OUR PLACE IN SPACE
EDUCATOR GUIDE

INTUITIVE® PLANETARIUM
at the U.S. Space & Rocket Center®

HOW TO USE THIS GUIDE

This resource is a guide to the solar system for the adventurous traveler. It is designed to serve as a companion to "Our Place in Space," the online, guided presentation led by an *INTUITIVE*® Planetarium Specialist, as well as prepare your students for their cosmic excursion. Here's how it works:

"Our Place in Space" is an online and live tour through the solar system that introduces your students to a new and closer look at the planets they know and love. We will begin at the heart of our solar system, fly to every planet as well as some moons, visit every tourist's favorite dwarf planet (Pluto, of course), and end our journey with a simulated view of the total observable universe before returning home.

Before your presentation, the "Planet Overview" will introduce some of the planets and delve into the habitability of each of the worlds your students will explore with us and give tips for what to expect when planet-hopping.

The "Curriculum" sections include preparation questions and lesson plans designed for your classroom for before and after the show. The pre-show activities will introduce students to concepts that will be fundamental to their navigation through space and invite them to engage with the broader implications of the material; the post-show activities will foster a deeper understanding of the solar system by prompting students to think critically about the ideas they have encountered during the presentation. Using these ideas, students will engineer their own hypothetical missions to places in space and plan their colonization of these places such that they and their travel companions would survive the venture.

The "References" section provides a glossary to consult for definitions of certain scientific terms, a list of online resources to help shape your lesson plans, and a reference page of the education standards fulfilled by the field trip and activity guides.

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PREPARATION QUESTIONS

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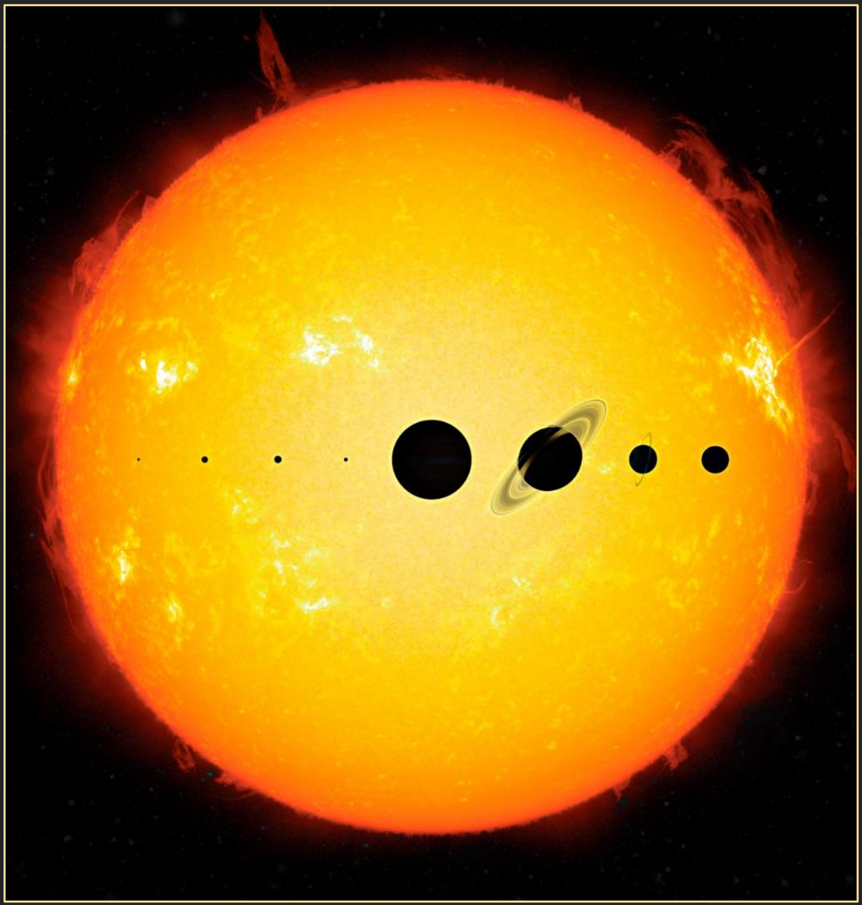
PREPARATION QUESTIONS

These questions will encourage your students to begin thinking creatively about the broader implications of the material. Give them the opportunity to think and answer the questions for themselves before sharing the provided answers with them.



This artist's rendering shows the eight planets lined up as if they were transiting the Sun. This view would not be possible in reality, but it is intended to show an accurate scale of the planets' relative size.
Image credit: NASA / Moore Boeck

WHERE DOES SPACE BEGIN AND HOW IS THIS DETERMINED?

The general answer to this is that Earth's atmosphere ends and space begins at 100 kilometers above the surface of the Earth. This line is called the "Kármán line," named for Theodore von Kármán, the Hungarian scientist who determined that this is the altitude at which the atmosphere becomes too thin to support aeronautical flight.

WHAT IS A PLANET?

According to the International Astronomical Union's most recent definition (2006), a planet is a body that orbits a star, is big enough to have enough gravity to force it into a spherical shape, and is big enough that its gravity clears away any other objects of similar size near its orbit around the Sun. This does not mean that scientists unanimously agree on this verdict—the subject is still a source of great debate. Science is constantly changing according to new discoveries and new ideas, and there is nothing in the field of science that we can know is absolutely true. So, what does the definition of a planet really mean? Why is it important to define these things if their definitions are not unanimously agreed upon?

ARE THERE OTHER UNIVERSES BESIDES OUR OWN?

It is actually not a controversial idea among physicists that multiple universes exist. Some theories suggest an infinity of universes, and some even suggest that if you travelled far enough, you would eventually encounter a parallel version of yourself living in a parallel version of our world.

WHAT DOES IT MEAN TO SAY THAT SPACE IS A VACUUM?

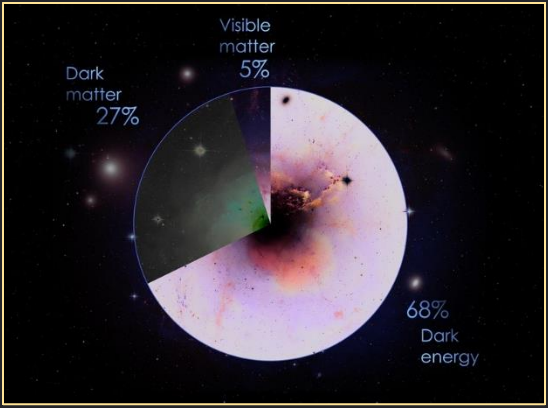
In the field of physics, a vacuum is a space in which there is no matter or in which the pressure is so low that any particles in that space do not affect any processes occurring there. What we really mean in saying "space is a vacuum" is that the parts of space that are far away from objects such as planets, stars, etc. are almost a vacuum—the concentration of particles in that space is miniscule in comparison to the concentration in our atmosphere.

ARE THERE PLACES OTHER THAN EARTH THAT MAY BE HABITABLE FOR HUMANS?

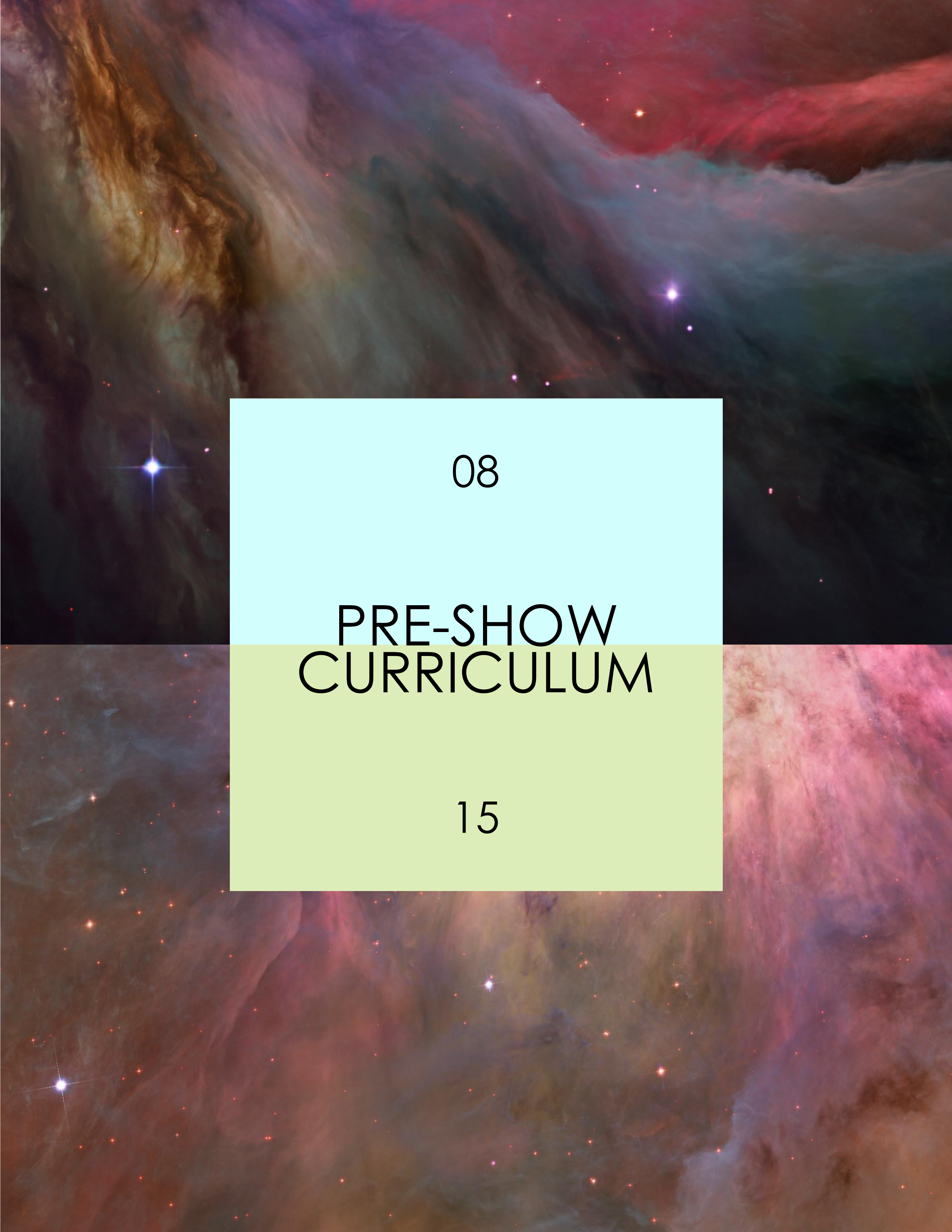
Though we do not currently know of a place where we could live as comfortably as we do on Earth, there are places that have potential. For example, if we created a floating habitat that hovered in the atmosphere of Venus, we would avoid the extreme temperatures of the surface. Can you think of any possible habitats we could construct in other cosmic locations?

