the predictions of Lowell and others, astronomers at the Observatory began the search for Planet X, a project that continued even after Lowell’s death in 1916. In 1929 a new hire – the young and ambitious Clyde Tombaugh – was assigned to the search. He used a recently purchased photographic telescope that took pictures of small plots of the sky and recorded the images on plates. Pictures were taken of the same region of the sky a few nights apart, and then viewed pairwise in a “blink comparator”. This device switched the operator’s view rapidly back and forth, from one image plate to the other. Objects such as stars, which appear stationary from Earth, also appeared in the comparator to remain in the same place. Nearby objects, such as a planet, would appear to jump back and forth, or “blink”, between two positions in the comparator.

Why does a planet appear to move against a fixed background of stars? Pluto does in fact move in its orbit about the Sun, but our view of Pluto changes mainly because Earth is moving much more rapidly. Earth moves about 1 degree per day in its orbit around the Sun, since there are 360 degrees in a circle and about 365 days in a year. Perhaps you think 1 degree isn’t very far to move, and wonder how this causes Pluto to appear to move against the background stars. Moving one degree in our orbit means the Earth moves a distance of about 2.6 million kilometers (1.6 million miles)! Pluto, meanwhile, moves more slowly, covering only about one sixth the distance that the Earth does in a single day.

Since we move daily in our orbit about the Sun, the telescope’s viewpoint changes from night to night. Even though it is far away, Pluto is tens of thousands of times closer to us than the nearest star. So the stars appear to us to be stationary with respect to one another, but our changing viewpoint (and to a lesser extent, Pluto’s own motion) makes Pluto appear to move against that background.

The technical term for this apparent displacement of an object caused by a change in the viewer’s position is *parallax*. Parallax is easily demonstrated. Extend your arm in front of you and hold a pencil up. Look at the pencil with your right eye closed and then with your left eye closed. As you blink back and forth, shifting your viewpoint from side to side, the pencil will appear to shift position from side to side against the background of more distant objects. While it may not seem that there is a change in your position, your eyes are separated by a distance of a few centimeters. Therefore the viewing position is shifting by the same amount.

Perhaps it is easier to imagine if the viewing position changes due to an observable change in the viewer's location. For example, imagine you are in a park, looking at a city skyline far off in the distance. Notice the apparent shift of a nearby object, such as a tree, with respect to the distant skyline as you change your location from **A** to **B**.



If you were to move further away, straight back from the tree, the angle separating **A** and **B** would get smaller and smaller. If you moved far enough back, the tree would not appear to move at all from side to side against the backdrop as you changed your viewpoint from **A** to **B**. Such is the case with the distant stars. Despite the Earth's motion around the Sun, and therefore the changing location of our telescopes, the stars do not appear to shift a measurable amount (unless one is using very sensitive equipment!).

Tombaugh photographed the night sky, developed pictures, and interpreted the plates over the course of a year. On February 18, 1930, he placed the plates from January 23 and January 29, 1930 in the blink comparator. Bingo!! Tombaugh saw what he thought must be a planet. The images in the accompanying animation were created from the actual images taken on those nights by Tombaugh.

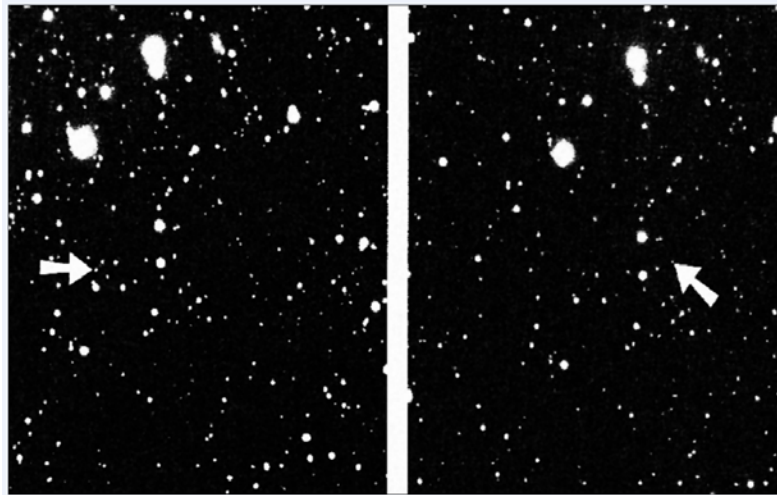


Figure 1. These are portions of the photographic plates taken by Tombaugh. The images are separated by six days, with the left plate from Jan. 23 and the right plate from Jan. 29, 1930. Pluto is indicated by the arrows. (Image courtesy of Lowell Observatory).

Astronomers at Lowell Observatory confirmed Tombaugh's blinking object, observing it for several weeks to be sure before announcing the discovery of Planet X on March 13, 1930. People from all over the world submitted possible names for the new planet. One of these suggestions was from an 11-year old in Oxford, England, who suggested Pluto. In Greek mythology, Pluto is the god of the Underworld, Saturn's third son, and a brother to Jupiter, Neptune, and Juno. According to myth, Pluto could become invisible when he desired. To the staff at Lowell Observatory, this seemed to be a fitting name.

This was surely an amazing discovery. Perhaps more amazing is that the calculations predicting the location of the unknown planet were incorrect. They hinged on a careful analysis of the effects of the known planets on the orbit of Uranus. At the time, the masses of these planets—especially the mass of Neptune—were not known with sufficient accuracy. Therefore, Pluto's discovery was based on coincidence and great dedication, rather than mathematical precision.

Materials:

- 2 yard or meter sticks
- 2 copies of Pluto picture
- Copies of Student Data Sheet (classroom set)
- Rulers (classroom set)
- 1 set of Stars pictures (Note: if you have a color copier you can print out the “color” version. Otherwise, print out the black and white version and color them in using markers).
- markers/crayons/colored pencils (if necessary)
- scissors to cut out Star pictures (if desired)
- tape/material to affix stars to board and Pluto picture to yard/meter stick
- computers with internet access (enough for at most 3 students per computer, or students can rotate through)
- masking tape to mark positions on the ground

Procedure:

Generally speaking...

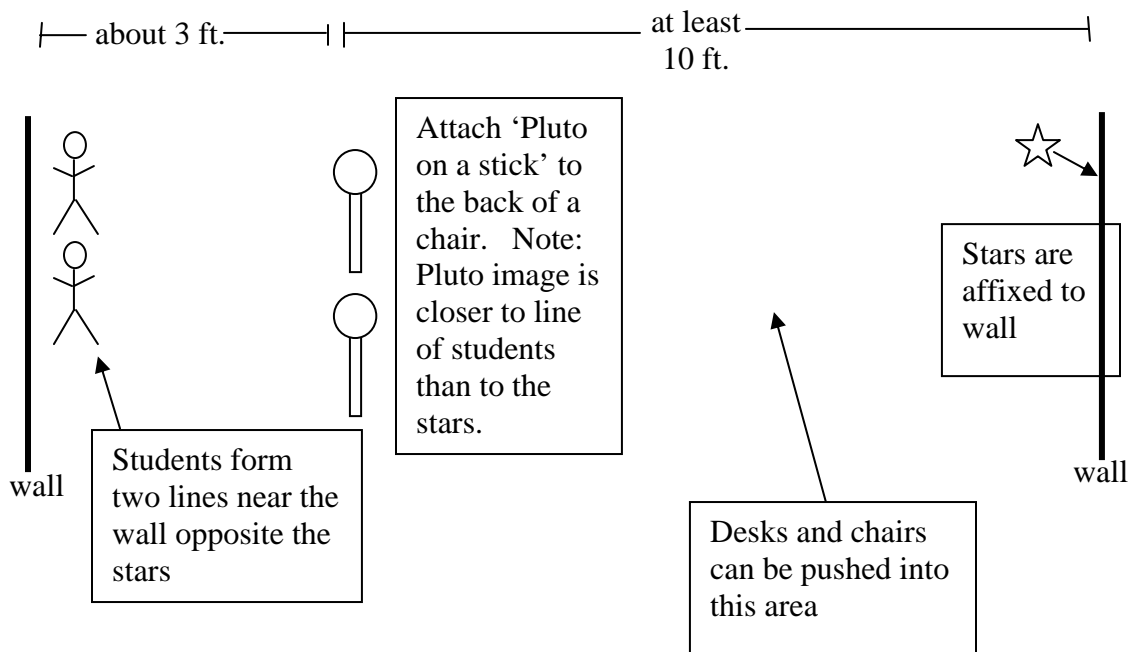
What the teacher will do: Begin with the simple demonstration of parallax in which students extend their arms and hold up a pencil, closing one eye and then the other. Be sure to explain that, while the students don’t physically move, in fact their observing position is changing by the distance that separates their eyes. Draw a diagram on the board similar to the example in the Background section above and define parallax. Color Star pictures and affix them to the wall/board at front or back of room. Help students with the parallax activity. Lead a discussion of the discovery of Pluto using the Blink Comparator. Oversee students using the online interactive of the Blink Comparator.

