HUDSON
RIVER
MUSEUM

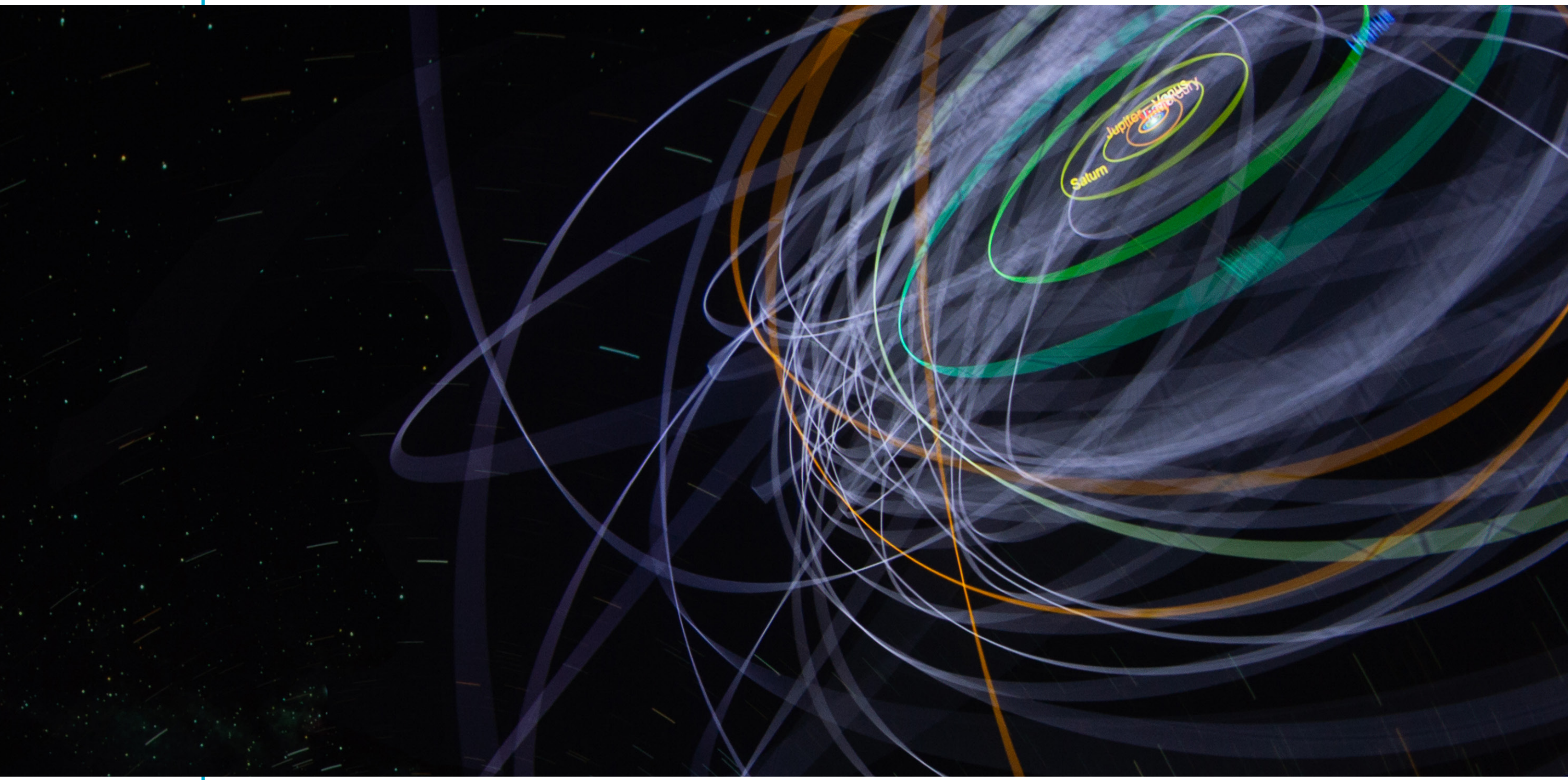
Orbits
Teaching Resource

Ages: 10+ (Grades 4–12)

Duration: 1.5 hours (includes 3 activities)

Materials needed:
- Paper
- Pencil
- Colored pencils, crayons, or markers
- Measuring tape or tape measure
- Ruler or yardstick
- Calculator
- String or yarn
- Body weight scale, if available
- Thermometer, if available
- Access to a mirror

Essential questions:
- What is data?
- What are physical properties?
- What are some of the types of data used by astronomers and astrophysicists when studying and analyzing space?
- What is deductive reasoning?
- What are the unique properties of planets in our solar system?
- What similarities and/or differences can be found between the planets?