WHAT IS THE UNIVERSE MADE OF?

It is thought that the universe is made up of three kinds of substance, including normal matter, dark matter, and dark energy. Most scientists believe that dark energy accounts for about 68% of the universe, dark matter accounts for 27%, and normal matter (what stars, planets, you, and I are made of) accounts for 5%. Dark matter is a mysterious substance that has gravitational pull but does not give off or absorb light. Given these limiting characteristics, how might scientists detect the presence of dark matter in space?



This pie chart shows rounded values for the three known components of the universe: normal matter, dark matter, and dark energy.
Image credit: NASA



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PRE-SHOW CURRICULUM

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ANOTHER WORLD:
SOLAR SYSTEM EXPLORATION

THINKING CRITICALLY ABOUT EXPLORATION

OVERVIEW

In this activity students will work in small groups to investigate the possibilities of exploring other worlds in our solar system. Through critical thinking they will determine exploration priorities based on environmental conditions and natural resources of other worlds as they relate to Earth.

OBJECTIVES

· Students will select three worlds in the solar system to explore based on their environmental conditions and natural resources.
· Students will prioritize their selections based on scientific or commercial objectives.

MATERIALS

USSRC Another World Resources Sheet
USSRC Another World Data Sheet

NATIONAL EDUCATION STANDARDS

NGSS: ESS1.B; ESS2.A; ESS3.A; LS2.A
CCSS ELA-Literacy: RI.4.4; RI.5.4; RST.6-8.4; SL.4.1; SL.5.1; SL.6.1

INTRO: EXPLORATION OBJECTIVES

HOW TO CHOOSE A DESTINATION

When compared to the whole solar system, the Earth is a relatively small place with limited resources. Luckily for us, there are many other worlds in our solar system that offer great potential for scientific and commercial opportunities. Through exploration of these other worlds, scientific discovery and commercial efforts will lead to new technologies that will benefit our home planet. As our population continues to grow, other worlds can provide much-needed resources for fuel, manufacturing, and even colonization.

Our solar system contains a vast number and variety of worlds, ranging from enormous gas giants to small, rocky worlds and moons. In addition, there are untold millions of other space rocks such as asteroids and comets. Many of these solar system objects contain valuable resources or may even be suitable for colonization—or both! With so many options to choose from, where do we go first? How do we prioritize our objectives? Those are the questions that you and your group will attempt to answer in this activity.

But before we investigate other worlds in the solar system, we first need to know something about the natural resources on our own planet and why we need them in order to prioritize our efforts to expand beyond our own small world. You can refer to the Resources Sheet for the information you will need about planetary and solar system resources.

ACTIVITY INSTRUCTIONS

PHASE 1
Activity

· Prior to attending the "Our Place in Space" show, divide the class into groups (four students for each group is recommended).

· Teams will select three worlds to explore using the USSRC Another World Reference sheet and will answer the questions on the Another World Data Sheet.

PHASE 2
Post Activity

· After attending the show, have the teams re-examine their data sheets and priorities.

· Then, have teams fill out a new Another World Data Sheet.

· Have each team briefly explain the rationale for any modifications or additions to their original plan. Alternately, if there are no modifications, have them present a justification.

· Follow up with a classroom discussion:

· Is there a consensus on the selection of some worlds? Why or why not?

· Are some worlds excluded? If so, why?

· What are the greatest advantages of exploring other worlds?

· Which world(s) offer(s) the most scientific interest or possibilities?

· Which world(s) offer(s) the greatest commercial opportunities?

PLANETARY RESOURCES

EARTH'S NATURAL RESOURCES

There are three categories of natural resources from Earth: **renewable, non-renewable, and flow resources**. Natural resources include air, water, soil, metals, and minerals. In addition, there are many energy resources, including fossil fuels, geothermal, tidal, wind energy, solar energy, and biological resources such as plants, trees, and animals.

RENEWABLE, NON-RENEWABLE, AND FLOW RESOURCES

Trees, animals, water, and soil are **renewable resources** because they replenish themselves. Renewable resources, if they are not killed off, over-harvested, or polluted, continue to regenerate. **Non-renewable resources** are those that cannot be replaced after they are exhausted. Some examples are coal, petroleum, and fossil fuels that are used to produce energy, plastic products, and gasoline. Wind, solar power, and the tides **are renewable flow resources** that do not require regeneration or reproduction.

SOLAR SYSTEM RESOURCES

MERCURY

· Mercury is a rocky planet with a huge iron core, which takes up nearly 3/4 of the planet's diameter, making Mercury the most iron-rich planet in the solar system.

VENUS

· Carbon dioxide: 96 percent.
· Nitrogen: 3.5 percent.
· Carbon monoxide, argon, sulfur dioxide, and water vapor: less than 1 percent.
· In addition to warming the planet, the heavy clouds shield it, preventing visible observations of the surface and protecting it from bombardment by all but the largest meteorites.

THE MOON

- Water ice.
- Craters, regolith, caves.
- Sodium, potassium, iron, titanium, aluminum, magnesium, silicon.

MARS

- Mineral resources are in abundance, including iron, titanium, nickel, aluminum, sulfur, chlorine, calcium, methane.
- Compounds O_2, N_2, and H_2O.

JUPITER

- Jupiter's clouds are composed of ammonia and water vapor drifting in an atmosphere of hydrogen and helium.
- Small amounts of methane, hydrogen sulfide, water.
- Extremely large and powerful magnetic field.
- Dense core of metals such as iron and nickel surrounded by rocky material and other compounds solidified by intense pressure and heat.
- Metallic hydrogen envelops the core.

JUPITER'S MOONS

- A deadly dose of radiation in the form of high-energy electrons and ions continuously bombards the surfaces due to their orbit within Jupiter's radiation belts.

EUROPA

- Icy surface.
- Salty liquid ocean underneath (H_2O).

GANYMEDE

- Icy surface.
- Salty ocean beneath icy surface.
- Thin oxygen atmosphere.

IO

- Most volcanically active world in the solar system.
- Computer models suggest Io formed in a region around Jupiter where water ice was plentiful; combined with the possibility of liquid water, Io's heat could have made life plausible underground, where water might still be abundant and geothermal activity and sulfur compounds could provide microbes with sufficient energy to survive.
- Sulfur dioxide snowfields.

(Pictured left. Image credit: NASA)

CALLISTO

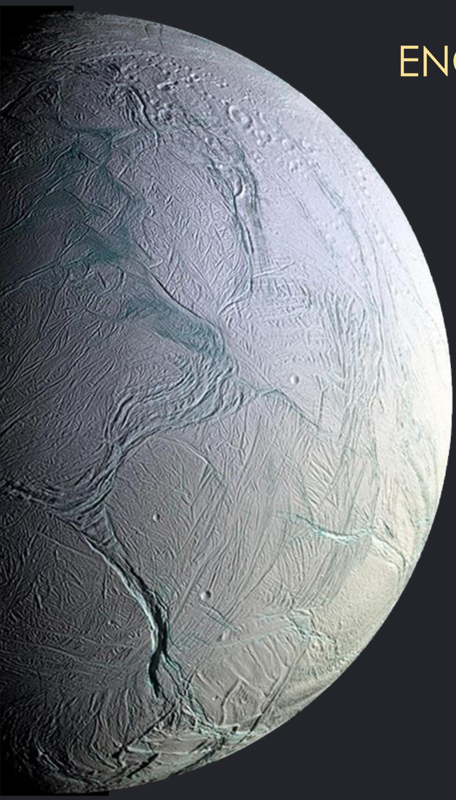
- May have a salty ocean beneath its icy surface.
- Thin carbon dioxide exosphere and extremely thin atmosphere.
- Indications of oxygen and hydrogen in its exosphere.

SATURN

· Saturn is mostly made of hydrogen and helium.
· It has a strong magnetic field.
· Dense core of metals such as iron and nickel surrounded by rocky material and other compounds solidified by the intense pressure and heat.
· Core enveloped by liquid metallic hydrogen inside a layer of liquid hydrogen. It is similar to Jupiter's core but considerably smaller.

SATURN'S MOONS

ENCELADUS



· There is liquid water ocean beneath its frozen shell.
· Scientists have determined that Enceladus has most of the chemical ingredients needed for life and likely has hydrothermal vents spewing out hot, mineral-rich water into its ocean.
· Water jets called plumes come from relatively warm fractures in the crust.
· Several gases such as water vapor, carbon dioxide, methane, maybe some ammonia, and either carbon monoxide or nitrogen gas make up the gaseous envelope of the plume along with salts and silica. (Pictured left. Image credit: NASA)

TITAN

· Only moon in the solar system with a substantial atmosphere.
· Titan is the only place in the solar system besides Earth known to have liquids in the form of rivers, lakes, and seas on its surface. Most of these are hydrocarbons such as methane and ethane.
· Atmosphere is made mostly of nitrogen, like Earth's, but has a surface pressure 50 % higher than Earth's.
· Beneath Titan's thick crust of water ice is an ocean primarily made of water rather than methane.