What the students will do: Demonstrate parallax using extended arm and pencil and a distant background object. Observe parallax with Pluto attached to a meter stick in front of a background of stars affixed to the wall. They observe Pluto and the background stars from one position and then walk several steps to one side and observe again. They record their observations on the Student Data Sheet. If computers are available in the classroom, they can proceed to a computer to complete the online interactive Blink Comparator. If not, students can move to the sides of the room and quietly answer questions on the Student Data Sheet. At some point they ‘discover’ Pluto using the online interactive—the Blink Comparator. Again, students record observations in the Student Data Sheet.

Advance Preparation

1. Print and cut out copies as follows:
 - a. 2 copies of the Pluto picture, cut around the edge

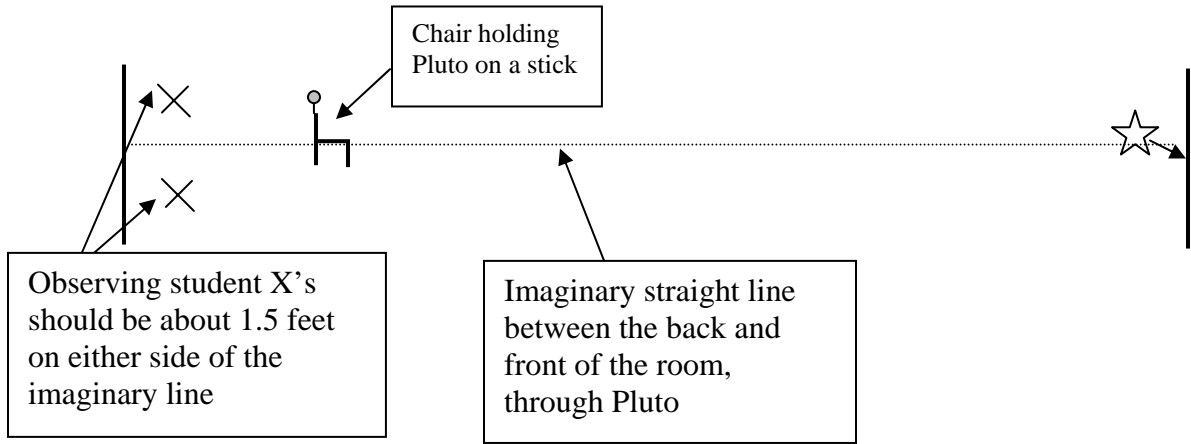
- b. 1 set of Star pictures, color stars as indicated on page, cut around edges of stars (if desired)
 - c. classroom set of Student Data Sheets (1 per student)
 - 2. Locate 2 yard/meter sticks
 - a. Affix Pluto pictures to the ends of the meter sticks (a.k.a. Pluto on a stick)
 - b. Attach other end of meter stick to the back of a chair so Pluto is at about eye-level for most students
 - 3. Bookmark the online interactive website on computers:
<http://www.patchyvalleyfog.com/blinkcomparator/final/blinkComparator.html>
 [Note: exact URL may change, but forwarding information will be provided at this URL if a change occurs.]
 - 4. Affix stars to the board/wall. Stars should be arranged in a horizontal line in the following order: red, orange, yellow, green, blue, purple. They should be evenly distributed across the wall, using as much space as possible. In other words, place the red and purple stars as far apart as possible and then place the other stars in between so they are evenly spaced. You will likely be arranging the room after students have arrived and you have introduced the topic of parallax, but keep in mind that the room should be arranged such that the desks could be pushed against the board where the stars are, which will free up room for the chairs holding the 'Pluto on a stick' and will also allow enough space for the rest of the class to form two lines along the opposite wall (with the stars in the 'distant' background). This diagram should help with the relative positions:



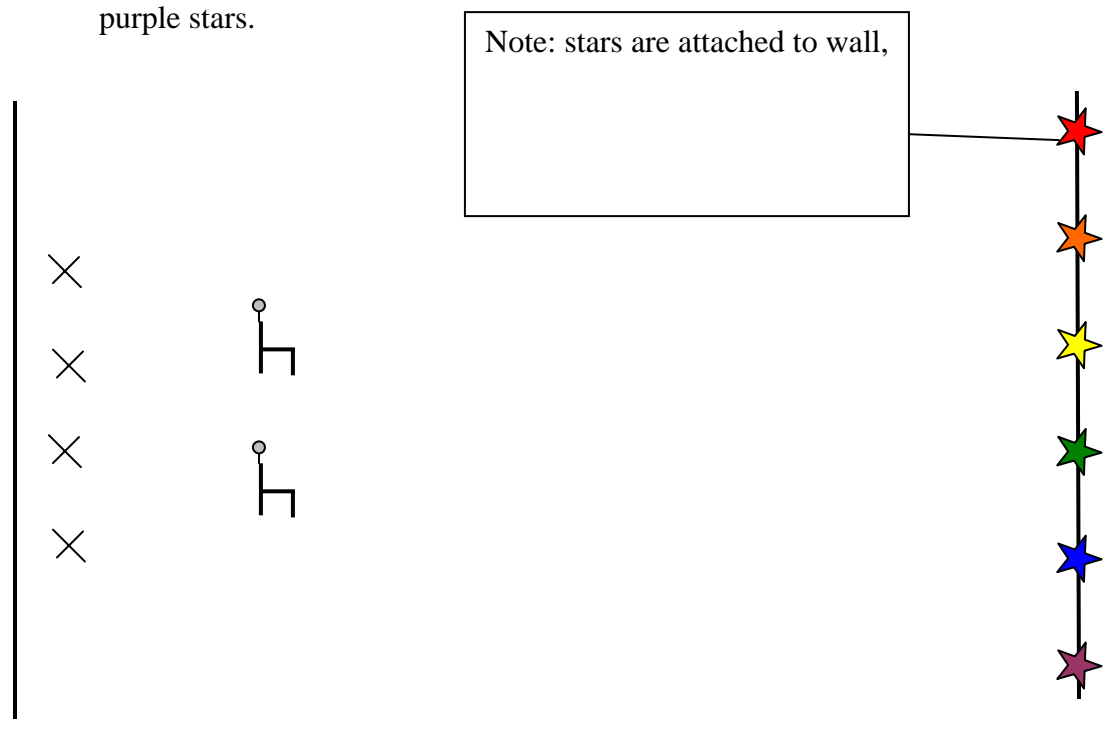
- 5. Place X's on the ground where the observing students should be.

The following instructions apply to each group:

- a. Place the chair with Pluto on a stick about 3 feet in front of the observing students at the back of the room. Pluto should be facing the observing students. Therefore the stars will be behind Pluto from the perspective of the observing students.
- b. Place two "X"s on the floor where the observing student should stand as follows in this bird's eye view:



- c. The two groups of students should be close to the center of the room (and therefore close to each other). That is, they should be positioned opposite the yellow or green stars rather than off to one side and opposite the red or purple stars.



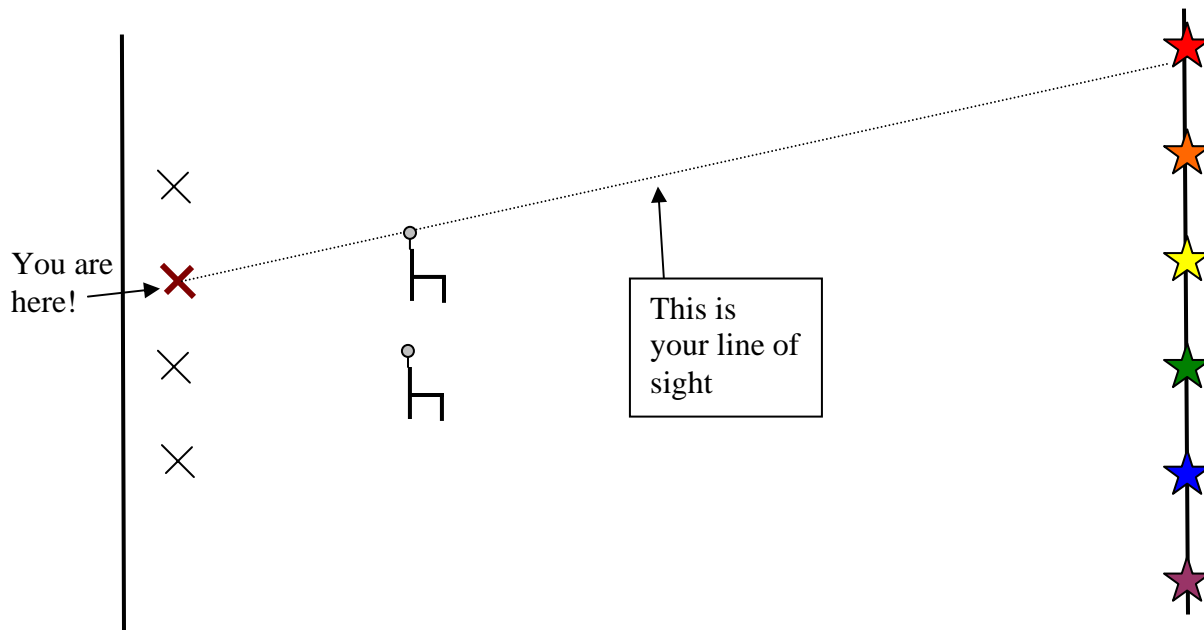
NOTES:

- Stars are arranged as follows:
 - Forming a horizontal line: red, then orange, then yellow, green, blue, purple.
 - They should be evenly distributed across the entire wall if possible. Maximize the distance between the two end stars.
- Pluto images that are attached to the meter stick and then attached to a chair should be oriented such that they face the students lined up at the back of the room (observing students).
- Pluto images should be no less than about 10 feet from the stars on the wall. Also, Pluto images should be closer to the students than the stars; try to arrange the room so Pluto images (on sticks) can be about 3 feet from the observing students.
- These locations do not have to be exact, but the room should be arranged similar to the preceding diagram. It is important that Pluto and the observing student locations are as far from the stars as possible.
- Stars are colored so students can easily distinguish the apparent shift in Pluto's position as they move from one 'x' to the other. Also, the student data sheet has a similar color coding so they can easily record the observed apparent shift.
- If students are having problems with Pluto shifting beyond the red or purple stars you have four options:
 - You can spread the stars out so they cover a greater total width of the wall (i.e., place one almost near the corner and the other near the far corner so they maximize the total width of the wall).
 - You can decrease the parallax angle by moving the students further from the wall of stars.
 - You can create one observing group instead of two, so that the group is exactly in the middle of the row of stars (i.e. in front of the yellow and green stars, rather than off to one side in front of the red or purple stars).
 - You can move the Pluto on a stick closer to the background of stars.

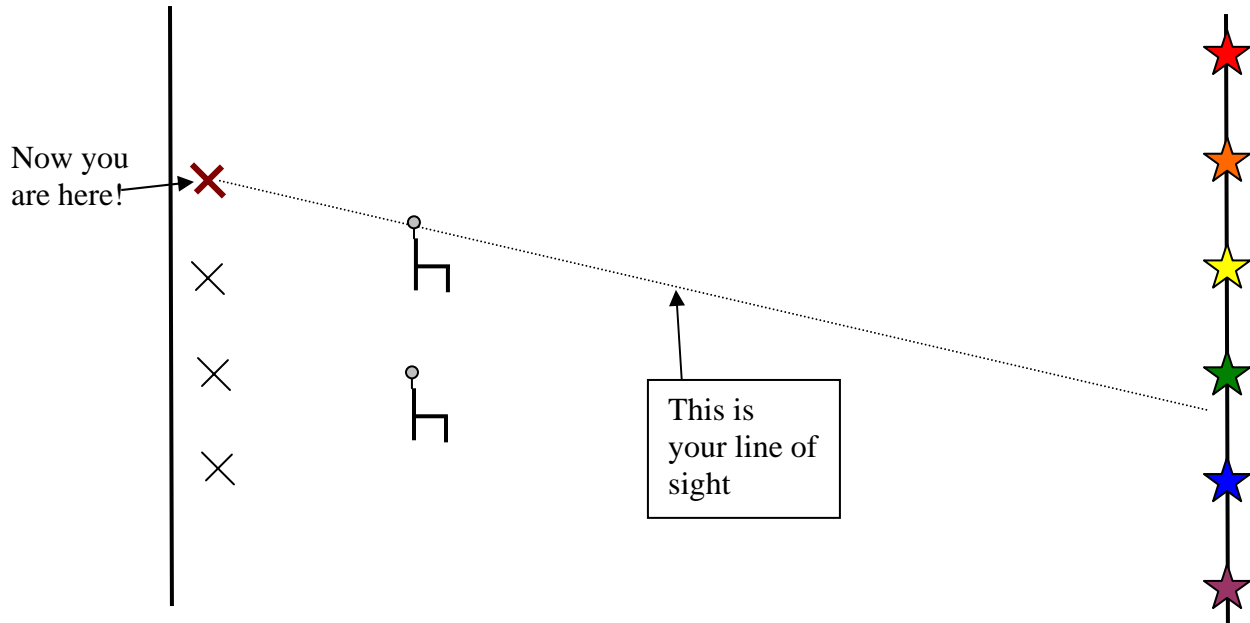
In-class Procedure

1. Introduce the concept of parallax. Explain that this causes stars, which are very far away, to appear stationary relative to one another, whereas objects that are closer, such as planets, appear to move as Earth's position changes. Be sure students understand that the planets appear to move against the background of stars due to the orbit of the Earth around the Sun and also, in varying degrees, due to their own orbits around the Sun. (Planets closest to the Sun move a greater distance each day than do planets far away from the Sun. Therefore, Pluto will move in its own orbit very little compared to how far the Earth has moved in its orbit over the same period of time. See the Background section for more details.)

2. Demonstrate parallax, with students following along, by extending your arm and holding a pencil vertically. Ask students to close one eye, and then the other while looking at the pencil. Repeat this several times. Does the pencil appear to move with respect to background objects, such as items on the wall (or stars affixed to the board)? Make certain students understand that the pencil appears to shift because they are observing it from two different positions. Since their eyes are separated by a few centimeters, by closing one eye and then the other the location from which they are observing the pencil has changed by a few centimeters! Is the pencil really moving? Make note that parallax is the *apparent* shift from side to side against a background of more distant objects.
3. Explain to students that they will be observing parallax while you are distributing Student Data Sheets. Ask students to help move desks toward the stars on the board/wall. Place the two chairs holding the two Pluto (on sticks) in their appropriate locations and have students forms two groups at the back of the room (opposite the stars).
4. Demonstrate for the students the proper observing technique. Stand on one of the X's and look just over the top of the Pluto. Look with both eyes open! Which star is behind Pluto from this point? Students would record their observation on the Student Data Sheet. Here is a diagram (again, modified bird's eye view):



Notice from this location Pluto appears to be in front of the RED star. Now move to the other location!



Notice that as your location changed so did the apparent position of Pluto! Now Pluto appears to be in front of the area between the GREEN and BLUE stars! Again, students would record this in their Student Data Sheets.

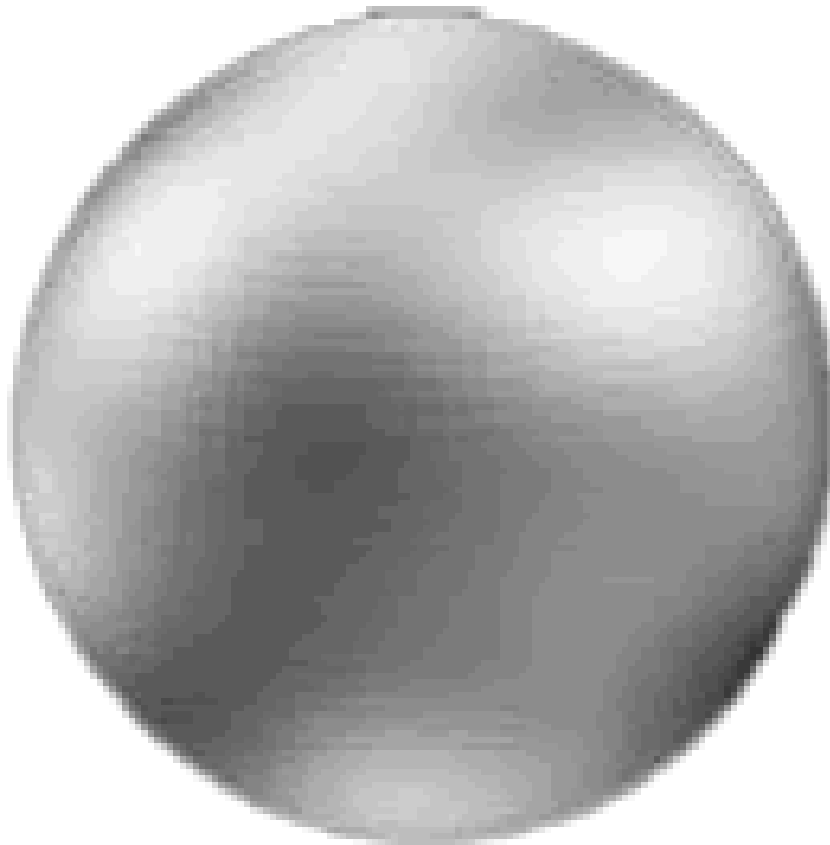
5. After students have completed the parallax activity, they can either move on to the Blink Comparator online interactive or move to the side of the classroom to complete their Student Data Sheets. There are questions on the Student Data Sheets that require the Blink Comparator interactive, so if classroom access to computers is limited you may need to proceed to a computer lab to complete the lesson. Note: students should try to discover Pluto in the Blink Comparator interactive in the existing scale, but if they are having trouble they can zoom in on different parts of the image until they find the blinking planet.

Pluto Picture

Directions:

- Cut around edge of this image of Pluto.
- Tape the top of the image to the top of the meter stick.
- Also secure the bottom of the image to the meter stick.