Part 1: Introduction

Astronomers and **astrophysicists** are scientists who observe and **analyze** space, study the **celestial bodies** in our **solar system** and beyond, and who observe and hypothesize about the complex processes and movements that take place beyond Earth. They work from the understanding that they actually know very little about the subject in which they are experts!

An essential part of any field of science is to never make assumptions. Instead, it is important to state a **hypothesis** that can be tested or to observe and analyze enough **data** so that a reasonable **deduction** can be made. In this teaching resource, three activities will help you understand and experiment with observing and analyzing sets of data in different ways, as well as dig deeper into aspects of planetary science through exploration of planetary **orbits**.

Part 2: Personal Properties (Activity 1)

Duration: 30 minutes

Materials needed:

- Paper
- Pencil
- Colored pencils, crayons, or markers
- Calculator
- Measuring tape or tape measure
- Ruler or yardstick
- String or yarn
- Body weight scale, if available
- Thermometer, if available
- Access to a mirror

Introduction:

In this activity, you will write an autobiography using only data. Instead of writing the story of your life in narrative form, you will document your physical properties through scientific observation and recording. Once you have documented yourself in this way, you will gather data about another person in your home in order to compare the physical properties of two similar physical objects (humans!) in a shared space.

Procedure:

1. Start by gathering any and all materials you have available that can help you with measurement. This can be a tape measure from a toolbox or measuring tape used in sewing, a ruler or yardstick, a scale for weighing yourself, a thermometer for temperature, etc. If you don't have measuring tools available, use a piece of string or a shoelace to represent a standardized unit of your own.
2. Using paper and pencil, begin recording as many sets of numerical data about yourself as possible.
   - How old are you in years? What about months (age x 12 months)? Days (age x 365 days)? Don’t forget leap years, which have 366 days!
   - How tall are you in feet? Inches? Meters and centimeters?
   - How much do you weigh in pounds? What about kilograms? Does this number change if you weigh yourself at different points of the day?
   - What is the circumference of your head? Your waist? Your bicep? Your wrist? Your thigh? Your calf? How long is your foot? How long is your hand from the tip of your middle finger to your wrist?

How wide is your palm?
- Can you take your temperature? What does it read in Fahrenheit versus Celsius? If you take your temperature at different times during the day do you notice any changes?

3. After creating a numerical autobiography, find a mirror and describe your surface features. Sketch your face and/or your entire body.
    - What colors are your hair, eyes, skin tone, clothing?
    - What textures do you notice?
    - What unique features do you have? Do you have freckles or a birthmark? Do you have any significant scars?
4. Find someone else in your home or that you are in contact with and follow the same data gathering process above for this subject.
    - What differences are apparent between you and the other subject or subjects?
    - What similarities can you find?
    - What conclusions can you draw from comparing your data?

Part 3: Space Scale (Activity 2)

Duration: 30+ minutes (Depending on the scale you decide to use, the duration of the activity may be longer! It is up to you.)

Materials needed:

- Paper
- Pencil
- Tape or stapler
- Unit of measurement, like a ruler, yardstick, or a piece of string to use as your own customized unit of measurement

Introduction:

Our solar system is the collection of eight **planets**—traditionally recognized since antiquity—and their moons in orbit around our Sun, together with smaller bodies in the form of asteroids, meteoroids, and comets. The eight planets collectively can be considered a family of celestial objects, because they all orbit the same object (the Sun). Just like in a human family, however, each individual planet has unique characteristics and details that set it apart from the others. The order of the planets from closest to the Sun to farthest away is always the same: **Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune**. **Pluto** was known as a member of the planetary family until 2006, when the International Astronomical Union classified it as a **dwarf planet** due to the discovery of objects of similar size near it in the **Kuiper Belt** ring of distant icy objects in our outer solar system.