URANUS

· Uranus is made of water, methane, and ammonia fluids above a small, rocky center.
· Its atmosphere is made of hydrogen and helium like that of Jupiter and Saturn, but it also has methane. The methane makes Uranus blue.
· Unusual, irregularly shaped magnetosphere.

NEPTUNE

· Neptune is very similar to Uranus. It is made of a thick soup of water, ammonia, and methane over an Earth-sized solid center.
· Atmosphere is made of hydrogen, helium, and methane. The methane gives Neptune the same blue color as Uranus.

PLUTO

· Rocky core surrounded by a mantle of water ice.
· Ices such as methane and nitrogen frost coat its surface.

ANOTHER WORLD DATA SHEET

1. List the three worlds you would like to explore:

a.

b.

c.

2. How far from the Earth are the worlds you want to explore?

a.

b.

c.

3. How will you get there?

a.

b.

c.

4. What type of mission are you planning (short-term, long-term, permanent)?

a.

b.

c.

5. What is the environment on each world?

a.

b.

c.

ANOTHER WORLD DATA SHEET

6. What will you need to survive on each world?

a.

b.

c.

7. What natural resources (renewable, non-renewable, and flow) are available?

a.

b.

c.

8. What kinds of supplies would you bring with you to each location?

a.

b.

c.

9. How would you fund your mission? Would you convince corporations to fund your mission to further their commercial objectives? Would you approach humanitarian organizations and focus on scientific objectives? Use your imagination!

a.

b.

c.

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PLANET OVERVIEW

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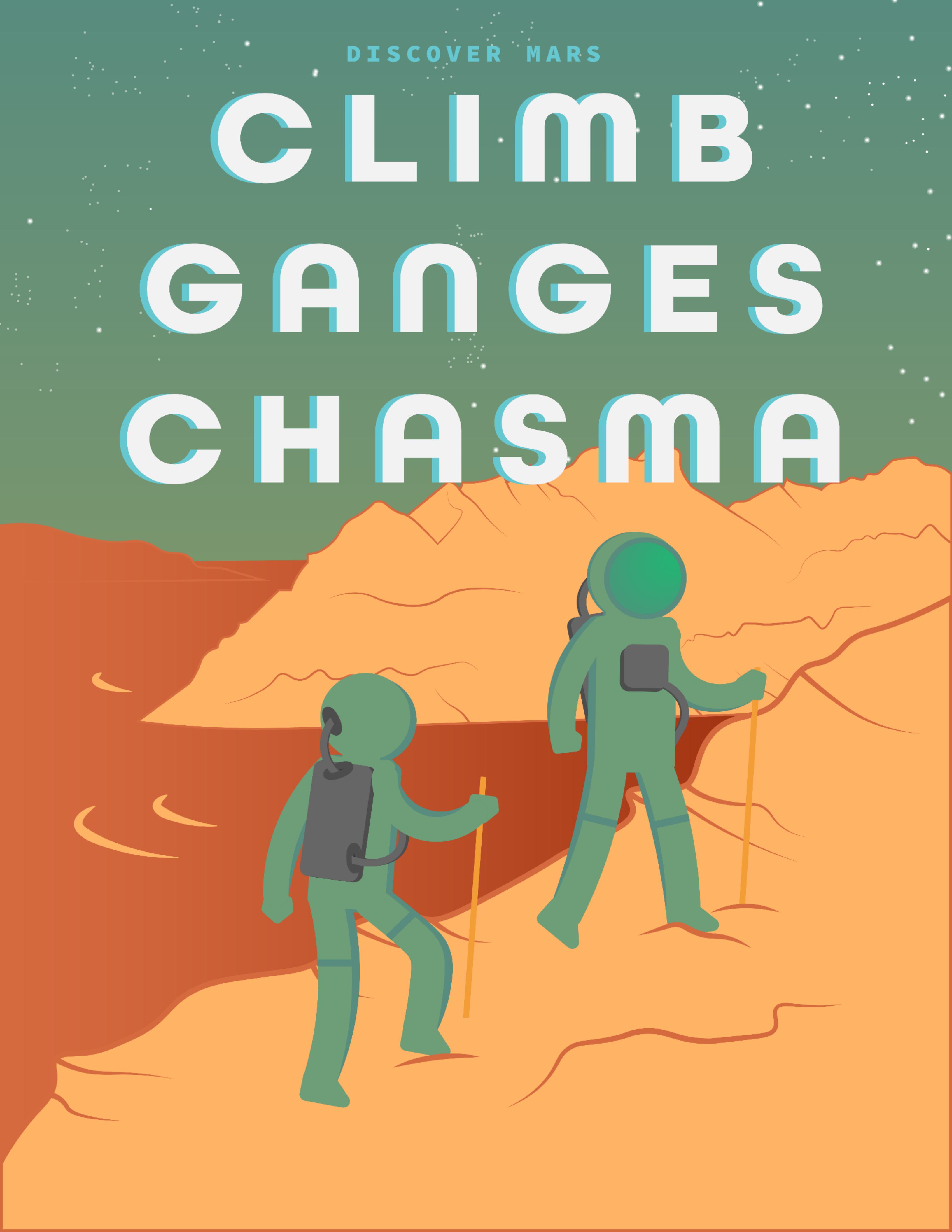
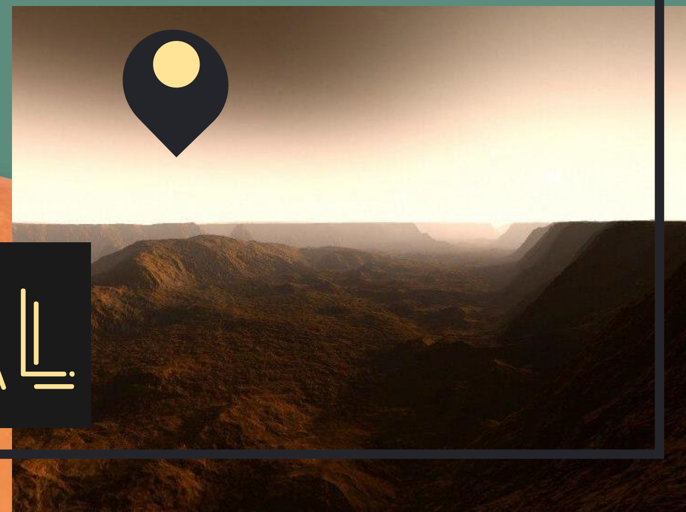

DISCOVER MARS
CLIMB GANGES CHASMA

MARS: TERRESTRIAL PLANET



DID YOU KNOW?

1. Water has been found on Mars in ice form, and there is even evidence to suggest that Mars once held a significant amount of liquid water on its surface.

2. One of the most famous features of Mars is Valles Marineris, a valley as long as the United States is wide and five times deeper than the Grand Canyon in some points.

3. The atmosphere on Mars is very thin and changes dramatically with height, such that if you stood at the equator, it could be 24° Celsius at your feet and 0° Celsius at your head at the same time.

LOCATION OF INTEREST: GANGES CHASMA

Shown in the image above is Ganges Chasma, a deep canyon located on the eastern side of Valles Marineris. Running 3 or 4 km deep, it is thought to have been formed by the flow of water and CO_2.

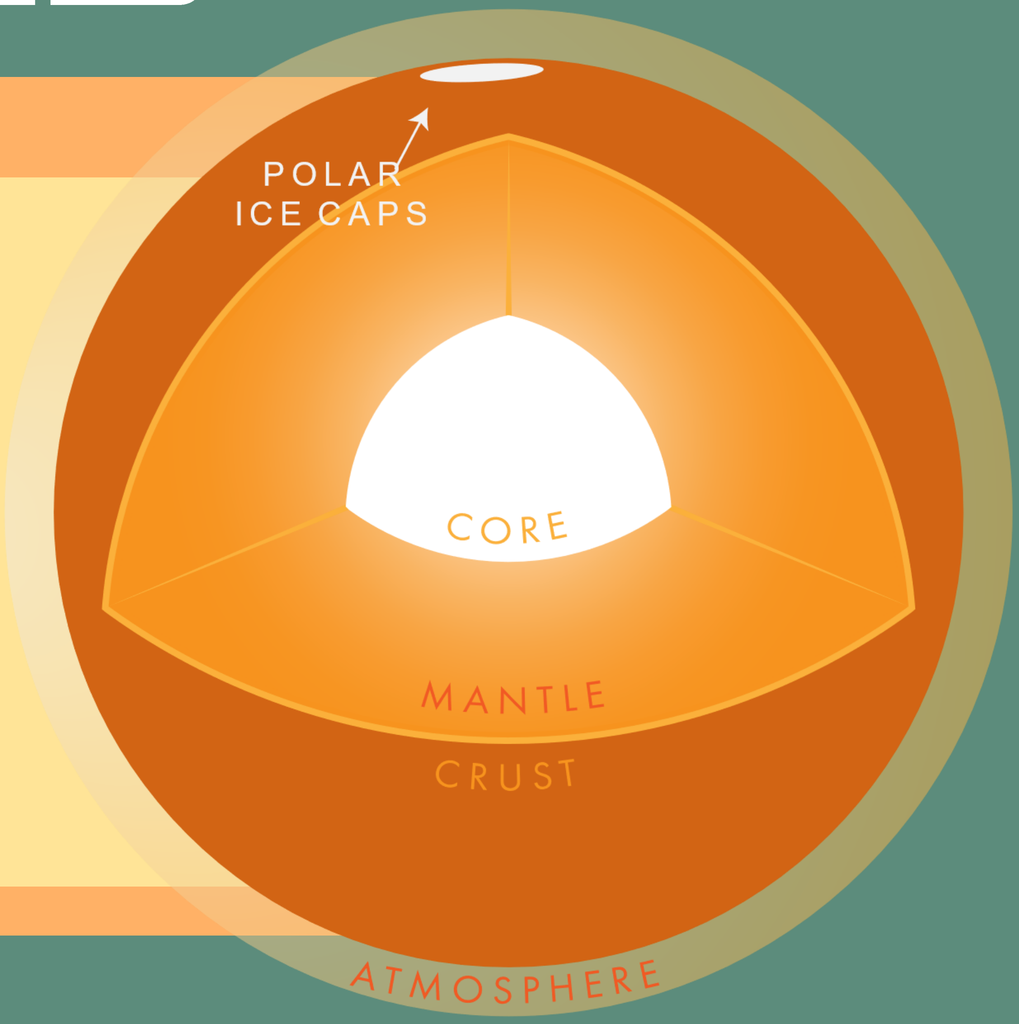
CURRENT CONDITIONS

Look no further for your favorite new summer vacation spot! Summertime in the lower **latitudes**, such as Ganges Chasma, would make for a quite comfortable stay at a balmy 24° Celsius. However, dust storm season is intense, and storms can range from the size of a small tornado to a planet-wide squall.

