beetles
Science and Teaching for Field Instructors

Student Activity Guide

How Big and How Far

The sizes and distances of things in space are awe-inspiring, but hard to fathom. Things that are unimaginably massive can look tiny to us from Earth, and things that appear very large to us may be among the smallest in the sky. Although students can learn names and features of objects in the night sky, scale is one of the biggest stumbling blocks they need to overcome to actually understand what they're looking at and to understand astronomy in general. But students have lots of daily life experience with bigger things looking smaller because of relative distance (and visa versa). How Big & How Far takes this experience of observing relative sizes and distances here on Earth and challenges students to apply it to night sky objects.

In this Night Sky Activity, the group measures how many fists tall a volunteer is. Then, students scatter and measure again, this time with outstretched fists and with much smaller and varied measurements. Students discuss how the distance you are from an object can make it appear larger or smaller. This activity sets them up to apply this idea afterwards as they observe night sky objects and attempt to better understand the actual sizes of the objects they see.

Students will...

- **Learn that some objects in the night sky are small and some are huge.**
- **Understand that huge objects in the night sky may appear small if they are very far away.**
- **Recognize that relatively small objects in the night sky that are closer may appear larger than other objects.**

Grade Level:
Grades 3-8. Adaptable for younger or older students.

Timing:
10-15 minutes

Related Activities:
Night Hike Scavenger Hunt, Double Take, Moon Balls

Materials:
None needed

Tips:
To ensure a successful experience, review the teaching tips found on page 2 and throughout this guide.

Setting:
Any setting in which students can safely observe nature and organisms.

NEXT GENERATION SCIENCE STANDARDS

FEATURED PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
not applicable	Scale, Proportion, and Quantity	The Universe and Its Stars

For additional information about NGSS, go to page 8 of this guide.

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

How Big and How Far

ACTIVITY OVERVIEW

How Big and How Far	Learning Cycle Stages	Estimated Time
Measuring A Student's Height Together	Invitation, Exploration	5 mins.
Measuring A Student's Height Independently	Exploration, Concept Invention	3 mins.
Discussing Why Measurements Differ	Concept Invention	5 mins.
TOTAL		~15 minutes

TEACHING TIPS

Field Card. On page 10 of this guide is a pocket-sized version of this lesson that you can use in the field.

Read the Instructor Support Section. Beginning on page 6, you'll find more information about pedagogy, student misconceptions, science background, and standards.

Connections to Other Night Sky Activities. This activity is meant as an introduction just before a night sky viewing experience. Make sure it's followed by an opportunity to apply the ideas to the actual night sky (Application phase of the Learning Cycle), and to think back on how they applied the idea to the night sky (Reflection phase of the Learning Cycle). It's ideal to do immediately before the introduction of *Night Hike Scavenger Hunt*. Introducing students to the idea of relative size helps them better understand the scale of the size and distance of objects they observe during the scavenger hunt.

This should be a quick introductory activity, so keep it moving!

TEACHING NOTES

Doing or not doing the silent challenge. If asking your students to do this challenge without talking doesn't seem useful to you, then go ahead and let them talk. We've found that the silent element adds to the fun and to the teambuilding. To add even more to team-building, ask the students afterwards to debrief the experience from a teamwork perspective. E.g., "How did we work together as a team? How did we communicate? Did anyone feel left out or frustrated by how it went? How could we do a group challenge like this better in the future?

