Which Planetary Bodies in Our Solar System Are Candidates For Life?

Introduction

If aliens are playing a game of planetary hide and seek with us, then our job is to find *them*. But where in this immense solar system should we begin to look, and what should we look for? If we could narrow the number of possible hiding places to a smaller number, then we could spend our time taking a close look at these places. If we could identify a few key conditions we feel confident are associated with life, then we could take a close look at places that have those conditions, and maybe life.

To decide where to look for aliens, you will need to think about what alien creatures might need in order to live and what the characteristics of their home planets might be.

See the *Activity At A Glance* and Procedure pages to see how this activity helps students understand life's key requirements and identify places in the solar system that might fulfill those requirements.

Activity At A Glance

Purpose
To understand life's key requirements and identify places in the solar system that might fulfill those requirements

Task for Students to Accomplish in This Activity
Using the information in the Planetary Information Sheets, identify the strongest candidates for life out of the nine planets and 61 moons in our solar system. This activity can be done equally well on-line or from printed versions of the pdfs.

Grade Level: 5-12

Time
- Day 1: Introduction, preassessment, compare habitability on Earth and Mercury
- Day 2: Identify factors essential for life, compare habitability on Venus and Jupiter
- Day 3: Students examine the remaining Planetary Information Sheets
- Day 4: Students identify the strongest candidates for life and present their choice(s)

Overview
Students begin by revealing their ideas of what alien life looks like. Next, they examine Information Sheets detailing each planet and the seven largest moons to become familiar with the actual conditions in our solar system. They rank the planets and moons as likely, possible, or unlikely places for life. After discussing the connections between planetary features and the possibilities for life, students refine their list. Finally, students synthesize their understanding by producing a poster report and debating contrasting positions.

Key Concepts
- Our solar system has nine planets and 61 moons.
- Except for Earth, life is not readily apparent on any planet or moon in our solar system.
- Life has basic requirements such as food, water, and a suitable temperature and habitat.
- Planetary features provide clues to specific geologic processes or planetary conditions. As a result, these features can be used to identify places that may be conducive to life.
- Looking for conditions conducive for life is easier than looking for actual organisms.
- Several of the planets and moons have or had conditions that might be conducive to life.
- Except for Earth, each planet/moon currently has major limitations for life, as we know it.
- If organisms exist in our solar system beyond Earth, they are probably very small.
- We are currently exploring our solar system with a series of robotic missions.

Key Skills
- *Interpreting* images and data
- *Comparing, Sorting,* and *Categorizing* data
- *Generalizing* and *Inferring* from observations
- *Drawing* conclusions and *Speculating*
- *Summarizing* information, *Synthesizing* understanding, and *Presenting* it clearly
- *Supporting* positions with evidence and *Debating* contrasting positions
- *Contributing* thoughtfully to group and class discussions

Materials
- Information Sheets on the planets and moons in the solar system
- Optional -- Supplemental astronomy materials such as texts and CD-ROMs

Preparation
- Collect supplemental astronomy materials
- Provide one set of Planetary Information Sheets for every student, if possible

Which Planetary Bodies in Our Solar System Are Candidates For Life?

Procedure

<u>Day 1: Introduction, preassessment, compare habitability on Earth and Mercury</u>

1. To get a sense of students' prior understanding and to have students take a position and become aware of their preconceptions, ask students, "What makes a planet/moon a good home for living things?" Have them hand in their answers.