MARS

OVERVIEW

- Mars is the fourth planet from the Sun and about half the size of the Earth.
- It is home to both the deepest canyon (Valles Marineris at 7 km deep) and highest peaks (Olympus Mons at 21,000 m) in the solar system.



COMPOSITION

PLANETARY
Core: iron, nickel, and sulfur
Mantle: silicon, oxygen, iron, and magnesium
Crust: iron, magnesium, aluminum, calcium, and potassium

ATMOSPHERE
primarily carbon dioxide, nitrogen, and argon

DATA

MASS
6.42×10^{23} kg
0.11 x Earth mass

RADIUS
3,390 km
0.5 x Earth radius

VOLUME
1.63×10^{11} km^3
0.15 x Earth volume

ATMOSPHERIC PRESSURE
0.006 bars

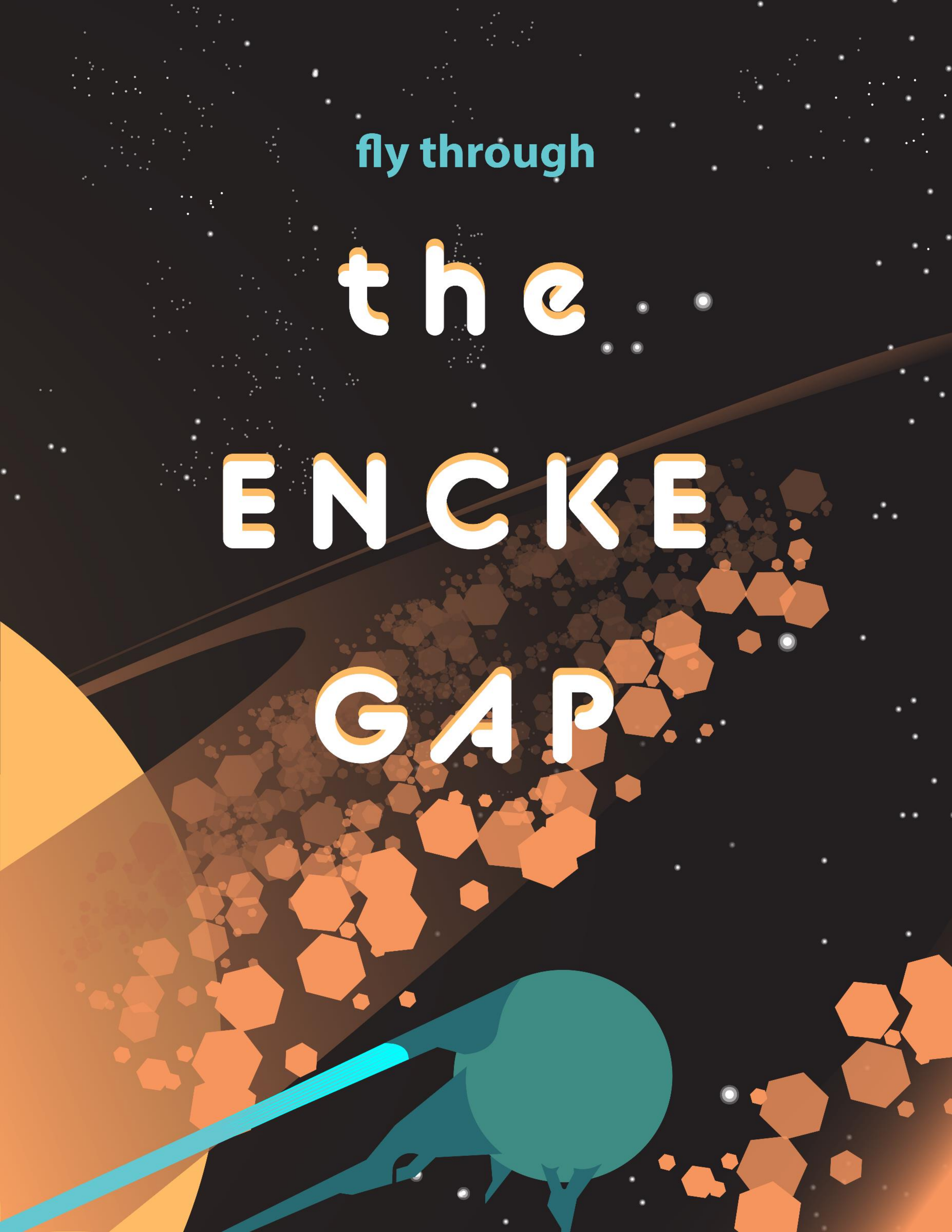
TEMPERATURE
Average: -28° C

ORBITAL PERIOD
687 Earth days

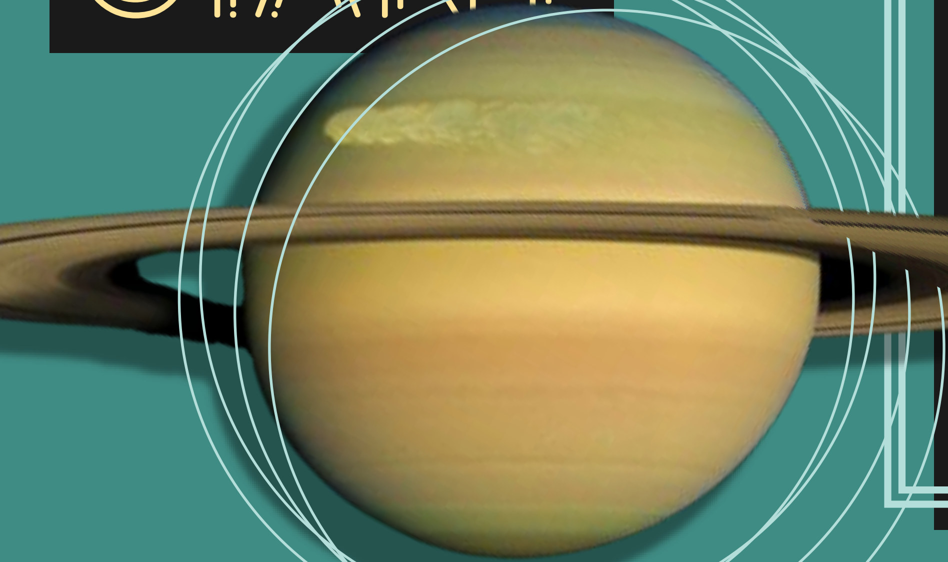
ROTATIONAL PERIOD
24.6 hours

GRAVITY
0.38 x Earth gravity

KNOWN MOONS
2


fly through
the
ENCKE
GAP

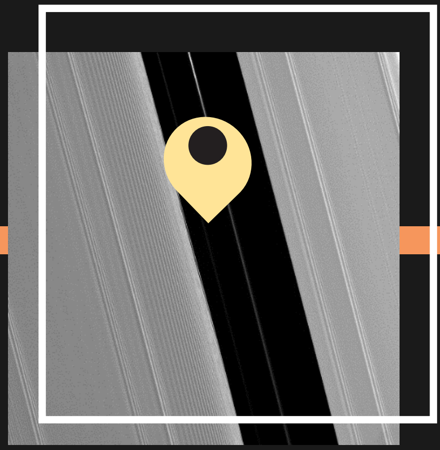
SATURN: GAS GIANT



DID YOU KNOW?

1. Saturn is the second gas giant from the Sun and the second largest planet in our solar system.
2. In the final stage of its study of Saturn, the spacecraft Cassini flew between Saturn and its rings several times, similar to the blue loops shown below.
3. Saturn's rings were likely formed from a moon that strayed too close and was torn apart by Saturn's gravity.

LOCATION OF INTEREST: ENCKE GAP



Saturn is most known for its multitude of rings. There is a gap called the Encke Gap within the A ring, which is about 350 km wide. The gap is caused by the orbit of Saturn's moon Pan.