Measuring a Student's Height Together

1. **Gather students in lighted area.** Gather students in an area with light, either outdoors before it gets dark, outdoors in an area with artificial light, or indoors with lights. If such spaces aren't available, you might let students use flashlights, or have adult chaperones provide light for the activity with flashlights.
2. **Explain that when they'll be looking at objects in the night sky, it can be hard to tell size and distance.** Tell students they'll soon be looking at objects in the night sky. Explain that when you look at things in the sky, it can be hard to tell how big they are or how far away they are.
3. **Explain that this is a quick activity to help think about size and distance.**
4. **Ask a volunteer to stand in the center of a seated circle.** Seat students in a circle, with a volunteer standing in the center. The shorter the volunteer, the easier it is to measure them, but try not to choose a child who might be sensitive about their height.
5. **Ask the group to begin silently collaborating to measure the student's height with stacked fists.** Tell students their challenge will be to work together to measure how many fists high the volunteer is. Get another student to help you model stacking fists to measure height, but point out that a lot more than 4 fists will be needed. Explain that they'll do it with no talking, so they'll need to communicate non-verbally. Tell them to begin.
6. **At some point, you may need to say (or communicate non-verbally), that more fists are needed, and that some of those who only have one fist in will need to put in two.** If all the fists in your group aren't enough, (which might happen if you're measuring a taller student), you'll need to mark how high the stack of fists reached, (for example, the bottom of their collar), have the group stand and make another stack of fists to measure the rest, then add up the fists from both stacks.
7. **Ask student(s) to count & announce the student's height in fists.** Ask one or more students to count and announce how many fists tall the volunteer is. Remember this number.

Measuring the Student's Height Independently

1. **Ask the student who was measured to stay put.** Make sure the student who's being measured stays standing in the same spot during the next part.
2. **Immediately tell the rest of the students to spread out around the area and each measure the fist height of the volunteer from where they stand, with arm outstretched and one eye closed.** Keep their spreading out within reason. With some groups and settings you may need to state clear boundaries. Show students how to measure how many fists tall the student is from where they are with their arm fully outstretched. Tell students it's easier to do this with one eye closed.

3. **With students still standing where they measured, tell them to hold up the number of fingers that matches how many fists tall they measured the student's height from where they're now standing.** (Typically, you'll get a variety of measurements within a range, e.g. between 1 & 6 fists)

Discussing Why Measurements Differ

1. **Ask students to look around and think about the differences in measurements, from before, and from each other.** Don't start discussion yet, but get students ready for it by pointing out the discrepancy between measurements. E.g. "Davon, we just measured Eduardo at 23 fists tall, but now you're measuring him at 3 fists tall? Whaaaat? Did he suddenly shrink? Sariah, you're measuring him at 1 fist tall, but Christian is measuring him at 3 fists tall. How could different people get such different measurements?"
2. **Tell students to look at the fingers held up by different people in the room, and look for a pattern.** Ask if they notice any patterns. If they're confused by what's meant by a pattern, ask if they notice similarities in measurements of students who are closer vs. farther. The important pattern is that students who are closer will tend to have higher numbers of fists in their measurements, and students who are farther will have fewer. Ask:
   - ▶ *Do you notice any patterns in how many fingers people are holding up in different areas? What do you notice about the measurements by people who are closer to [XX], compared with measurements by people farther away?*
3. **Pair-Share about possible explanations for why you think the measurements are different from each other, and from before.** Ask students how it's possible that they got so many different measurements of the volunteer's height, and why they are different from the first measurement.
4. **Ask one or two students to explain to the whole group why the measurements are different.** Get the attention of the whole group, and ask for someone to explain why the measurements were different. Usually, students come up with a similar explanation ("things look smaller the farther away you are, and they look bigger the closer you get"). Use student body placement to illustrate their explanation. Eg: "So you're saying that the reason Eduardo looks smaller than Christian, is because Christian is farther away, and if Christian moved closer, he'd look bigger?"
5. **Explain that huge things in the sky may look very small because they're far away, and smaller things may look larger because they're closer.** Tell students that with the night sky it's important to keep relative size in mind - because many of the things in the sky are very, very large, but also very far away. Something that looks tiny might actually be unimaginably big. And something that looks bigger than other things in the sky might be a lot smaller than the other things – only closer.
6. **Ask questions during the night hike to help students think about the actual size of objects compared to the size they appear.** During the night

TEACHING NOTES

For more information on leading the Pair-Share discussion routine, see the BEETLES resource, Discussion Routines

TEACHING NOTES

hike, now and then ask students if they think an object they're looking at is huge or small.