   Teacher Note: *When students hand things into a teacher, they often express themselves more completely and clearly than when they just write for themselves. In addition, their responses give the teacher a good idea of students' preconceptions and range of understanding. At the end of the investigation, the teacher will return these responses, and the students will compare their ideas at the beginning and end of the investigation.*

2. To make sure they understand which factors are key in terms of life, conduct a class discussion to develop a set of criteria for habitability and to consider the kinds of life that might live in the conditions found in the solar system. You might ask:
   (a) In general terms what does life need? (*e.g., food, water, habitats, and conducive temperatures*)
   (b) What kinds of things might limit life? (*e.g., extreme temperatures, high levels of radiation such as UV, lack of food and water*)
   (c) Which type(s) of life are best able to survive dryness, low nutrient availability, UV radiation, extreme temperatures, etc.? (*e.g., plant? animal? microbe? large/small organisms?*)

3. To increase student awareness of what life needs and how planetary factors might impact life, have student groups examine Earth's and Mercury's Information Sheets and list as many things as possible that they think make Earth hospitable to life and Mercury seemingly inhospitable to life.

   Teacher Note: *Encourage students to identify specific factors important in supporting life and then compare these factors on both Earth and Mercury. For example:*

Factor Important to Life	Situation on Earth	Situation on Mercury
Temperature	The temperature range enables water to be liquid in nearly every part of Earth.	The side facing the sun is so hot that the chemicals in a cell would be destroyed. The dark side is so cold that chemicals in a cell couldn't react fast enough to support life.
Water	Liquid water circulates nutrients through the environment and prevents the toxic build-up of wastes by removing them.	There is no surface water. Mercury is so hot that any ground water would be very far below the surface.
Protection from Radiation	Our atmosphere shields us from harmful ultra-violet radiation from the sun.	Since there is no atmosphere, life would have to live underground to protect itself.
Atmosphere	Oxygen makes it possible to tap carbon-based energy sources (e.g., sugar, starch, & carbohydrates). Also, many organisms use the carbon dioxide as a carbon source.	There is virtually no atmosphere, so any organisms would be anaerobic and would extract their carbon from minerals containing carbon.
Energy Source	Plants capture sunlight and make possible the food chain. Some microbes can live off the chemical energy in inorganic compounds such as iron.	It's so hot that any life would have to be underground. Light can't penetrate the ground very deeply, so life would have to depend on chemical energy.
Nutrients	Everything we need to build our bodies is already on Earth.	In general, Mercury and Earth have the same chemical composition.

Day 2: Identify Factors Essential For Life, Compare Habitability On Venus And Jupiter

1. To help students differentiate between essential and non-essential factors important to life, have each group present one of the factors they thought made Earth hospitable and Mercury inhospitable and explain their thinking behind their choice. As a class, discuss the merits of each idea and decide how useful a criteria it is for judging the chances for life on one of our solar system's other planets or moons.

   Teacher Note*: Students should come away from this discussion with a clearer (it does not have to be perfect!) sense of what makes a planet conducive for life. What they need before going on is a rudimentary set of criteria for judging the possibility of life on a planet. These criteria will be refined in subsequent activities. For an overview to habitability, see the chart that accompanies this activity entitled "A Table of Key Factors Related to the Habitability of Planets and Moons."*

2. To see if their criteria can help them identify strong candidates for life, have groups examine Venus's and Jupiter's Information Sheets and assess the chances for life on these planets.

   Teacher Note*: Chances for life on both planets are considered almost nil. Venus is so hot that its surface is thought to have melted and remelted several times. If life had existed early in Venus' history, before a runaway Greenhouse Effect raised planetary temperatures to near the melting point of rock, the evidence would have been eradicated when the surface melted in fairly recent times (geologically speaking). Jupiter is made of gas. Gas is too diffuse to concentrate nutrients in a way that life requires. In fact, developing life in the first place requires bringing together compounds essential to life and keeping them together long enough so biotic molecules can form. Life on Earth is thought to have evolved in pools where nutrients could accumulate and become concentrated when water evaporated. In this regard, it is hard to imagine a similar sustained process leading to life on any gaseous planet. Other factors such as low temperatures, the release of large amounts of energy, and pressures thousands times that of Earth make Jupiter a highly unlikely candidate for life.*

3. To strengthen students' abilities to judge the possibilities for life on Venus and Jupiter, repeat the process outlined above in Step 1. As a class, discuss the merits of each idea and decide how useful a criteria it is for judging the chances for life on one of our solar system's other planets or moons.