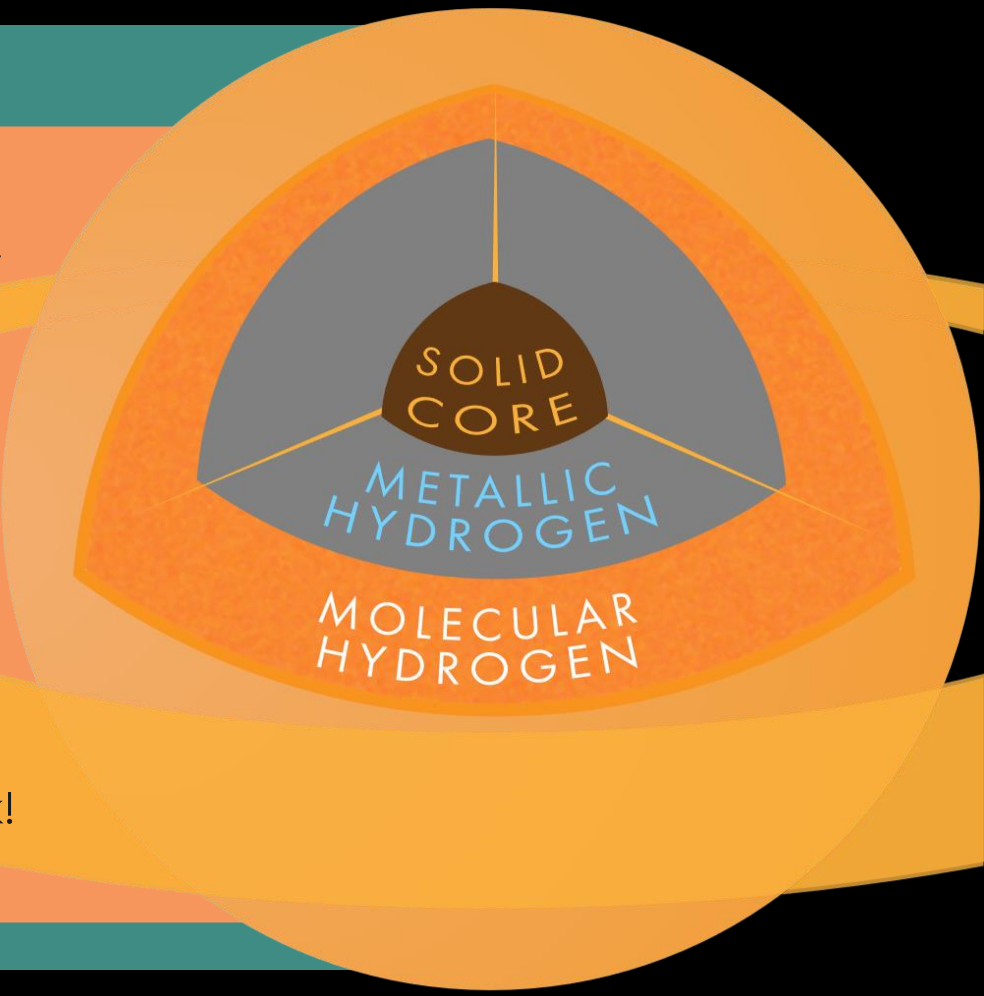
CURRENT CONDITIONS

The inner edge of the gap (on the left side) is rough and scalloped because of the disturbances Pan makes as it sweeps through the rings. Watch out for Pan as it sweeps by once every 0.58 days.

SATURN

OVERVIEW

- Even though it is the second largest planet, Saturn is the least dense. It is even less dense than water.
- If you lined up nine Earths, they would almost reach as wide as Saturn's diameter.
- Though its rings are wide enough to be visible from Earth, they are only 9 meters thick!



COMPOSITION

<u>CORE</u>
iron and nickel surrounded by liquid metallic hydrogen

<u>ATMOSPHERE</u>
primarily molecular hydrogen and helium

DATA

<u>MASS</u>
5.68×10^{26} kg
95 x Earth mass

<u>RADIUS</u>
58,200 km
9 x Earth radius

<u>VOLUME</u>
8.27×10^{14} km^3
765 x Earth volume

<u>ATMOSPHERIC PRESSURE</u>
>> 1,000 bars

<u>TEMPERATURE</u>
Average: -138° C

<u>ORBITAL PERIOD</u>
29 Earth years

<u>ROTATIONAL PERIOD</u>
10.7 hours

<u>GRAVITY</u>
1.07 Earth gravity

<u>KNOWN MOONS</u>
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ENCELADUS: SATURNIAN MOON

DID YOU KNOW?

1. Enceladus reflects almost 100% of the sunlight that strikes it, making it one of the brightest objects in the solar system.

2. Enceladus has at least 5 different types of terrain: cratered landscape, smooth landscape, plains, fissures, and breaks in the crust.

3. Some of the smooth terrain that does not show evidence of craters suggests recent geological activity.

LOCATION OF INTEREST: WATER PLUMES

Enceladus has plumes of icy water that are emitted from the tiger stripes in its surface. Some of the particles from these plumes accumulate to form Saturn's E-ring, and the rest fall back to the surface of Enceladus.

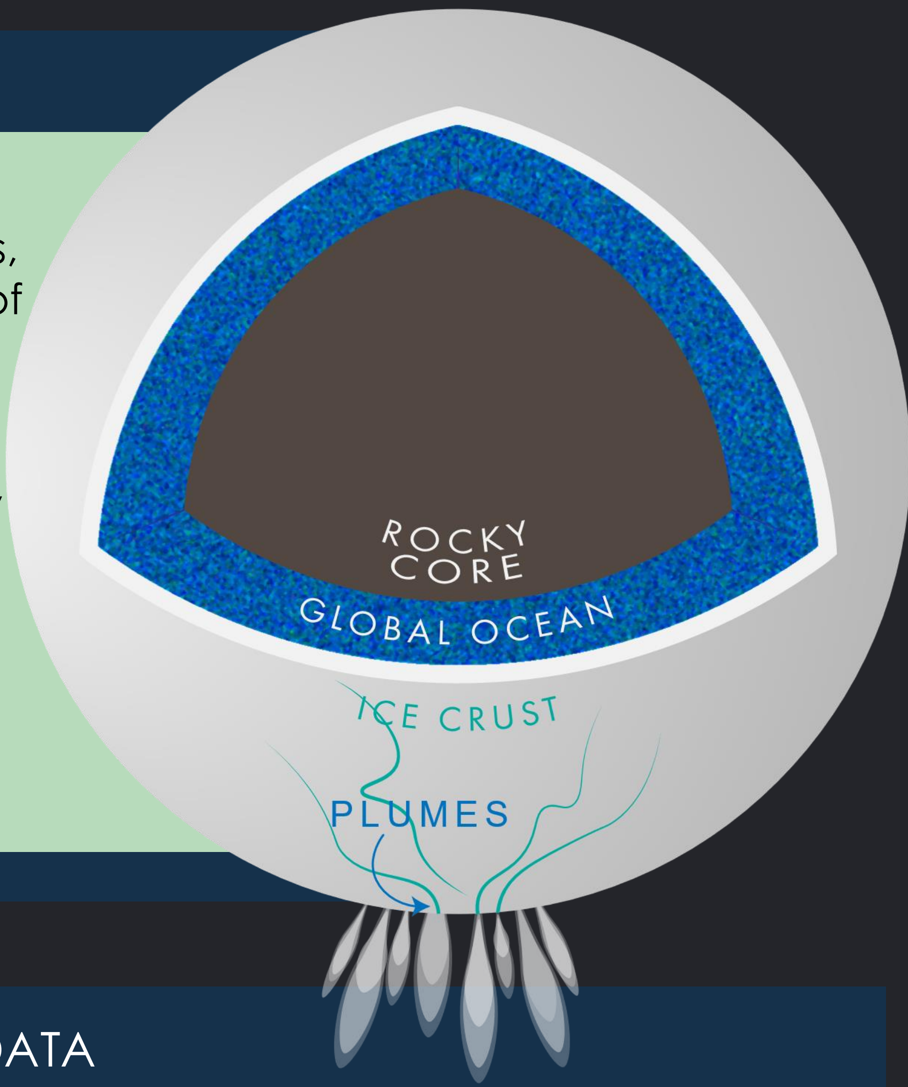
CURRENT CONDITIONS

It seems that these eruptions are continuous and jet out at about 400 meters per second, so be sure to watch out for icy particles shooting at your head from the ground while you visit this snowy destination.

ENCELADUS

OVERVIEW

- As one of the smallest of Saturn's spherical moons, the entire surface area of Enceladus is only 15% larger than that of the state of Texas.
- Despite its extremely low temperatures, the interior liquid ocean has not frozen, possibly because the presence of ammonia acts as antifreeze.



COMPOSITION

INTERIOR
Core: silicate rock and iron
Crust: ice water

EXOSPHERE
water vapor

DATA

MASS
1.08 x 10^{20} kg
0.00002 x Earth mass

RADIUS
252 km
0.04 x Earth radius

VOLUME
6.71 x 10^{7} km^3
0.0001 x Earth volume

ATMOSPHERIC PRESSURE
insignificant

TEMPERATURE
-201° C

ORBITAL PERIOD
1.4 Earth days

ROTATIONAL PERIOD
1.4 Earth days

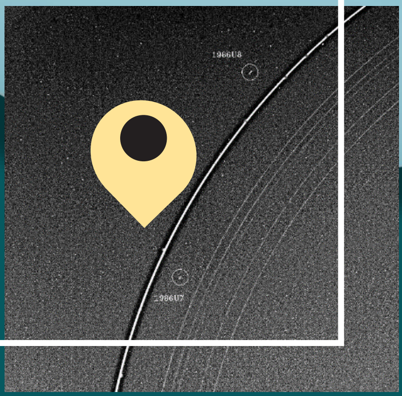
GRAVITY
0.01 x Earth gravity


BEAUTIFUL VIEWS OF
URANUS'
SHEPARD MOON
CORDELIA

URANUS: ICE GIANT

DID YOU KNOW?

1. It is believed that an Earth-sized object (not the Earth) collided with Uranus and knocked it onto its side.
2. Because it rotates sideways relative to other planets, Uranus's poles are located in its equatorial region.
3. Uranus' atmosphere is rich with methane, which is the reason for its blue quality.



LOCATION OF INTEREST: CORDELIA

Uranus has 27 known moons, the innermost of which is called Cordelia, shown above, marked by the location icon. Above it is a Uranian moon called Ophelia. Both are named after Shakespearean characters.