In this activity, you will explore the concepts of **scale** and of the **Astronomical Unit (AU)**, the standard unit of length used by astronomers to measure distances in space, and how differences in AU from the Sun directly affect sense of time. The eight planets all have different orbits, or paths around the Sun, and the farther a planet is from the Sun the longer it takes to make a complete orbit, or planetary year. Planet Earth takes 365.25 days to make a complete orbit, but that is in no way standard for any of the other seven plants in the solar system family.

Procedure:

1. Begin by making a mark for the Sun on a piece of paper. The Sun is your point of reference for measuring the distance in AU's for each of the eight planets and for creating a visual diagram.
2. Next, decide on a scale you can use that will allow you to include all eight planets in your diagram. For example, start with a scale of *1 AU = 1 inch* or *1 AU = 2 inches*. In reality, a single astronomical unit is equal to the distance of the Earth to the Sun, or about 93 million miles!

3. Refer to the AU chart in order to plot the locations of each planet from the Sun using the scale you have chosen. What do you notice about the distances and placements?
4. Try out other means of plotting planetary distances using a slightly larger scale. Maybe you have access to an outdoor space or hallway. What does it look like if your AU scale is 1 AU = 1 foot? What do your planetary placements look like if you use a scale of 1 AU = 1 yard?
5. Finally, compare the distance in AU from the Sun to the length of one complete orbit each planet takes around the Sun. Visit the Exploratorium's Your Age on Other Worlds tool and enter in your birth date information.
    - What are your observations and reactions to this data?
    - What connections can you make between the data sets of length versus time?

Share your work:

Take a photo of your work and post it to Instagram using the hashtags #MuseumFromHome and #Orbits, and tag @HudsonRiverMuseum.

Planets	**Distance from Sun (AUs)**	**Distance from Sun (km)**	**Distance from Sun (miles)**
Mercury	0.4	57,910,000	35,983,606
Venus	0.7	108,200,000	67,232,363
Earth	1.0	149,600,000	92,957,130
Mars	1.5	227,940,000	141,635,350
Jupiter	5.2	778,330,000	483,631,840
Saturn	9.5	1,429,400,000	888,187,982
Uranus	19.2	2,870,990,000	1,783,950,479
Neptune	30.1	4,504,000,000	2,798,655,850








Part 4: The Deduction Derby (Activity 3)

Duration: 30 minutes

Materials needed:

- Paper
- Pencil
- Calculator

Introduction:

When studying the eight planets in our solar system, astronomers observe and collect data in many different categories. Space scientists observe a planet's surface features and characteristics, its temperature at different points in its rotation or orbit, measure its circumference and diameter, and measure its **mass** and **chemical composition**. Data collection, analysis, comparison, and interpretation is constant, and as space technologies evolve they allow for astronomers and astrophysicists to access new information that can alter a previously held hypothesis. The classic example is the reclassification of Pluto from a planet to a dwarf planet after the discovery of dwarf planet Eris in 2005, changing the long held understanding of our solar system containing nine planets to one of eight.

In this activity, you will read through sets of data that represent each of the eight planets that orbit our Sun. Not every set of data will include the same kind of information. Through cross-referencing data and a process of **deduction**, you will make educated guesses about which planet is represented by each particular data set.

Procedure:

1. View the data sets on the next page. Read through each one from left to right, noting data that stands out to you. Perhaps it's that mystery planet's temperature, surface features, or distance in AU from the Sun. You may come up with a guess immediately, or after looking at one or two bits of data, but hold your hypotheses!
2. Read about the planets in detail by visiting links provided in the Further Resources section included below. The process of cross-referencing data and information is a key practice in the **scientific method**.
3. Make your guesses after testing your assumptions by checking data and/or after analysis of what is available to you through the process of deduction.
4. An answer key is provided for you on page 12. Don't worry if you've made the wrong guess—scientists check and re-check their data constantly, learning from their mistakes!