7. **Example questions:**
   - *That airplane looks bigger than those stars. Is it?*
   - *Wow, the Moon sure looks a lot bigger than the planet Venus. Which do you think is actually bigger?*

Instructor Support

Teaching Knowledge:

The importance of teaching scale to students. Aspects of astronomy are often taught to young students, and they are often eager to learn planet names, what planets are like, etc. But to actually understand what space objects are, and to understand space in general, you've got to have some grasp of scale: how enormous space objects can be, and the equally enormous distances between them. The main ingredient of space is...space! Adding to the confusion is that if we rely only on our direct observations, it's easy to have misconceptions about sizes and distances of objects in the sky. Lack of understanding of scale is a big stumbling block for student understanding of space.

It can be challenging to teach astronomy in a student-centered way. A student can make observations of an insect, and through their observations begin to figure out a lot about it. It's a lot more challenging for students to observe and interact with night sky objects because of their size and distance. Partly because of this, night sky instruction sometimes consists mostly of an instructor pointing out night sky objects and telling students about them. This activity is meant to help make a night sky experience more student-centered. Particularly if followed immediately with *Night Hike Scavenger Hunt*, it sets students up with a perspective that will help them inquire about and discuss what they see in the night sky.

Conceptual Knowledge

Why do the Moon and Sun appear to be the same size? The Moon and Sun appear to be about the same size when viewed from Earth, but the Sun is actually ~400x bigger than the Moon. Why doesn't the Sun look 400x bigger to us? It's because the Sun also coincidentally happens to be ~400x farther away than the Moon.

How do scientists measure huge distances? Students may ask how scientists are able to measure things so far away, but unfortunately some of the techniques are pretty tough for elementary/middle school students to truly understand, without significant time spent on it. In short, many objects are measured using the speed of light and radio waves, which travel at the constant breathtaking blow-back-your-hair-and-then-some speed of 186,000 miles per second. The time it takes a light or radio wave to reach an object and bounce back to us can be measured. We are able to use this measurement system most easily with the Moon, because astronauts left a mirror there that Earth-bound astronomers can use. From Earth, scientists reflect a powerful laser there and back to get precise measurements of the Moon's distance. Other objects are measured by measuring the apparent shift in an object when seen from different points of view. And there's a lot of math involved.

Light and Distance. Light is the fastest thing in the Universe. When you look at stars, you're looking back in time, because the light took years to travel to us. So cool! Special telescopes can look billions of years into the past because they can see light from objects billions of light years away. If a star were to

TEACHING NOTES

explode, we wouldn't know it until the light traveled to Earth. It takes light less than a second to travel across North America. It takes ~1 ½ seconds to travel to the Moon. It takes ~8 minutes to travel from the Sun to Earth. Our Sun is our nearest star, and is ~8 light minutes away. The second nearest is ~4 light years away (Proxima Centauri). That means that traveling at 186,000 miles per second, it takes light ~4 years to travel to our second nearest star! That's a long ways away, but other stars are much farther. Sirius, or the Dog Star, is the brightest star in the sky. It's located below and to the left of Orion. It's 8.6 light years away. Because the light we see from it left the star only 8.6 years ago, it's fun for many kids to think about where they were that many years ago.

Sizes in Space. Here's a rough ranking of some visible objects in the night sky from smallest to largest: Most meteors/shooting stars (not counting the trail of light), artificial satellites, airplanes, most clouds, the Moon, the planets, the Sun and other yellow stars, blue stars, red stars , nebula, constellations, galaxies. Most stars we can see are hundreds or even thousands of light years away. Earth is ~8,000 miles in diameter, and Venus is only slightly smaller. The Moon is about 1/4 the size of Earth (~2,000 miles diameter). Here are the miles in diameter of other planets visible with the naked eye: Mercury = ~3,000, Mars = ~4,000, Saturn = ~75,000, and Jupiter comes in at a whopping ~89,000. But the Sun beats them all by far at ~864,000 miles diameter! And the Sun is only an average-size star. It looks bigger to us than other stars, because it's so much closer to us.

Common Relevant Misconceptions

- **Misconception.** The Earth is bigger than the Sun or Moon, and the Sun and Moon are about the same size.