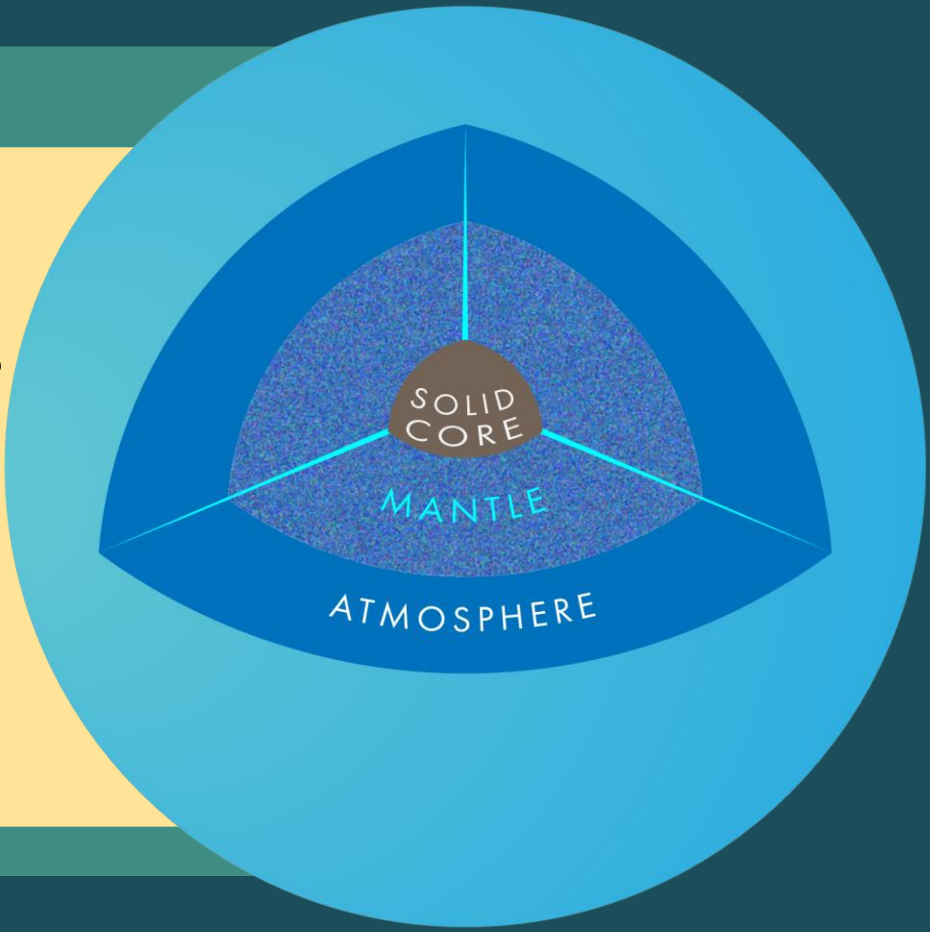
CURRENT CONDITIONS

Cordelia is a shepherd moon to Uranus, meaning that it shepherds the rings of Uranus, keeping them in orbit. It is likely that the surface of Cordelia consists of the dark, unprocessed carbon-rich material found on the C-class of asteroids.

URANUS

OVERVIEW

- Uranus is the first ice giant in our solar system.
- It was the first planet to be discovered by use of a telescope.
- Because of its sideways rotation, the north pole sees 21 years of nighttime in winter and 21 years of daytime in summer.



COMPOSITION

INTERIOR
Core: silicate rock
Mantle: water, ammonia, methane ice

ATMOSPHERE
primarily molecular hydrogen, helium, and methane

DATA

MASS
8.68×10^{25} kg
14.5 x Earth mass

RADIUS
25,400 km
4 x Earth radius

VOLUME
6.83×10^{13} km^3
63 x Earth volume

ATMOSPHERIC PRESSURE
>> 1,000 bars

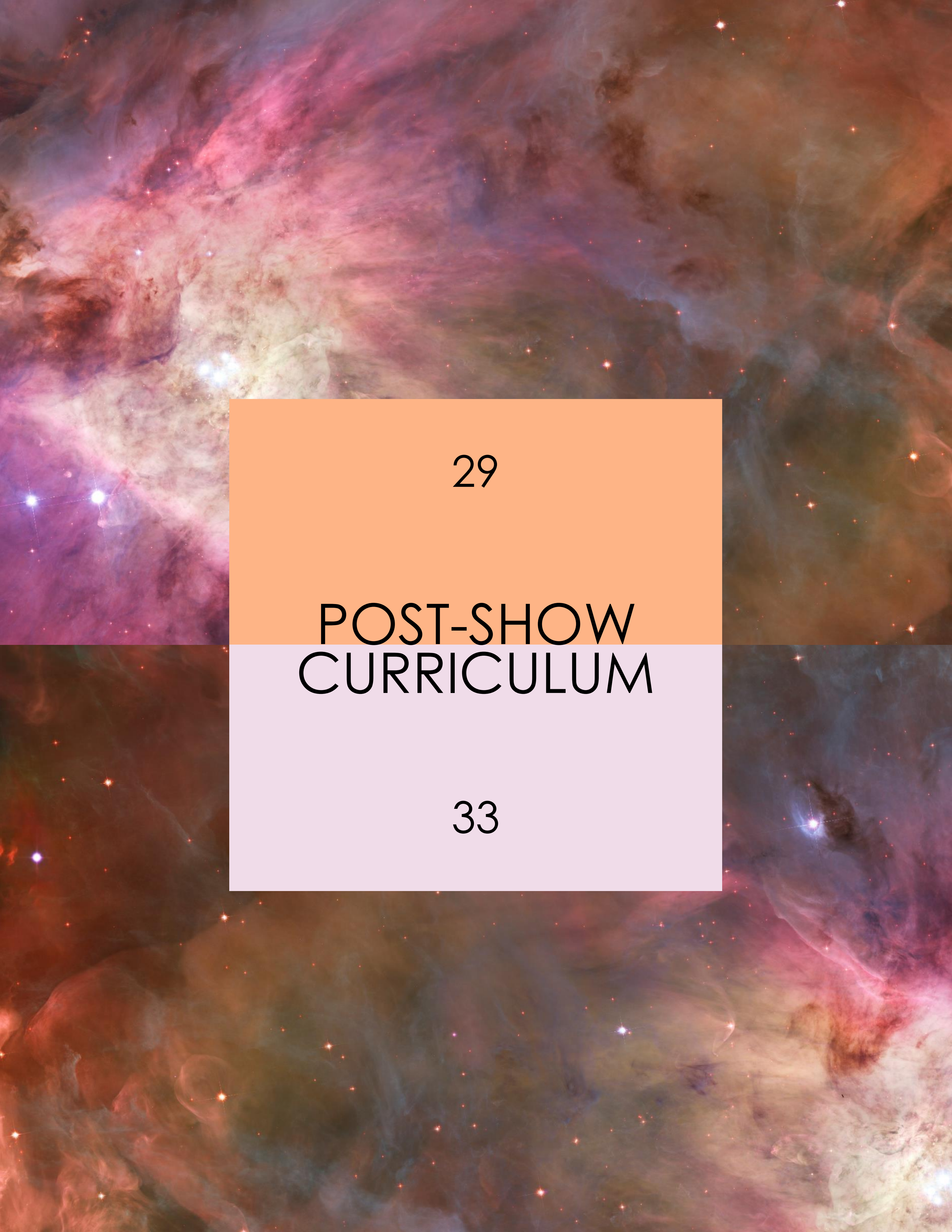
TEMPERATURE
Average: -195° C

ORBITAL PERIOD
84 Earth years

ROTATIONAL PERIOD
17.25 hours

GRAVITY
0.9 x Earth gravity

KNOWN MOONS
27



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POST-SHOW CURRICULUM

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OUR PLACE IN SPACE PRESENTATION ACTIVITY

THINKING CRITICALLY TOGETHER

OVERVIEW

Students will demonstrate the relative size of and distance between solar system objects and give a brief presentation of their findings. There are two options for this activity: design a tour presentation using WorldWide Telescope (a virtual telescope application at www.worldwidetelescope.org) or design a poster presentation.

OBJECTIVES

· Students will construct representations of solar system planets and fact sheets.
· Students will demonstrate knowledge of the relative size of and distance between solar system objects.
· Students will demonstrate communication skills by creating a presentation based on their research.

MATERIALS

(Option 1)
Computers with internet access

(Option 2)
Poster boards
Drawing materials: rulers, compass, pencils, markers, etc.

NATIONAL EDUCATION STANDARDS

NGSS: ESS1.B; ESS3.A; ESS3.B; PS2.B; LS2.A
CCSS ELA-Literacy: RI.4.4; RI.5.4; RI.5.9; RST.6-8.4; SL.4.1; SL.4.4; SL.4.5; SL.5.1; SL.5.5; SL.6.1; SL.6.4; SL.6.5

ACTIVITY INSTRUCTIONS

PHASE 1
Project Planning

· Divide class into groups (four students per group is recommended). For larger classes, a group working on asteroids and the asteroid belt or planetary moons is an option to lower the number of students in each group.

· Assign a solar system object to each group.

· Explain the project to the students, including expectations of their report and presentation. Have each group spend some time discussing their project and working together to distribute tasks (research, poster design, presentation, project management, etc.).

· Posters and presentations should include information on the group's assigned solar system object such as mass, composition, distinguishing surface features, habitability, science or commercial potential, etc.

PHASE 2
Research, Tour or Poster Design, and Presentation

Option 1: WorldWide Telescope Presentation

· Go to www.worldwidetelescope.org, a virtual telescope application called WorldWide Telescope

· Have each group conduct research on their object and prepare their presentation by selecting the "Create a New Tour" option in WorldWide Telescope. Presentations should incorporate 10 – 20 facts about the solar system object.

Option 2: Poster and Graphic Arts Presentation

· View the Solar System Overview section of this guide.

· Have each group assemble materials, conduct research, and design their poster. Presentation should include at least 10 – 20 facts about the solar system object.

· Have each team give a short presentation on their solar system object.