Planet?	Distance from the Sun (miles)	Diameter (miles)	Terrestrial or Gaseous	Average Temperature	Chemical Composition of Atmosphere	Visual Features
	887,750,000	?	Jovian	-200°F	Hydrogen Helium	Rings
	?	4,222	Terrestrial	-200° to 50°F	Carbon Dioxide Argon	Dusty, red
	483,500,000	88,846	Jovian	-200°F	?	Storm systems
	36,000,000	3,031	?	-300° to 800°F	Sodium Helium	Cratered surface
	2,795,770,000	?	Jovian	-330°F	Hydrogen Helium Methane	Deep blue color
	67,000,000	7,521	Terrestrial	900°F	?	Visible from Earth
	1,740,200,000	31,763	?	-350°F	Hydrogen Helium Methane	Faint ring system
	?	7,926	Terrestrial	-80° to 120° F	Nitrogen Oxygen	Varied surface

Part 5: Glossary

Analysis: Detailed examination of the elements or structure of something. To analyze is the act of discovering or revealing (something) through this detailed examination.

Astronomical Unit: A unit of length used by astronomers; the distance from Earth to the Sun (93 million miles) is one astronomical unit.

Astronomer: A scientist who studies planets, stars, galaxies, and anything else in space.

Astronomy: The branch of science that deals with celestial objects, space, and the physical universe as a whole.

Astrophysics: Branch of astronomy concerned with the physical processes associated with the celestial bodies and the intervening regions of space.

Celestial bodies: A natural object that is located outside of Earth's atmosphere, such as the Moon, the Sun, an asteroid, planet, or star.

Chemical composition: The identities, and relative numbers, of the elements that make up any particular compound.

Data: Facts and statistics observed and collected together for reference or analysis. Data can take many different forms.

Deductive reasoning: A method scientists use to test hypotheses, also known as top-down logic. Basic deductive reasoning includes making a statement (hypothesis), then examining that statement until a logical conclusion is made. An example of deductive reasoning is: "All green plants need sunlight (hypothesis). This rosebush is a green plant (example). Therefore, this rosebush needs sunlight to live (conclusion)."

Dwarf planet: A body, other than a natural satellite (like the Moon), that orbits the Sun and that is, for practical purposes, smaller than the planet Mercury, yet large enough for its own gravity to have rounded its shape

Gravity: The attractive force of a body; (the larger or more dense the body, the greater the gravitational force). The Sun is the largest body in our solar system and therefore has the largest gravitational force within it.

Hypothesis: An educated guess. A hypothesis is a proposed explanation for a phenomenon. For a hypothesis to be a scientific hypothesis, the scientific method requires that one can test it.

Inductive reasoning: The process of using examples and observations to reach a conclusion. Using a pattern to predict what may happen next is an example of inductive reasoning.

Jovian (gas) planets: Four of the planets in the solar system. They are between four and twelve times the width of the Earth, and up to 330 times as massive, but far less dense. All have deep atmospheres, rings or ring fragments, and no distinct solid surfaces. Two, **Jupiter** and **Saturn**, are similar in composition to the Sun and considerably larger and more massive than anything else orbiting the Sun, containing complex systems of moons and rings and powerful magnetic fields. Slightly smaller are the two "Ice Giants," **Uranus** and **Neptune**, that are comprised of substantial amounts of methane, water and ammonia in thick mantles, larger cores, and mysteriously off-center magnetic fields.

Kuiper Belt: A doughnut-shaped ring of icy objects around the Sun, extending just beyond the orbit of Neptune from about 30 to 55 AU.

Mass: Mass is a measure of the amount of matter in an object. Mass is usually measured in grams (g) or kilograms (kg). 1 kg = 2.2 lbs. An object's mass is constant in all circumstances; contrast this with its weight, a force that depends on gravity. Your mass on the earth and the moon are identical. Your weight on the moon is about one-sixth of your weight on the earth.

Observation: The action or process of observing something or someone carefully or in order to gain information.

Orbit: The path an object takes as it moves around another object. The eight planets of our solar system orbit the Sun; as the largest object in our solar system the Sun's gravity pulls on the planets, maintaining their various orbital paths.

Planet: A large object such as Jupiter or Earth that orbits a star.

Planetary rotations: As a planet rotates around its axis, the stars appear to move around a projection of the planet's axis into space. The time required for the stars to move once around their paths is called the sidereal period of rotation, or the rotation period of the planet.