Note: Image was captured by the Hubble Space Telescope!





Name: _____

Discovering Planet "X"

Parallax: the apparent displacement of an object caused by a change in the viewer's position. In other words, when you extend your arm out and hold a pencil vertically, it appears to shift back and forth when you close one eye and then the other.

Using the same principal, but in the scale of the stars and the planets in the sky, parallax was used in the discovery of a planet.

You are going to explore **how** it was used and **which planet** was discovered!

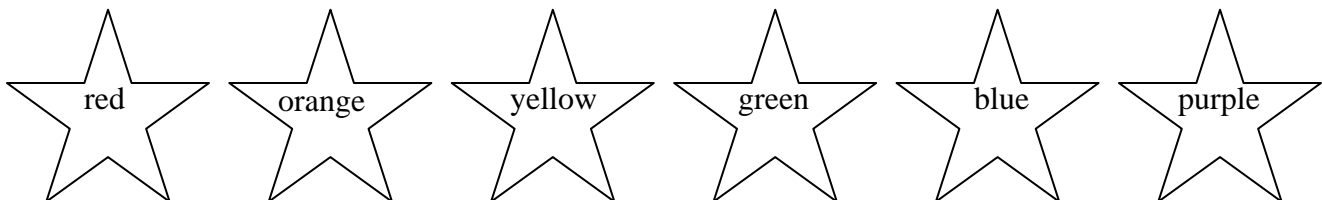


Part 1: Observing Parallax

Directions: Stand on an 'X' and look just over the top of Pluto. This time you are using both eyes at once! Which star is Pluto in front of...or almost in front of?

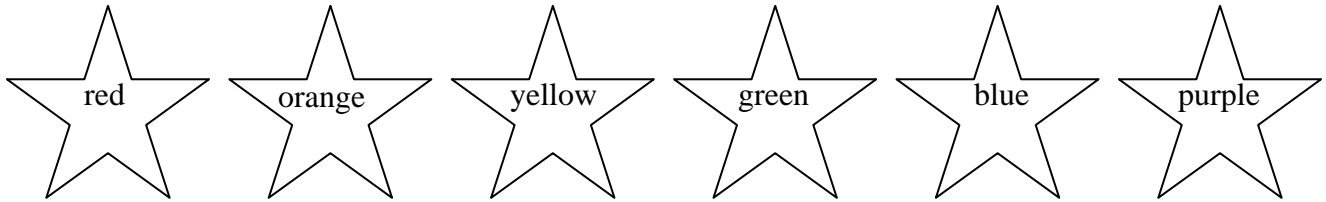
1. You are to observe Pluto against a background of stars. Which color of star is Pluto in front of? Draw Pluto as it appears (covering or partially covering a star) from the first 'X' on which you were standing.

POSITION 1



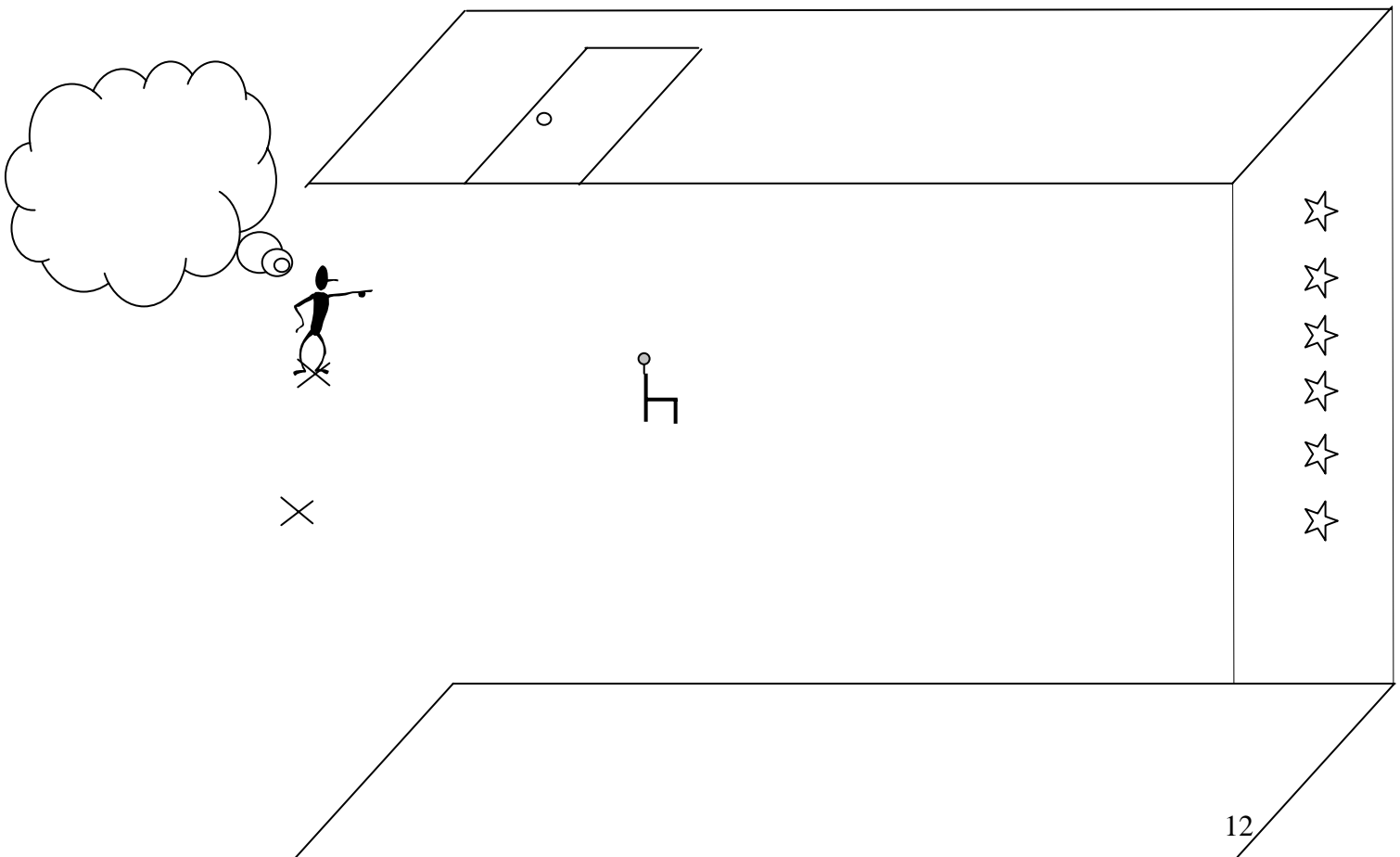
Now draw Pluto as it appears (covering or partially covering a star) from the second 'X' on which you were standing.