  More accurate information. Although these notions may seem ludicrous to many adults, they make total sense based on what's observable. From our position on Earth, our planet does seem immense compared to the Moon and Sun in the sky. And the Moon and Sun appear to be almost the same size when seen in the sky (never look directly at the Sun, unless wearing special protective lenses – NOT just sunglasses). But students also know from their day-to-day experience that objects appear smaller when far away, and larger when closer. They know that a car doesn't actually get smaller when it drives away. This activity is effective because it helps students apply an illusion with which students have experience to the night sky.

- **Misconception.** The Sun, planets and stars are all about the same distance away from Earth.

  More accurate information. It's very hard to tell how far away something is in the night sky just by looking at it, so students commonly develop a mental model of the sky as a sphere with stars, with planets and the Sun on the inside of the sphere, all at the same distance from us. In fact, many young students also use this model to explain how the Earth can be round, which they've been told, but in all their direct observations it looks flat (and bumpy). Cleverly, students construct a mental model in which we live inside a giant round sphere, the bottom half of which is full of dirt, and the top half of which is full of air, with the stars, planets and Sun on the inside of the upper half of the sphere facing in at us. And according to this model, we live on the flat but round (like a plate) Earth at the midpoint of the sphere. This model is very similar to that proposed by the Flat Earth Society. Misconceptions can be very cleverly constructed! Students in your group may very well carry some of these misconceptions (often quietly), which is why opportunities like this activity to gather evidence that challenges them are good. It's also important for students to get opportunities to discuss their ideas with each other, because that's often when they are exposed to conflicting ideas, and when they become aware of flaws in their mental models, and may consider changing them.

Misconception. The Moon is larger when it's near the horizon, and gets smaller as it moves away from it.

More accurate information. This is an optical illusion, but the explanation for it is still under debate (which is kinda cool, cause it makes it an authentic task to try to explain it).

Connections to Next Generation Science Standards (NGSS)

BEETLES student activities are designed to provide opportunities for the "three-dimensional" learning that is called for in the NGSS. To experience three-dimensional learning, students need to engage in scientific practices to learn important science concepts (Disciplinary Core Ideas) and make connections to the big ideas in science (Crosscutting Concepts). In simple terms, students should be using the tools of science to explore and investigate rich phenomena, trying to figure out how the natural world works.

In *How Big & How Far*, students use the crosscutting concept Scale, Proportion, and Quantity to build foundational understanding of Disciplinary Core Ideas related to The Universe and Its Stars. Students do not fully engage in a science and engineering practice during this activity, but if it's immediately followed by the activity, *Night Hike Scavenger Hunt*, they will engage in the science and engineering practice of Constructing Explanations.

Featured Crosscutting Concepts

Learning science through the lens of Scale, Proportion, and Quantity. According to the NRC's A Framework for K-12 Science Education, it's important that students understand that systems and processes vary in size, and that some systems or processes are too large to be observed directly. When students make measurements and notice that the size of an object differs when measured from different perspectives and consider the relative sizes and distances of stellar objects, students are applying the lens of scale and proportion.

To fully apply this crosscutting concept, students need to be aware that they are applying it. If you choose to emphasize this crosscutting concept in your field experience, point out to students that they are applying the "big idea" of scale, proportion, and quantity, and give them multiple opportunities to relate what they learn to that idea.

TEACHING NOTES

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The NGSS make it clear that students need multiple learning experiences to build their understanding of disciplinary core ideas. *How Big & How Far* provides students with an opportunity to build understanding of disciplinary core ideas related to the following topic within Earth and Space Sciences: ESS1.A: The Universe and Its Stars.

When the instructor points out that objects in the night sky might be far larger or smaller than they appear, students build some understanding of the idea that the Sun appears larger and brighter than other stars because it is closer (ESS1.A). Students also may develop understanding of the idea that stars vary in their size and distance from Earth (ESS1.A).

To more fully develop students' understanding of these ideas, engage them in subsequent activities that give them the opportunity to consider the relative sizes and distances of stellar objects, including the Sun and the Moon.