Scale: Defined as a system or series of marks used for measuring or registering. An example of scale is what someone would use to figure out the length of something.

Scientific method: A method of research in which a problem is identified, relevant data are gathered, a hypothesis is formulated from these data, and the hypothesis is empirically tested.

Solar system: The collection of eight planets and their moons in orbit around the Sun, together with smaller bodies in the form of asteroids, meteoroids, and comets.

Terrestrial (rocky) planets: Four of these exist. Two, **Earth** and **Venus**, are nearly identical in size. They are larger than the other two and have molten cores, kept hot by leftover heat from their formation and radioactive decay that cause them to exhibit active volcanism. The other two, **Mars** and **Mercury**, are smaller. Mars, the slightly larger one of the pair, shows hints of recent geological activity. Mercury has no signs of geological activity that we know of.

Part 6: Further Resources

Bob the Alien's Tour of the Solar System
https://www.bobthealien.co.uk/

Smithsonian National Air and Space Museum's "Diamonds in the Sky: Stars and Exoplanets"
https://airandspace.si.edu/multimedia-gallery/diamonds-sky-stars-and-exoplanets-stem-30-0

Smithsonian National Air and Space Museum's "Conducting Planetary Research Here on Earth" Blogpost
https://airandspace.si.edu/stories/editorial/conducting-planetary-research-here-earth

NASA's "Our Solar System: Overview"
https://solarsystem.nasa.gov/solar-system/our-solar-system/overview/

NASA's "Our Solar System: In Depth"
https://solarsystem.nasa.gov/solar-system/our-solar-system/in-depth/

NASA's "Space Place: How Long is a Year on Other Planets?"
https://spaceplace.nasa.gov/years-on-other-planets/en/

NASA's "Space Place: What is the Weather Like on Other Planets?"
https://spaceplace.nasa.gov/weather-on-other-planets/en/

CrashCourse Statistics "Data Visualization"
https://www.youtube.com/watch?v=hEWY6kkBdpo

National Geographic's "Solar System 101"
https://www.youtube.com/watch?v=libKVRa01L8

CrashCourse Astronomy
https://www.youtube.com/playlist?list=PLH2l6uzC4UEVvEIPjr--V9Rr-Qj-XBrmn

Answer Key: Saturn, Mars, Jupiter, Mercury, Neptune, Venus, Uranus, Earth

Part 7: Standards

Common Core Learning Standards

English Language Arts

Reading Informational Text:

Key Ideas and Details: CCSS.ELA-LITERACY.RI.4-12.1
Range of Reading and Level of Text Complexity: CCSS.ELA-LITERACY.RI.4-12.10

Foundational Reading Skills:

Phonics and Word Recognition: CCSS.ELA-LITERACY.RF.4-5.3
Fluency: CCSS.ELA-LITERACY.RF.4-5.4

Writing:

Texts Types and Purposes: CCSS.ELA-LITERACY.W.4-12.1-2
Research to Build and Present Knowledge: CCSS.ELA-LITERACY.W.4-12.7-9

Speaking and Listening:

Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.4-12.1-3
Presentation of Knowledge and Ideas: CCSS.ELA-LITERACY.SL.4-12.4-6

Language:

Conventions of Standard English: CCSS.ELA-LITERACY.L.4-12.1-2
Knowledge of Language: CCSS.ELA-LITERACY.L.4-12.3
Vocabulary Acquisition and Use: CCSS.ELA-LITERACY.L.4-12.4-6

Science and Technical Subjects

Key Ideas and Details: CCSS.ELA-LITERACY.RH.6-12.1-3
Integration of Knowledge and Ideas: CCSS.ELA-LITERACY.RST.6-12.7-9
Range of Reading and Level of Text Complexity: CCSS.ELA-LITERACY.RST.6-12.10

Mathematics

Measurement and Data:

Solve problems involving measurement and conversion of measurements: CCSS.MATH.CONTENT.4.MD.A.1-3
Represent and interpret data: CCSS.MATH.CONTENT.4-5.MD.B.4/2

New York State Learning Standards

The Mathematics, Science and Technology

Standard 1: Analysis, Inquiry and Design

Standard 3: Mathematics

Standard 4: Science

English Language Arts

Standard 1: Language for Information and Understanding