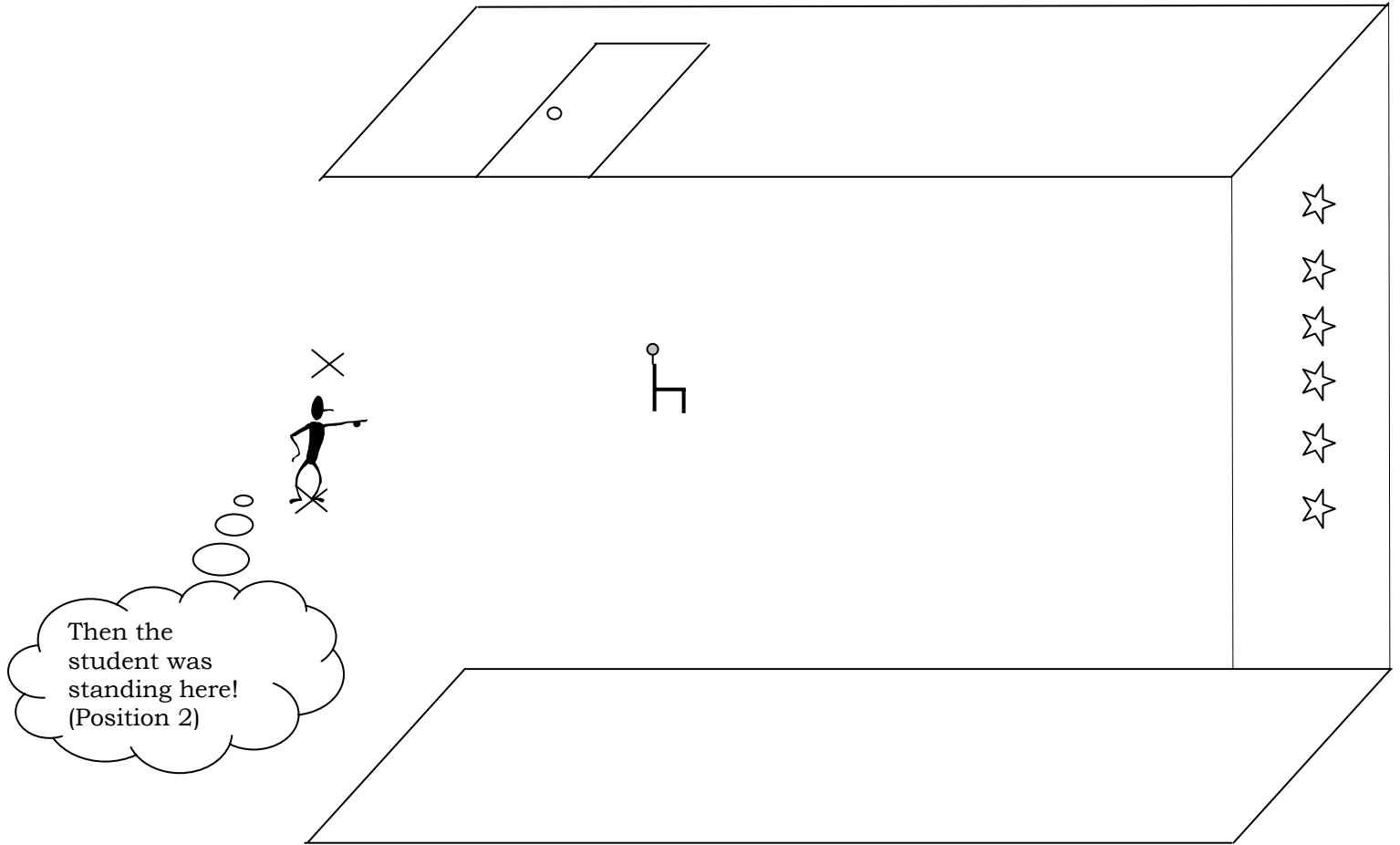
POSITION 2



2. Looking at the two diagrams in Question 1, is Pluto covering (or nearly covering!) the same color star from Position 1 and from Position 2?

3. A student was having trouble understanding why Pluto seemed to move compared to the stars behind it, even though Pluto and the stars remained in the same spot. He decided he needed to draw a small scale replica of the classroom to help him understand what was moving and why. Here is his diagram of the classroom from the perspective of a bird flying near the ceiling and looking down:





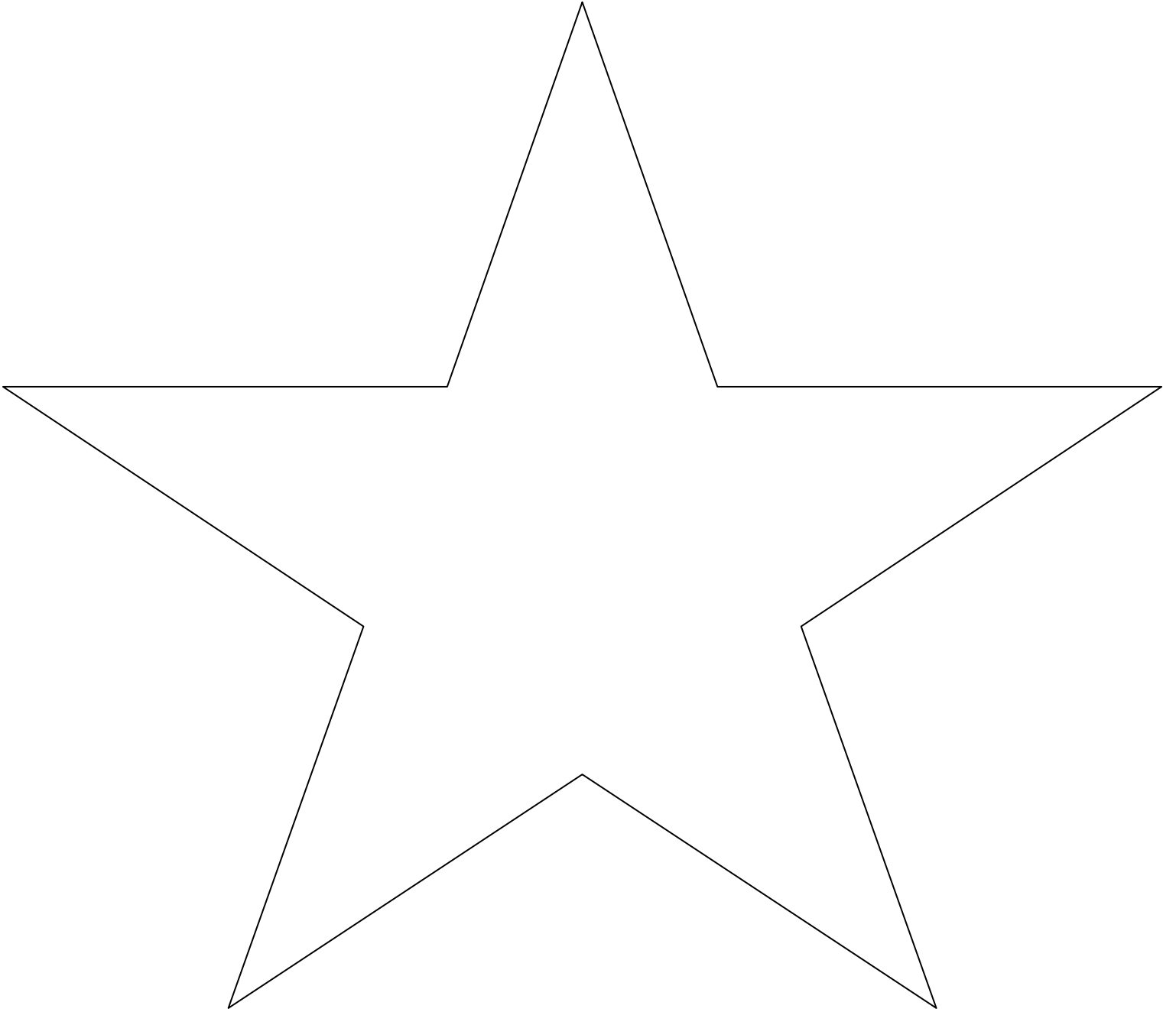
In both of these diagrams, using a ruler, draw a straight line starting at the eyes of the student, going through Pluto (attached to the chair), and ending at a star on the wall (or between two stars on the wall).

What moved in these two diagrams? Was it Pluto, the stars, and/or the student?

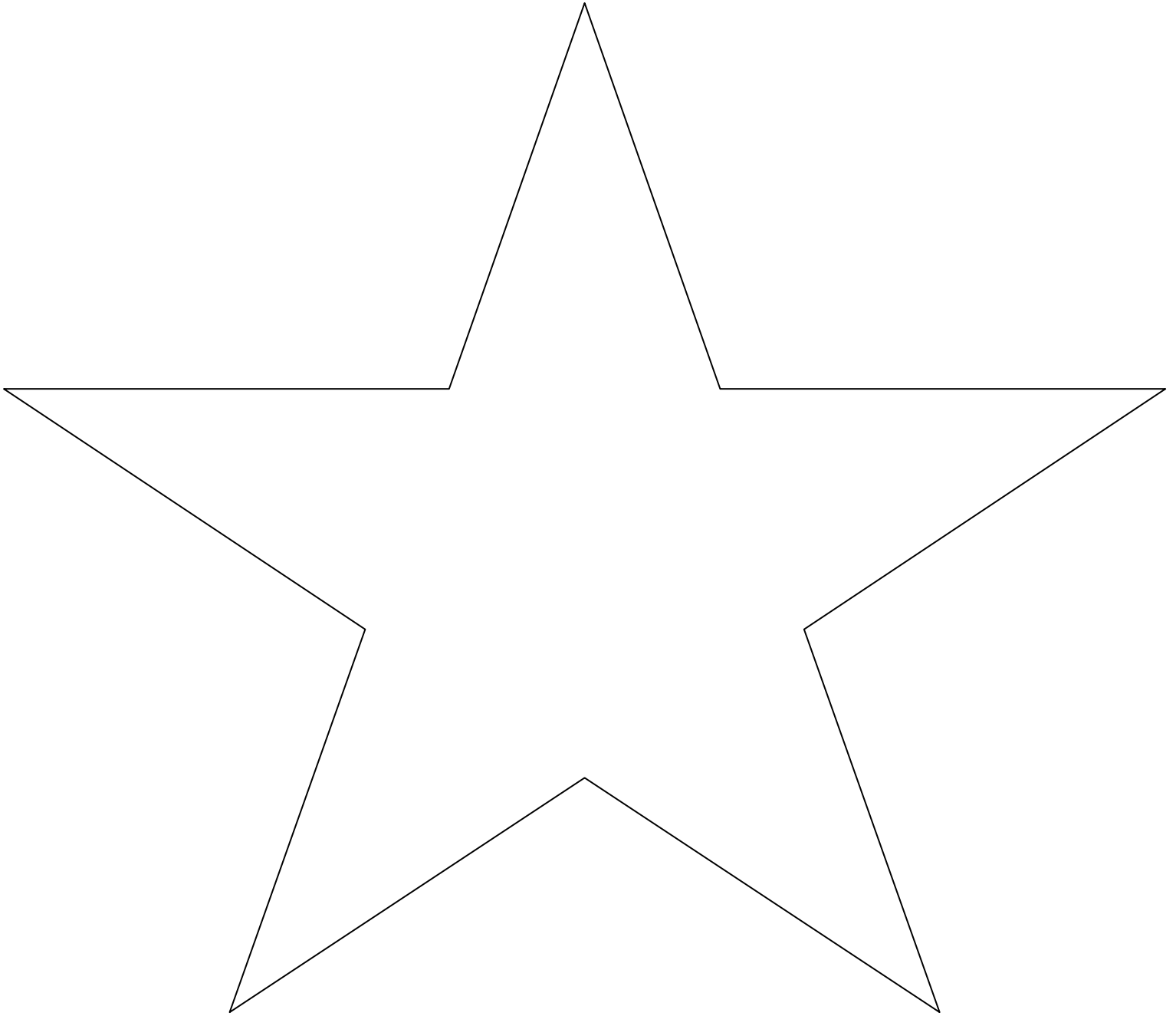
What remained in the same place in these two diagrams? Was it Pluto, the stars, and/or the student?