   Teacher Note*: Students should come away from this discussion with a clearer sense of what makes a planet conducive for life. In this case, they should see that gaseous planets can essentially be eliminated as contenders. They should also refine their previous set of criteria for judging the possibility of life on a planet.*

Day 3: Students Examine the Remaining Planetary Information Sheets

1. To investigate the possibility of life in our solar system, have groups examine the rest of the Planetary Information Sheets and rank each planet as a likely, unlikely, or possible candidate for life. Groups should articulate their reasoning for their choices.

   Teacher Note: *This step is really a puzzle to solve – the Information Sheets contain a lot of information, some more germane to the question of life on other planets and some less. The students' job is to sort through the sheets and find the information that will help them identify the strongest candidates for life. Tell groups that their job is to rank each planet as a likely, unlikely, or possible candidate for life. Remind them that the criteria the class developed over the past two days should help them focus on the key parameters and evaluate each planet and moon. If you feel the students may be overwhelmed by the amount of information, start with the Planetary Information Sheets and introduce the Moon Information Sheets if and when you feel it is appropriate. The moons Europa and Titan have many characteristics deemed important for life, so having students consider moons as potential candidates will most likely increase their number of strong candidates. Sorting information and understanding its significance is an important skill, especially if students are expected to construct meaningful arguments. Provide students enough time to truly consider the available information.*

Day 4: Students Identify The Strongest Candidates For Life And Present Their Choice(S)

1. While the solar system offers quite a range of environments, each planet/moon currently has major limitations for life, as we know it (with the exception of Earth). Have every group prepare a poster report by ranking each planet/moon as either a strong, medium, or weak candidate for life. They should describe their reasoning, articulate what more they would like to know, and summarize their thinking in a table similar to the one below.

Planet/Moon Name	Life is Likely	Maybe (has some things but not all)	Life is Unlikely	Reasoning	Questions
Planet A	X				
Planet B			X		

2. Have each group present its determinations and debate contrasting points of view.

   Teacher Note: *You might want to keep a running tally of the positions developed in the class. Using a format similar to the one above, record each group's analyses on a class chart.*

3. To connect students' conceptions of life in the solar system with their examination of the realities of the solar system, have students answer the following questions:
   (a) What would you expect to see on a planet's or moon's surface if one of the factors that you feel are necessary for life existed there? Did you see any of these things?
   (b) Did you see any life or evidence for life (e.g., forests, cities, canals, roads, grasslands)?
   (c) Based on your examination of the solar system, what are the implications for what the size of organisms might be or where on a planet/moon one might find life?

   Teacher Note: *Depending on whether you want an assessment of student thinking or just have them discuss their work to this point, you can ask students to answer the questions individually or in groups.*

Extension: If students are interested in learning about current explorations of the solar system, have them visit some of the following Web sites that describe past, on-going and future missions:

- NASA's Jet Propulsion Laboratory: http://www.jpl.nasa.gov/
- NASA's Atmospheric Experiment Branch: http://webserver.gsfc.nasa.gov/nojava/missions.html
- NASA's National Space Science Data Center: http://nssdc.gsfc.nasa.gov/planetary/planetary_home.html
- Hawaii Astronomical Society: http://www.hawastsoc.org/solar/eng/homepage.htm

Questions to Follow Up the Investigation

These questions can be used in several ways such as homework, group work, or as assessments.

1. How would you contrast the planets that are likely candidates for life and those that are only moderate possibilities for life? Unlikely candidates for life?
2. What indicators tell us that there is/was life on a planet/moon?
3. As we look for life in our solar system, what should we be looking for?
4. Should we only consider current conditions when thinking about the possibility of life in our solar system?
5. What does the term "alien" mean in our solar system?
6. What does the term alien mean beyond our solar system (i.e., in the galaxy and universe)?
7. How does your current idea of alien life compare with your idea of alien life when you began the investigation?
8. Why might finding actual organisms (alive or fossilized) in the solar system be difficult?
9. How is the search for single-cell life is different than the search for larger life forms?
10. If you were designing a mission to look for evidence of past or present life in the solar system, how would you structure your search?