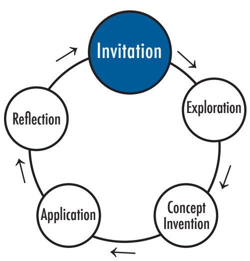
Performance Expectations to Work Towards

When examined closely, it's clear that the NGSS represent complex knowledge and multi-faceted thinking abilities for students. No single activity can adequately prepare someone for an NGSS performance expectation. Performance expectations are examples of things students should be able to do, after engaging in multiple learning experiences or long-term instructional units, to demonstrate their understanding of important core ideas and science practices, as well as their ability to apply the crosscutting concepts. As such, they do not represent a "curriculum" to be taught to students. Below is one of the performance expectations that this activity can help students work towards:

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.

Activity Connections

This activity is a great predecessor to *Night Hike Scavenger Hunt*, and helps students prepare to think about the relative sizes of objects they might observe in the night sky. *Night Hike Scavenger Hunt* will also give students additional opportunities to consider disciplinary core ideas relevant to The Universe and Its Stars.



Within a sequence of activities focused on the night sky, *How Big & How Far* is an invitation.

FIELD CARD

Cut out along outer lines and fold along the centerline. This makes a handy reference card that will fit in your pocket.

How Big and How Far

Measuring a Student's Height Together

1. Gather students in lighted area.
2. Explain that when they will be looking at objects in the night sky, it can be hard to tell size and distance.
3. Explain that this is a quick activity to help think about size and distance.
4. Ask a volunteer to stand in the center of a seated circle.
5. Ask the group to begin silently collaborating to measure the student's height with stacked fists.
6. Ask student(s) to count & announce the student's height in fists.

Measuring the Student's Height Independently

1. Ask the student who was measured to stay put.
2. Immediately explain: spread out & each measure the fist height of the volunteer from where you stand, with arm outstretched & one eye closed.
3. With students standing where they measured, explain: hold up the number of fingers that matches how many fists tall you measured the student's height from where you're now standing.

Discussing Why Measurements Differ

1. Ask students to look around and think about the differences in measurements, from before, and from each other.

   ▶ *We just measured [student] as X fists tall, but now you're saying that they're X fists tall? What's going on? Did they suddenly shrink? And some of you measured [student] as X, while others measured them as X. What's up with that?*
2. Tell students to look at the fingers held up by different people in the room, and look for a pattern. Ask:

   ▶ *Do you notice any patterns in how many fingers people are holding up in different areas?*

   ▶ *What do you notice about the measurements by people who are closer to XX, compared with measurements by people farther away?*
3. Pair-Share about possible explanations for why you think the measurements are different from each other, and from before.
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6. Ask questions during the night hike to help students think about the actual size of objects compared to the size they appear.

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BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) is a program of The Lawrence Hall of Science at the University of California, Berkeley, that provides professional learning sessions, student activities, and supporting resources for outdoor science program leaders and their staff. The goal is to infuse outdoor science programs everywhere with research-based approaches and tools to science teaching and learning that help them continually improve their programs.

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The following programs have contributed to the development of these materials by field testing and providing invaluable feedback to the development team. For a complete list of contributors and additional partners, please see our website at beetlesproject.org/about/partners/

California: YMCA Camp Campbell, Rancho El Chorro Outdoor School, Blue Sky Meadow of Los Angeles County Outdoor Science School, YMCA Point Bonita, Walker Creek Ranch, Santa Cruz County Outdoor Science School, Foothill Horizons Outdoor School, Exploring New Horizons Outdoor Schools, Sierra Nevada Journey's School, San Joaquin Outdoor Education, YMCA Camp Arroyo, Shady Creek Outdoor School, San Mateo Outdoor Education, Walden West Outdoor School, Westminster Woods.

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Photos: Pages 1 and 2 by Kevin Beals. *Icons*: Backpack by Rémy Médard; Growth by Arthur Shlain; Cut by Nathan Thomson; Outside by Petr Holusa; Park by Antar Walker; &Time by Wayne Middleton all from The Noun Project.

Funding from 2012-2015 for BEETLES publications such as this one has been generously provided by the S.D. Bechtel, Jr. Foundation, The Dean Witter Foundation, and the Mary A. Crocker Trust.

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