4. In all of the diagrams above, why does Pluto appear to be in front of different stars in Position 1 and Position 2?

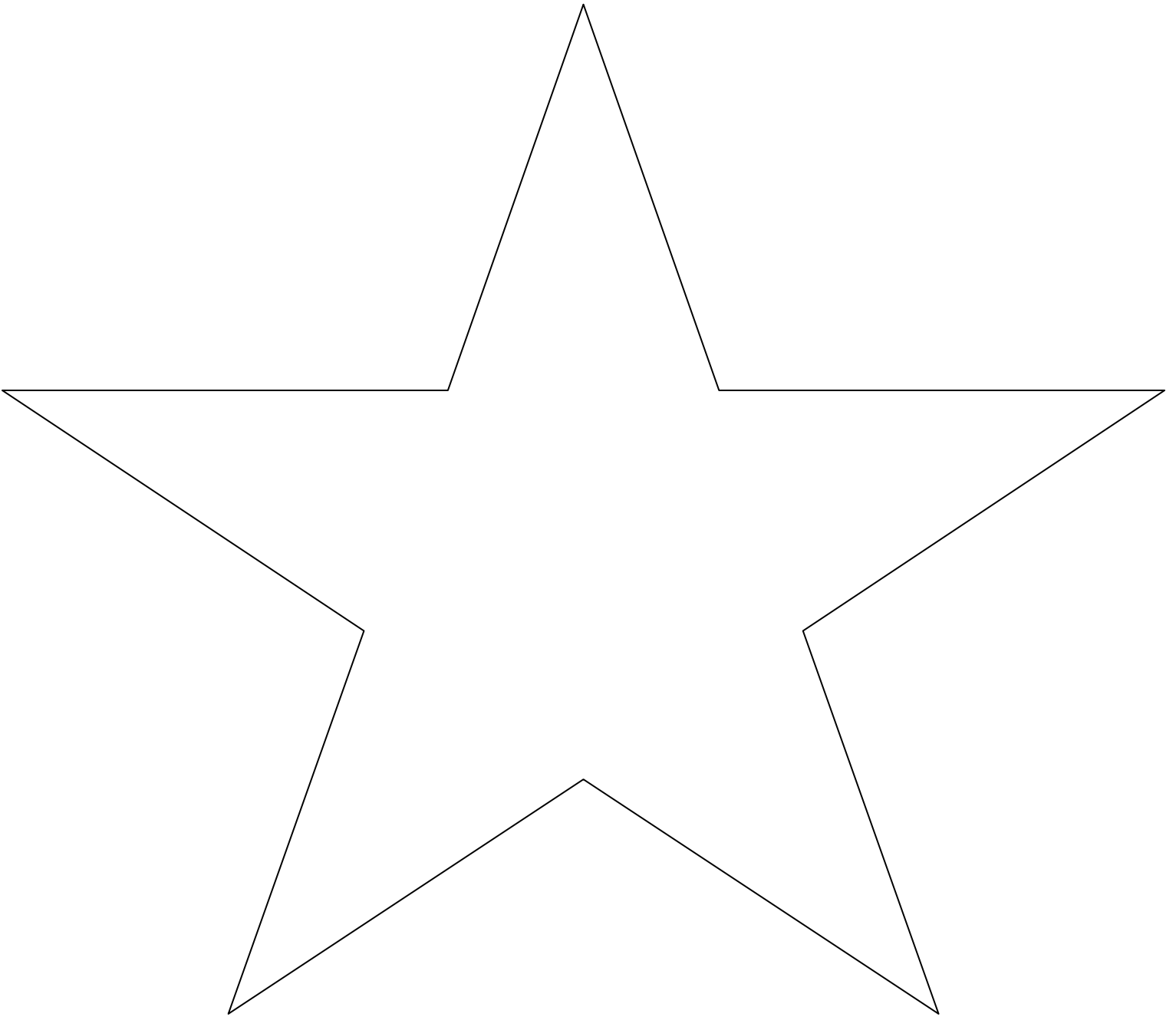
RED



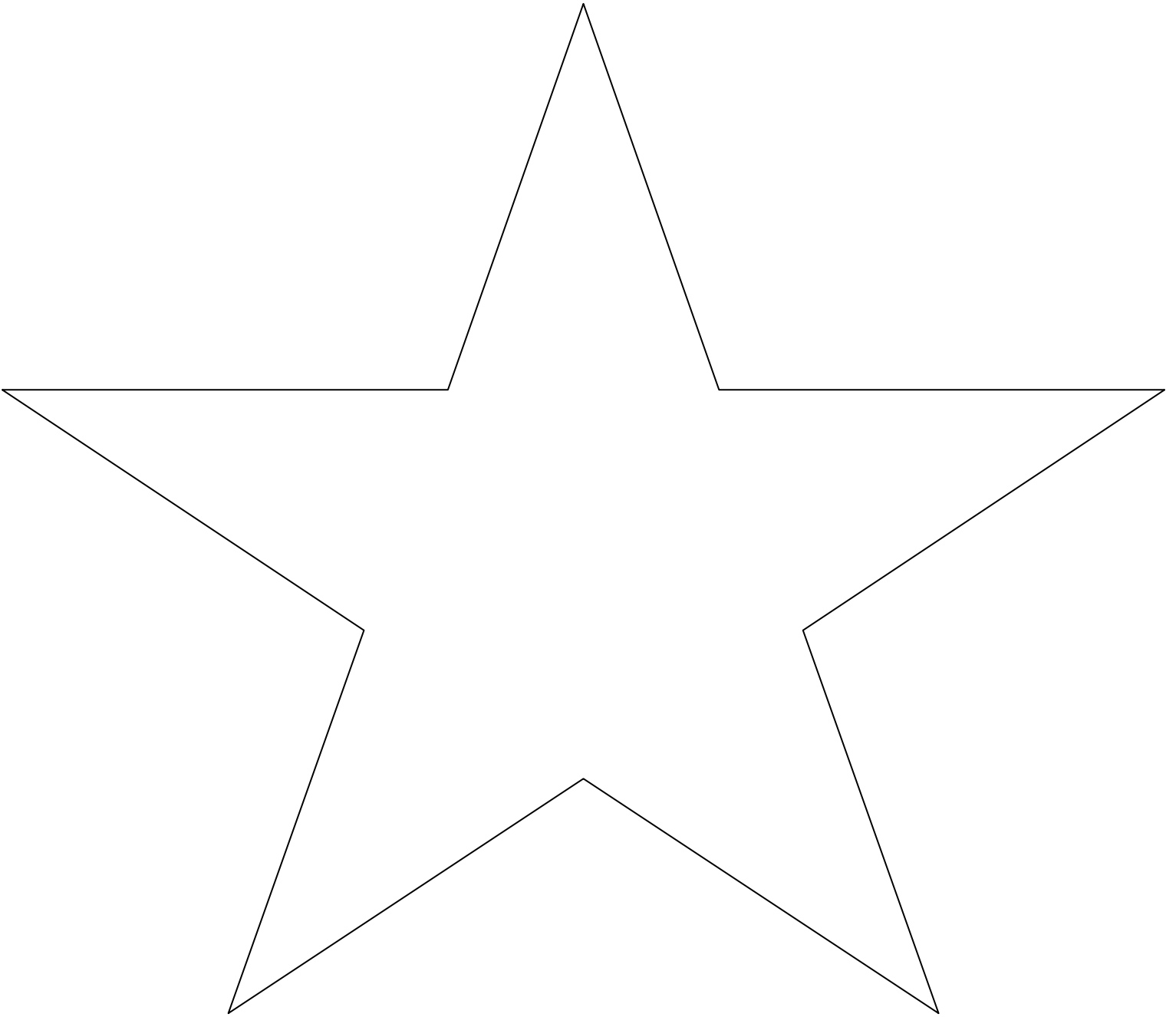
ORANGE



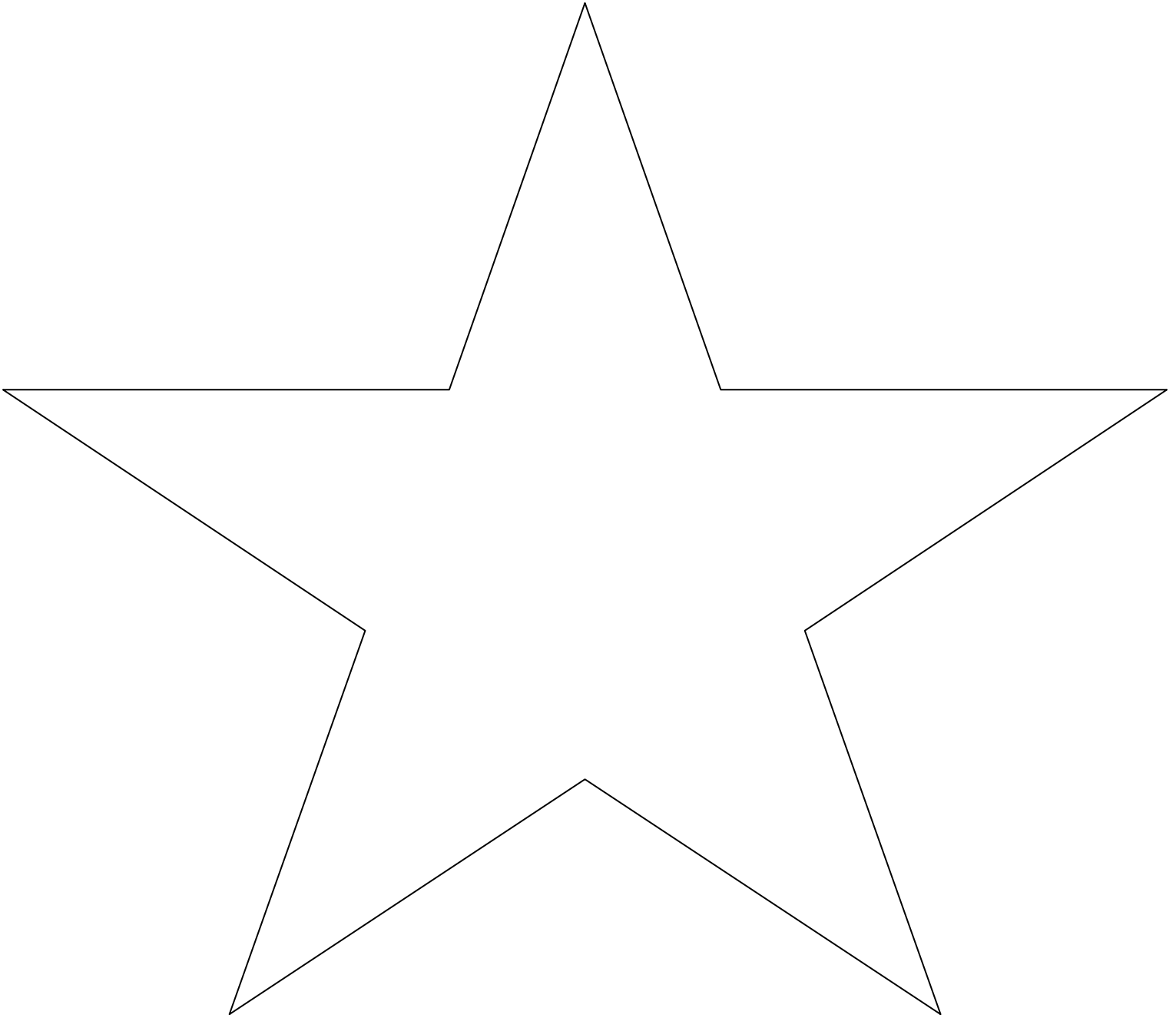
YELLOW



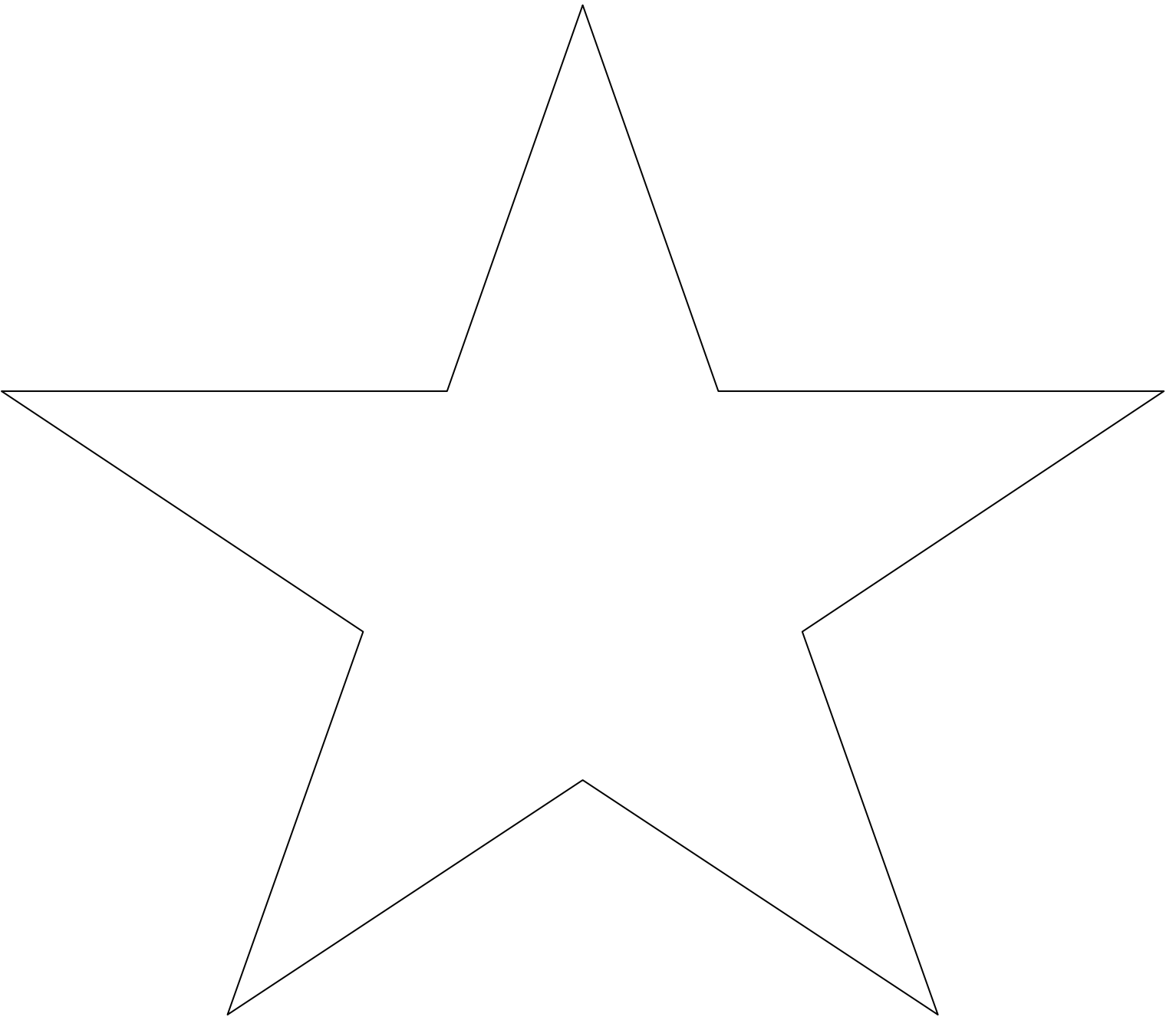
GREEN



BLUE



PURPLE



RED



ORANGE



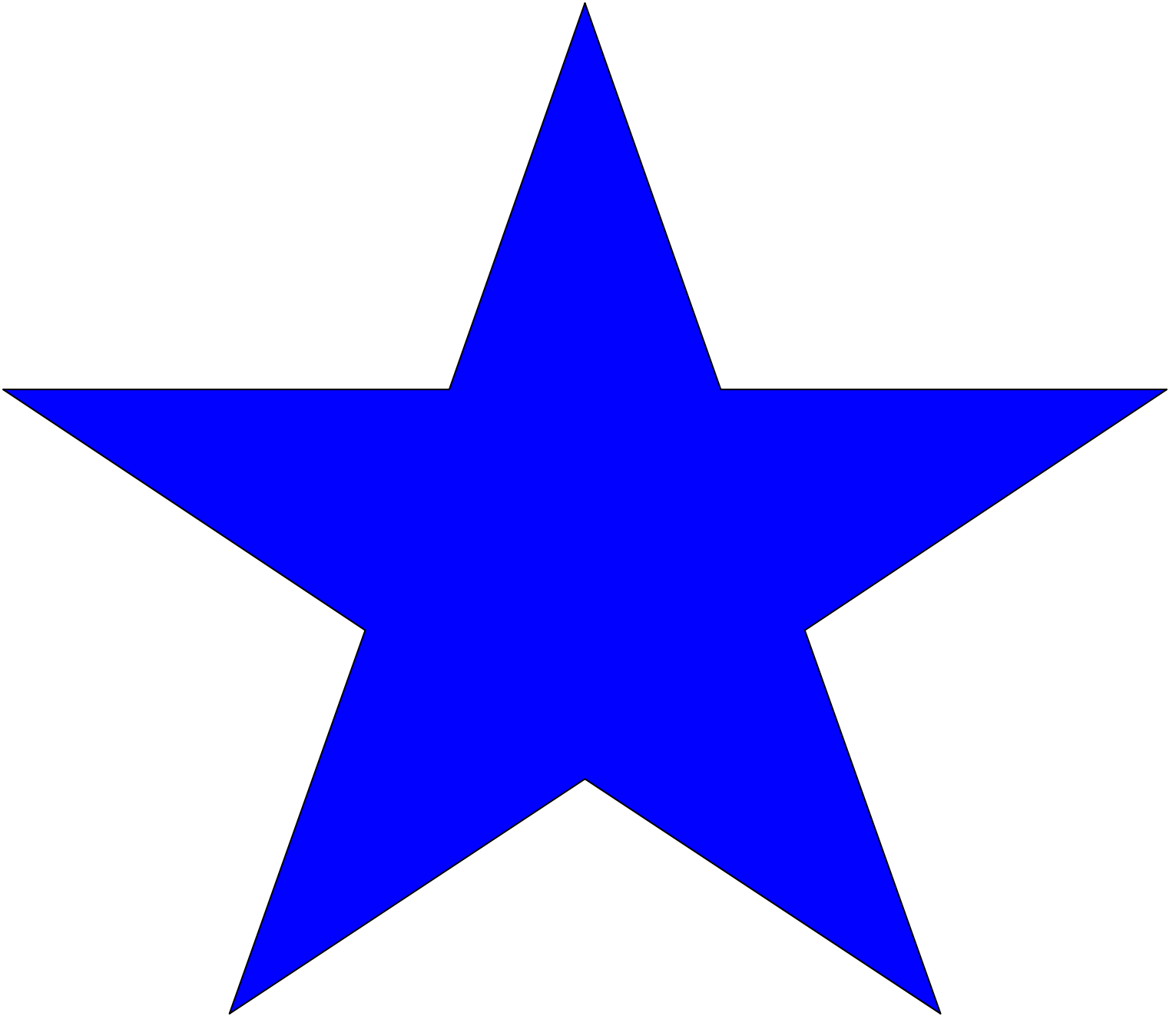
YELLOW



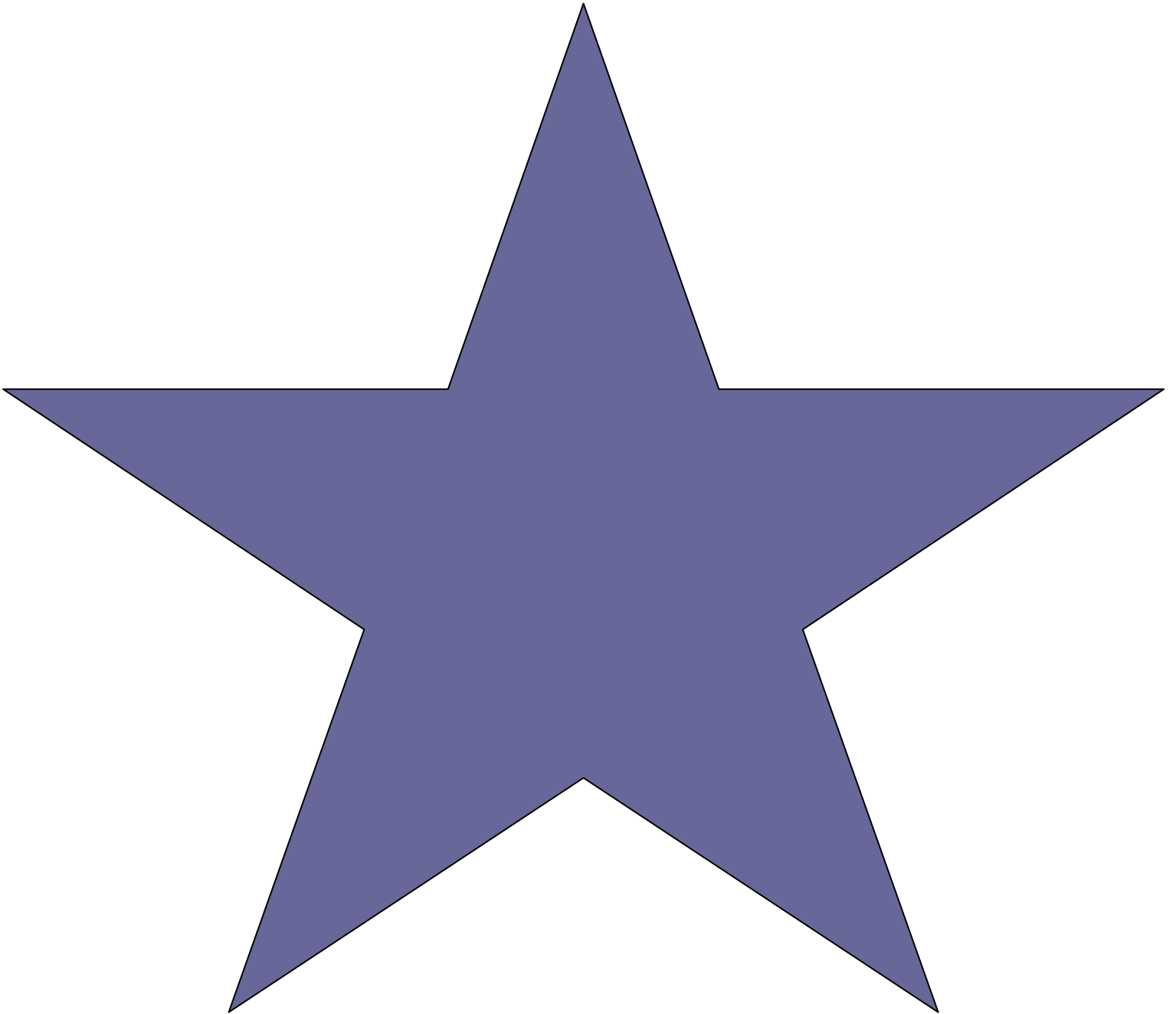
GREEN



BLUE



PURPLE



Extensions and Adaptations:

- You may wish to also write the colors of the stars within them or above them in case any of your students are color-blind.
- To incorporate reading, try these books:
 - Beyond Pluto, by John Davies
 - A Look at Pluto, by Salvatore Tocci
 - Postcards from Pluto, by Loreen Leedy
- For visually impaired students: assist them by holding an additional meter stick up along what would be the line of sight through Pluto from both locations. The student can then trace the path with their fingers along the meter stick from one line of sight and then the other.
- Here are a few internet resources that use animations to illustrate parallax:
 - <http://psych.hanover.edu/Krantz/MotionParallax/MotionParallax.html>
 - <http://instruct1.cit.cornell.edu/courses/astro101/java/parallax/parallax.html>

Ideas for grades 6-8:

- Have students observe Pluto from the distance described above, and then ask them to step back and proceed from this second location. Ask them to step back again and observe the parallax from a third distance, recording their observations. What happens as they move further from the stars and from Pluto? Can they extrapolate to what would happen if they were very far away?
- Quantify the data by measuring the distances between the observing location(s), Pluto, and the stars. Also ask them to quantify the distance between the stars so they can graph their data. Graph the distance from Pluto versus the distance between stars. Is there a pattern?
- Parallax can also be used by astronomers to determine the distance to far-away objects using some basic trigonometry and the small angle formula. Here are some resources if you wish to explore this topic further:
 - <http://www.noao.edu/outreach/nop/nophigh/steve9.html>
 - http://helios.astro.lsa.umich.edu/Course/Labs/parallax/px_intro.html
 - <http://ofcn.org/cyber.serv/academy/ace/sci/cecsci/cecsci088.html>
 - <http://www.phy6.org/stargaze/Lparalax.htm>

Standards Addressed:

National Science Education Standards (NRC, 1996)

Content Standards: K-4

Physical Science, CONTENT STANDARD B:

- Position and motion of objects

Earth and Space Science, CONTENT STANDARD D:

- Objects in the sky
- Changes in earth and sky

Benchmarks (AAAS, 1993)

Chapter 4. The Physical Setting

4A: The Universe

Grades 3 through 5

- The earth is one of several planets that orbit the sun, and the moon orbits around the earth.

4B: The Earth

Grades 3 through 5

- Like all planets and stars, the earth is approximately spherical in shape. The rotation of the earth on its axis every 24 hours produces the night-and-day cycle. To people on earth, this turning of the planet makes it seem as though the sun, moon, planets, and stars are orbiting the earth once a day.

Principles and Standards for School Mathematics (NCTM, 2000)

Geometry Standard

Grades 3 through 5

- Specify locations and describe spatial relationships using coordinate geometry and other representational systems
- Use visualization, spatial reasoning, and geometric modeling to solve problems