Questions for Pilot Test Teachers to Consider

(a) What does the word alien mean to students? Do students ever consider an alien's home planet when they discuss aliens? What did they expect to see on the planet surfaces?

(b) What was the students' experience with the Information Sheets? (i.e., amount of information, presentation of information, age-appropriateness of the information)

(c) Did the Information Sheets provide sufficient information to differentiate one planet from another and to have any of them seem like possible candidates for life?

(d) How much time is really required for students to become familiar with the information on the Information Sheets and to identify the elements that make a planet habitable?

(e) How well were students able to identify the salient parameters that might affect life?

(f) How well did students articulate that different types of organisms have different needs?

(g) How did students' notions or the solar system change? Of aliens in our solar system?

(h) How did you wrap up this segment?

(i) What kinds of questions came up in discussions?

(j) Were your students interested in continuing any part of this investigation?

(k) What kind(s) of background information or previous science experience would help students be more successful with this activity?

(l) How would you change this investigation to work better with your students?

A Table of Key Factors Related to the Habitability of Planets and Moons

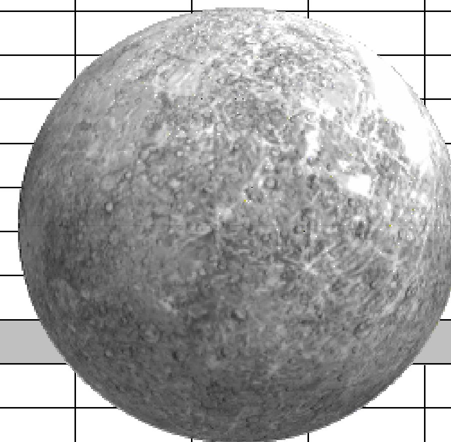
There are certain preconditions a planet or moon must meet in order to be habitable, and several are listed in the *Factor* column below. The middle column explains why each factor is necessary for life, and the last column describes a variety of ways to achieve these conditions. Because there is more than one way to meet these conditions, one can imagine life arising and/or persisting on quite a variety of planets/moons. This sheet can help you think about each planet or moon in our solar system and assess how strong a candidate it is for having life, either past or present.

Factor	Why It's Important for Life	Ways of Achieving It
Conducive Temperature Range	· Maintains biologically-active molecules such as proteins (too much heat can destroy molecules) · Enables chemicals to react efficiently (reaction rates slow down in colder temperatures. At some point they get so slow that they cannot proceed quickly enough to support processes needed for living. When temperatures are too hot, molecules break apart.)	· If the planet is cold, tap an internal heat source · Orbit an external heat source at the right distance (e.g., Earth) · Avoid wild temperature swings by moderating heat loss such as with an atmosphere · Avoid runaway greenhouse effect by orbiting a star that gives off low to moderate amounts of infrared energy which won't overheat a planet (Earth is an example of this) · Have temperature sensitive processes that help regulate planetary temperatures (e.g., Earth's carbonate-silicate cycle)
Energy Source	· Drives an organism's metabolism and cellular processes	· Using a planetary-based energy source (e.g., chemical energy) · Using an energy source external to the planet (e.g., light energy)
Liquid Water	· Makes nutrients available through weathering · Circulates nutrients through the environment · Prevents toxic build-up of wastes by removing them	· Surface water · Sub-surface water · Water beneath ice caps
Nutrients	· Provide the building blocks for biotic molecules such as proteins and carbohydrates	· Planets/moons have the necessary chemicals in the right form · Recycling processes turn chemicals into biologically-usable forms · Consumers are dependant on producers
Shielding	· Protects organisms from damaging ultra violet radiation	· Liquid water shields organisms below one to two meters · Ice blocks UV radiation · Gaseous atmosphere, and especially ozone, absorbs UV radiation · Solid surface layers block UV radiation completely
Time	· Enables life to arise and diversify · Long-term environmental stability enables increasingly complex organisms to evolve · Catastrophic events (e.g., collisions with large meteors) shorten the time for life to become established or for organisms to evolve. Once life is established, additional major catastrophic events will favor simpler organisms by making life for specialized or complex organisms more difficult.	· Limit the number of catastrophic events. One way to do this is to be in a system with several large planets such as Jupiter that attract much of the inter-planetary debris such as asteroids drifting about. · Orbit a stable, long-lived star such as our sun · Move to a new planet such as when microbes travel on meteorites that have been blasted from a planet's surface or humans using rockets to travel to another planet.