FOOTBALL FIELD SOLAR SYSTEM SCALE

THINKING CRITICALLY TOGETHER

OVERVIEW

Students will participate in demonstrating the relative size and distance between our solar system planets in an interactive and teambuilding activity. Measurements in this activity will be provided in English units rather than metric because you will be using a football field, which is measured in yards.

OBJECTIVES

· Students will construct representations of solar system objects.
· Students will demonstrate knowledge of the relative size and distance between solar system objects by creating a human scale solar system using a football field.

MATERIALS

Poster boards
Drawing materials: rulers, pencils, markers, crayons, etc.
Optional: camera (to take a picture of the students on the field)

NATIONAL EDUCATION STANDARDS

NGSS: ESS1.B
CCSS ELA-Literacy: RI.3.4; RI.3.5; RI.4.4; RI.5.4; RI.5.9; RST.6-8.4; WHST.6-8.2; RST.9-10.4; RST.11-12.4; SL.K.1; SL.K.5; SL.1.1; SL.1.5; SL.2.1; SL.2.5 SL.3.1; SL.3.4; SL.3.5; SL.4.1; SL.4.4; SL.4.5; SL.5.1; SL.5.5; SL.6.1; SL.6.4; SL.6.5; SL.7.1; SL.7.4; SL.7.5; SL.8.1; SL.8.4; SL.8.5; SL.9-10.1; SL.9-10.4; SL.9-10.5; SL.11-12.1; SL.11-12.5

Optional Phase 2 STEAM activity: CCSS Mathematics – 4.MD.1; 5.NBT.5; 5.NBT.7; 5.MD.1; 6.NS.2; 6.NS.3; 7.NS.3; 7.G.1

ACTIVITY INSTRUCTIONS

PHASE 1
Project Planning and Management

· Divide class into groups (four students per group is recommended). For larger classes, a group working on asteroids and the asteroid belt or planetary moons is an option to lower the number of students in each group.

· Assign a solar system object to each group.

· Have each group assemble materials and create a poster of their solar system object. The name of the solar system object should appear in large letters at the top of the poster so that it can be easily seen during the outdoor activity.

Note: During this time, the team will select an individual to represent their solar system object during the football field activity.

PHASE 2
Create Scale Solar System on the Football Field

· All teams proceed to the football field. They should bring their team posters and assemble at one of the end zones.

· Direct the placement of the students representing their groups' solar system objects according to the Scale Solar System Data sheet on the following page.

· Place the designated team members at the appropriate distance from the end zone. The designated team member should have their team poster with them to hold up on the football field at their solar system position.

Note: If planetary moons are used, place them to either side of and on the same yard line as their host planet. If asteroids and the asteroid belt are used, place asteroids randomly between Mars and Jupiter.

Note: We suggest taking a picture of the students on the field as they hold up their posters in their designated positions so that they can better grasp the visual effect of their project.

PHASE 3
Optional STEAM-Powered Activity

Using the scale of *1 inch = 1 million miles* used on the **Scale Solar System Data** sheet, each group can use the diameter of their solar system object to calculate how large their object would be at that scale. For example, the sun is *870,000 miles in diameter*. On our scale of *1 inch = 1 million miles*, the sun would be only *0.87 inches* wide or about *½ the size of a golf ball*.

SCALE SOLAR SYSTEM DATA

SUN:

- Place on the 0-yard line
- The sun is 870,000 miles in diameter
- On our scale of 1 inch = 1 million miles:
- The sun would be 0.87 inches wide
- About half the size of a golf ball

MERCURY:

- Place on the 1-yard line
- Mercury is 3031 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Mercury would be 0.003 inches wide
- About the size of a period: "."

VENUS:

- Place on the 1.86-yard line
- Venus is 7521 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Venus would be 0.0075 inches wide
- About the thickness of two one-dollar bills

EARTH:

- Place on the 2.58-yard line
- Earth is 7926 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Earth would be 0.0079 inches wide
- About the same size as Venus

MOON:

- Place the moon right next to the earth
- The moon is 2159 miles in diameter
- On our scale of 1 inch = 1 million miles:
- The moon would be 0.002 inches wide
- Twice the width of a human hair

MARS:

- Place Mars on the 3.93-yard line
- Mars is 4222 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Mars would be 0.0042 inches wide
- About the thickness of a dollar bill

JUPITER:

- Place Jupiter on the 13.43-yard line
- Jupiter is 88,729 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Jupiter would be 0.089 inches wide
- The thickness of a lollipop stick

SATURN:

- Place Saturn on the 24.63-yard line
- Saturn is 74,600 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Saturn would be 0.075 inches wide
- The thickness of a nickel

URANUS:

- Place Uranus on the 49.55-yard line
- Uranus is 32,600 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Uranus would be 0.032 inches wide
- Slightly less than the thickness of a dime

NEPTUNE:

- Place Neptune on the 77.61-yard line
- Neptune is 30,200 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Neptune would be 0.030 inches wide
- Slightly less than the thickness of a dime

PLUTO:

- Place Pluto on the 102-yard line
- Pluto is 1473 miles in diameter
- On our scale of 1 inch = 1 million miles:
- Pluto would be 0.001 inches wide
- The thickness of a human hair

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REFERENCES

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GLOSSARY

ACCELERATION DUE TO GRAVITY:
The rate at which velocity of a freely falling object changes over time, expressed in terms of the rate of increase of velocity per second: on Earth, it is 98.0665 meters per second per second is the standard.

ANTICYCLONE:
A large-scale circulation of winds around a central region of high atmospheric pressure, spinning clockwise in the Northern Hemisphere of a body and counter-clockwise in the Southern Hemisphere.

ASTERISM:
Any grouping of stars into a shape or pattern. Asterisms are not officially recognized and often vary from culture to culture. For example, Ursa Major is an official constellation, while the Big Dipper is a prominent and well-known asterism contained within it.

ASTEROID:
A small, rocky body orbiting the Sun. Large numbers of these are found in the asteroid belt, especially between the orbits of Mars and Jupiter. They can range in size from nearly 262 km across (Vesta) to dust particles.

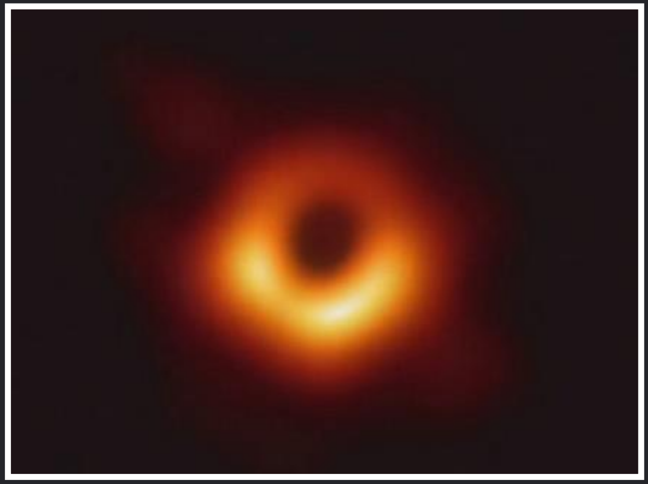
ASTEROID BELT:
A region of space between the orbits of Mars and Jupiter where most of the asteroids in our solar system are found orbiting the Sun.

ASTRONOMICAL UNIT (*AU*):
The unit of measurement that represents the mean distance between the Earth and our Sun. An AU is approximately 150 million km.

ATMOSPHERE:
The envelope of gases surrounding the Earth or another planet.

ATMOSPHERIC PRESSURE:
The force exerted against a surface by the weight of the air above the surface.

BLACK HOLE:
A region of space having a gravitational field so intense that no matter or radiation (light) can escape.



Pictured above: The first image taken of a black hole
Image credit: Event Horizon Telescope collaboration et al

COMET:
Celestial object consisting of a nucleus of ice and dust. When near the Sun, a "tail" of gas and dust particles form pointing away from the sun.

CONSTELLATION:
A group of stars forming a recognizable pattern that is traditionally named after its apparent form or identified with a mythological figure. Modern astronomers divide the sky into eighty-eight constellations with defined boundaries.

CORE:
Consists of the innermost layer(s) of a planet. Cores of specific planets may be entirely solid, entirely liquid, or a mixture of solid and liquid layers as is the case in the Earth. In our solar system, core size can range from about 20% (moon) to 85% of a planet's radius (Mercury).

CORONA:
The corona is the outermost part of the sun's atmosphere.

Pictured right: an image of the solar corona during a total solar eclipse, August 21, 2017

Image credit: NASA/Aubrey Gemignani

CRATER:
A bowl-shaped depression, or hollowed-out area, produced by the impact of a meteorite, volcanic activity, or an explosion. Craters produced by the collision of a meteorite with the Earth (or another planet or moon) are called impact craters.

CYCLONE:
A circulation of winds around a central area of low atmospheric pressure, spinning counterclockwise in the Northern Hemisphere of a body and clockwise in the Southern Hemisphere.

CRUST:
The outermost solid shell of a rocky planet, dwarf planet, or natural satellite

DENSITY:
A measurement that compares the amount of matter an object has to its volume. An object with a large amount of matter in a certain volume has high density.

DWARF PLANET:
A celestial body that orbits a star and is massive enough to be rounded by its own gravity, but has not cleared its neighboring region of planetesimals.

EFFECTIVE TEMPERATURE:
The temperature of a body's surface in the absence of an atmosphere.

ELECTROMAGNETIC SPECTRUM:
The entire range of wavelengths or frequencies of electromagnetic radiation extending from gamma rays to the longest radio waves and includes visible light.

EQUINOX:
The time or date (twice each year) at which the sun crosses the celestial equator, when day and night are of equal length (around September 22 and March 20 each year).

EXOSPHERE:
A thin, atmosphere-like volume surrounding a planet or natural satellite where molecules are gravitationally bound to that body, but where the density is too low for them to behave as a gas by colliding with each other.

GALAXY:
A system of millions or billions of stars, gas, and dust held together by gravitational attraction.