Nat'l Science Standards Addressed in Candidates Activity

Unifying Concepts and Processes	
√	Systems, Order, and Organization
√	Evidence, Models, and Explanation
√	Constancy, Change, and Measurement
√	Evolution and Equilibrium
√	Form and Function
Science as Inquiry	
	Abilities Necessary to do Scientific Inquiry
√	Understandings about Scientific Inquiry
Physical Science	
	Structure of atoms
	Structure and Properties of Matter
√	Chemical Reactions
	Motions and Forces
	Conservation of Energy and Increase in Disorder
√	Interactions of Energy and Matter
Life Science	
√	The cell
	Molecular Basis for Heredity
	Biological Evolution
√	Interdependence of Organisms
√	Matter, Energy, and Organization in Living Systems
	Behavior of Organisms
Earth and Space Science	
√	Energy in the Earth System
√	Geochemical Cycles
√	Origin and Evolution of the Planets
√	Origin and Evolution of Planetary Systems
	Origin and Evolution of the Universe
Science and Technology	
	Abilities of Technological Design
√	Understandings about Science and Technology
Science in Personal and Social Perspectives	
	Personal and Community Health
	Population Growth
	Natural Resources
	Environmental Quality
√	Natural and Human Induced Hazards
	Science & Technology in Local, National, & Global Challenges
History and Nature of Science	
	Science as a Human Endeavor
√	Nature of Scientific Knowledge
	Historical Perspectives

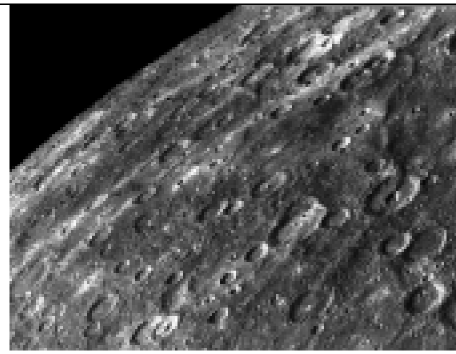
Fast Facts About Mercury



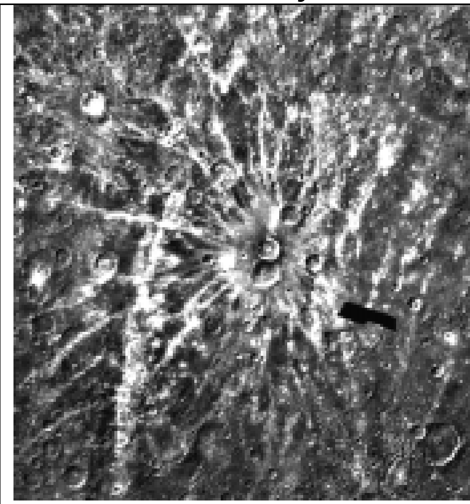
Planetary Parameters		Ratio (Mercury/Earth)
Planet Type	Terrestrial (i.e., a solid, rocky planet like Earth)	
Average Distance from Sun (kilometer)	57,910,000 as compared to Earth's 149,600,000	0.39
Equatorial Diameter (kilometer)	4,878 as compared to Earth's 12,756	0.38
Mass (10^{24} kilogram)	0.33 as compared to Earth's 5.9736	0.06
Volume (10^{10} $kilometer^3$)	6.1 as compared to Earth's 108.321	0.06
Average Density ($gram/centimeter^3$)	5.43 as compared to Earth's 5.52	0.98
Surface Gravity ($meter/second^2$)	3.7 as compared to Earth's 9.78	0.38
Magnetic Field ($gauss\text{-}Rh^3$)	0.0033 as compared to Earth's 0.3076	0.01
Orbital Parameters		
Year Length (One Orbit Around the Sun)	87.9 Earth days	
Day Length (One Rotation on its Axis)	58.8 Earth days	
Inclination of Axis (degrees)	0.1 as compared to Earth's 23.45	
Atmosphere and Climate		
Average Surface Temperature (C)	167 as compared to Earth's 14.8	
Maximum Temperature (C)	452 on the sunny side as compared to Earth's 47	
Minimum Temperature (C)	-183 on the shady side as compared to Earth's -33	
Atmospheric Pressure at Surface	1 x 10-12 millibar (Earth = 1,014 millibar)	
Major Atmospheric Gasses	42% Oxygen, 29% Sodium, 22% Hydrogen, 6% Helium, 0.5% Potassium, trace water vapor and carbon dio	
Summary of Water	No surface water or rainfall	
Summary of Climate	Most of the gasses in the atmosphere have been stripped away by the intense solar wind to which Mercury is exposed. With so little gas, no climate exists.	
Planetary Features		
General Overview	Looks like Earth's moon. Surface is fractured with compressive fractures that occurred when Mercury shrank after its core and mantle cooled.	
Composition of Poles	Amazingly, two ice poles may possibly exist at the bottom of deep craters that provide perpetual shadow.	
Core Composition	A cold core comprised of iron and nickel	
Known Moons/Rings	No moons, no rings	
Visits to Mercury		
1950-99	In 1974, Mariner 10 flew by twice, and once again in 1975. Only half of the planet has been imaged.	

Some Views of the Planet Mercury

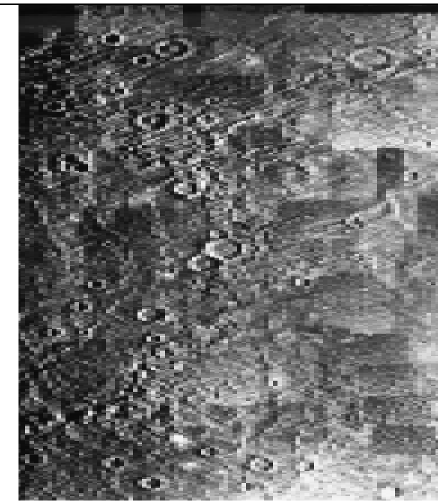
(1) In 1974 and 1975, Mariner 10 flew past Mercury three times. It is the only mission to visit Mercury. This image was taken from 200,000 km away. The light-colored crater in the upper-left is 160-km across.



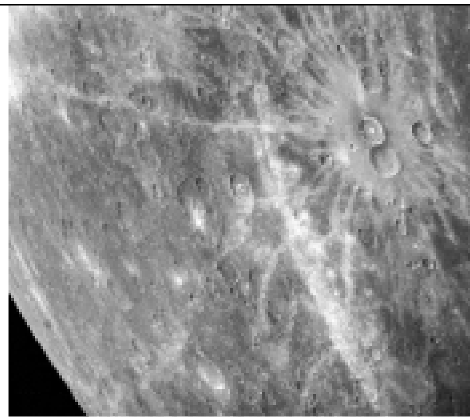
(2) This view of Mercury is 500 km across. You can see a faint ridge snaking along the right side of the image. This is the 450-km long Antoniadi ridge. You can see it best as it crosses an 80-km wide crater in the right center of the image.



(3) The bright-rayed Degas crater is 45-km across. The image is made from several smaller ones. The black section shows where some information is missing.