GAS GIANT:
A large planet of relatively low density consisting predominantly of hydrogen and helium, such as Jupiter and Saturn.

GRAVITY:
The force that attracts a body toward the center of the Earth or toward any other physical body having mass.

HELIOSPHERE:
The region of space that encompasses the solar system and in which the solar wind has a significant influence.

ICE GIANT:
A planet composed mainly of elements heavier than hydrogen and helium, such as oxygen, carbon, nitrogen, and sulfur. There are two ice giants in the solar system: Uranus and Neptune.

IONIZATION:
The process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons.

KUIPER BELT:
A region of our solar system that exists beyond the eight major planets, extending from the orbit of Neptune (at 30 AU) to approximately 50 AU from the sun. It is similar to the asteroid belt in that it contains many small bodies, all remnants from the formation of our solar system.

LATITUDE:
The lines circling a celestial body that run parallel to its equator. Usually expressed in degrees north or south of the equator.

LIGHT YEAR (*ly*):
A unit of astronomical distance equivalent to the distance that light travels in one year, which is 9.46×10^{12} km.

LONGITUDE:
The lines circling a celestial body that run from pole to pole. Usually expressed in degrees east or west of a designated prime meridian.

MAGNETIC FIELD:
Produced by churning motions of liquids at a planet's core that conduct electricity and have an electric charge. The magnetic fields act like giant bar magnets and can be offset from the rotation axis of a planet.

MANTLE:
A layer inside a planetary body between the core and the crust. Mantles are made of rock or ices and are generally the largest and most massive layer of the planetary body.

MASS:
The quantity of matter in a body, regardless of its volume or any forces acting on it.

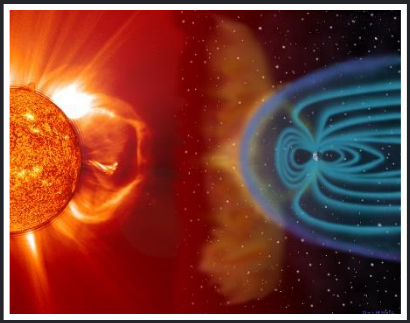
MATTER:
Anything that has mass and takes up space.

METEOROID:
A small, rocky or metallic body moving in the solar system that would become a meteor if it were to enter the Earth's atmosphere.

MOON:
A celestial body that makes an orbit around a planet, including the eight major planets, dwarf planets, and minor planets.

Pictured right: an illustration of radiation from the sun meeting Earth's natural protection, the magnetosphere

Image credit: NASA/SOHO



OORT CLOUD:
A theoretical spherical cloud of predominantly icy planetesimals that surrounds the sun at a distance up to 100,000 AU (2 lightyears).

PLANET:
A celestial body that (a) is in orbit around the sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighborhood around its orbit.

PROMINENCE:
A large, bright, gaseous feature extending outward from the sun's surface, often in a loop shape.

RADIATION:
The emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles, which cause ionization.

RADIUS:
A straight line from the center to the circumference of a circle or sphere.

REGOLITH:
A layer of loose, unconsolidated material covering solid rock. It includes dust, soil, broken rock, and other related materials and is present on Earth, the Moon, Mars, some asteroids, and other terrestrial planets and moons.

SIDEREAL DAY:
The time required for a planet to rotate once relative to the background of the stars, i.e., the time between two observed passages of a star over the same meridian of longitude.

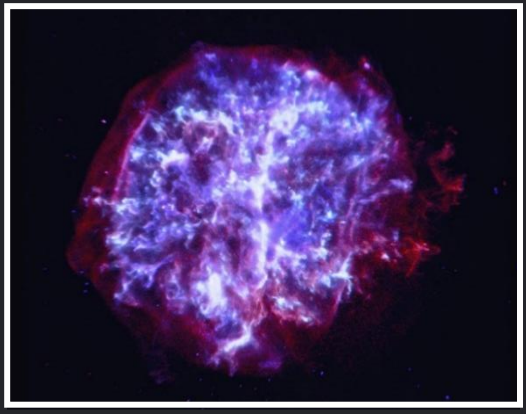
SILICATE ROCK:
Rock types that consist predominantly of silicate minerals and belong to one of three major classes: igneous, metamorphic, or sedimentary rock.

SOLAR DAY:
The time it takes for a planet to rotate about its axis so that the sun appears in the same position in the sky. On Earth, because the orbital motion of the Earth makes the sun seem to move slightly eastward each day relative to the stars, the solar day is about four minutes longer than the sidereal day.

SOLAR FLARE:
A brief eruption of intense high-energy radiation from the sun's surface, associated with sunspots and causing electromagnetic disturbances on the Earth, such as with radio frequency communications and power line transmissions.

SPEED OF LIGHT:
The distance light can travel in a unit of time through a given substance. Light travels through a vacuum at about 300,000 kilometers per second.

STAR:
A luminous ball of gas, mostly hydrogen and helium, held together by its own gravity.



Pictured above: a young supernova remnant about 20,000 light years away, catalogued as G292.0+1.8.

Image credit: NASA/CXC/SAO

SUNSPOTS:
Darker, cooler areas on the surface of the sun in a region called the photosphere. They are caused by interactions with the sun's magnetic field.

SUPERNOVA:
A star that suddenly increases greatly in brightness because of a catastrophic explosion that ejects most of its mass.

SUPERSONIC:
Involving or denoting a speed greater than that of sound (~340 meters per second).

TERRESTRIAL PLANET:
Composed primarily of silicate rocks or metals. Within the solar system, the terrestrial planets are the inner planets closest to the sun, i.e. Mercury, Venus, Earth, and Mars.

VOLUME:
A measure of the amount of space occupied by that object, not to be confused with mass.

WEIGHT:
The force of gravity on an object, defined as the mass times the acceleration due to gravity.

ONLINE RESOURCES

The following is a list of websites that can help shape and strengthen the educator's lesson plans for studies in space and science. These resources are free, safe, and will bring science to the classroom in an exciting and powerful way.

ASTRONOMY ACTIVITIES

American Museum of Natural History
https://www.amnh.org/explore/ology/astronomy
This site offers a variety of activities for students ages 7+, including crafts, informational articles, and space trivia quizzes.

DOCUMENTARIES

American Museum of Natural History
https://www.amnh.org/explore/videos
This resource displays links to an assortment of short documentaries regarding astronomy, Earth science, biology, and social perspectives.

INFORMATIVE SITES

NASA
https://science.nasa.gov/learners/wavelength
This link offers a collection of resources for science educators, peer-reviewed by educators and scientists.

INTERACTIVE STUDIES

Exploring By the Seat of Your Pants
http://www.exploringbytheseat.com/
This site is the homepage of an organization called Exploring By the Seat of Your Pants. They help teachers arrange virtual meetings with speakers and field trips with experts around the world.

Skype a Scientist
https://www.skypeascientist.com/
This program gives students the opportunity to interact via Skype with a real scientist.

NASA
https://solarsystem.nasa.gov/planets/earth/overview/
This link will take you to an interactive page where your students can explore, learn facts, study pictures, and gain a deeper understanding of each of the planets in our solar system.

WorldWide Telescope
https://worldwidetelescope.org
This program is basically a virtual telescope, allowing users to interact with and explore the universe via a browser on a computer or mobile device.

LESSON PLANS

NASA
https://www.nasa.gov/audience/foreducators/index.html
The link above will take you to a page where NASA provides detailed lesson plans updated weekly to enrich your STEM curriculum.

EDUCATION STANDARDS

The *INTUITIVE*® Planetarium strives to offer an educational experience that both fulfills the content requirements set by Next Generation Science Standards (NGSS) and fosters a lasting engagement with the material. The fulfilled standards include the following:

Another World: Solar System Exploration Activity

NGSS: ESS1.B; ESS2.A; ESS3.A; LS2.A
CCSS ELA-Literacy: RI.4.4; RI.5.4; RST.6-8.4; SL.4.1; SL.5.1; SL.6.1

"Our Place in Space" Planetarium Presentation

NGSS Earth and Space Science: 1-ESS1-1; 2-ESS2-1; 2-ESS2-2; 2-ESS2-3; 4-ESS2-1; 4-ESS2-2; 5-ESS1-1; 5-ESS1-2; MS-ESS1-1; MS-ESS1-2; MS-ESS1-3; MS-ESS2-2; MS-ESS2-4; HS-ESS1-4; HS-ESS2-5

NGSS Physical Science: K-PS3-1; 2-PS1-1; 5-PS1-3; 5-PS2-1; MS-PS1-1; MS-PS2-4; HS-PS2-4

"Our Place in Space" Presentation Activity

NGSS: ESS1.B; ESS3.A; ESS3.B; PS2.B; LS2.A
CCSS ELA-Literacy: RI.4.4; RI.5.4; RI.5.9; RST.6-8.4; SL.4.1; SL.4.4; SL.4.5; SL.5.1; SL.5.5; SL.6.1; SL.6.4; SL.6.5

Football Field Solar System Scale Activity

NGSS: ESS1.B
CCSS ELA-Literacy: RI.3.4; RI.3.5; RI.4.4; RI.5.4; RI.5.9; RST.6-8.4; WHST.6-8.2; RST.9-10.4; RST.11-12.4; SL.K.1; SL.K.5; SL.1.1; SL.1.5; SL.2.1; SL.2.5 SL.3.1; SL.3.4; SL.3.5; SL.4.1; SL.4.4; SL.4.5; SL.5.1; SL.5.5; SL.6.1; SL.6.4; SL.6.5; SL.7.1; SL.7.4; SL.7.5; SL.8.1; SL.8.4; SL.8.5; SL.9-10.1; SL.9-10.4; SL.9-10.5; SL.11-12.1; SL.11-12.5

Optional Phase 2 STEAM activity: CCSS Mathematics – 4.MD.1; 5.NBT.5; 5.NBT.7; 5.MD.1; 6.NS.2; 6.NS.3; 7.NS.3; 7.G.1