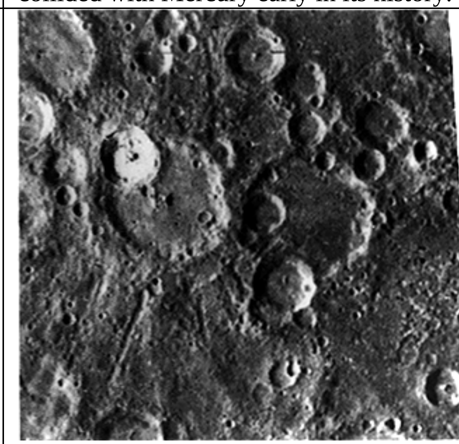


(4) The 1,300-km wide Caloris Basin, Mercury's most prominent feature, formed when a massive, asteroid-sized object collided with Mercury early in its history.



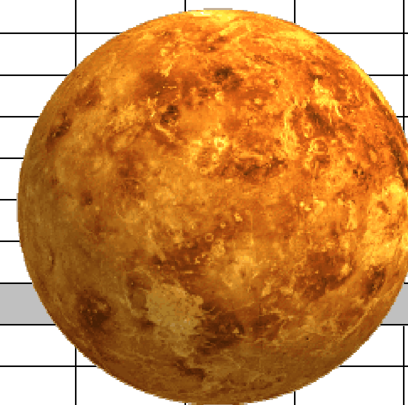
(5) This view of Degas crater shows the light-colored rays covering other features, indicating that the rays are younger features. By counting how many craters are in an area and by looking at how the debris thrown from the crater covers the surrounding features, people can figure out the age of an area or event. Degas is one of the most recent craters on Mercury.

(6) This hilly terrain is exactly opposite the Caloris Basin. Shock waves from the impact that created the Caloris Basin were focused on this point after they traveled through Mercury. They broke the crust into a series of complex, jumbled blocks. This image is 100 km across and the large crater on the left is 35 km across. North is toward the top of the image.



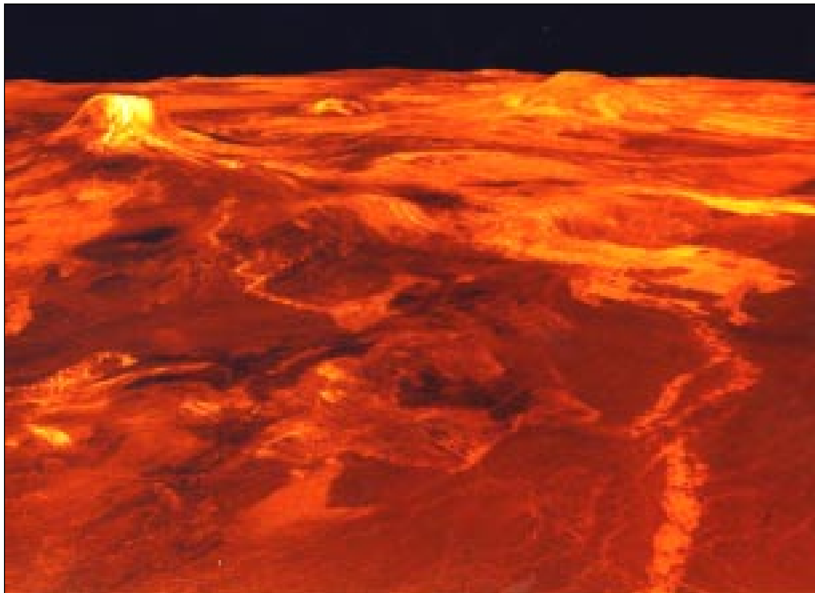
(7) Murasaki crater (the large crater in left center) is 125 km across. You can tell that the Kuiper crater on its rim is younger because it is on top of the older crater. Hiroshige crater (right) is 140 km in diameter. North is toward the top of the image.

Fast Facts About Venus

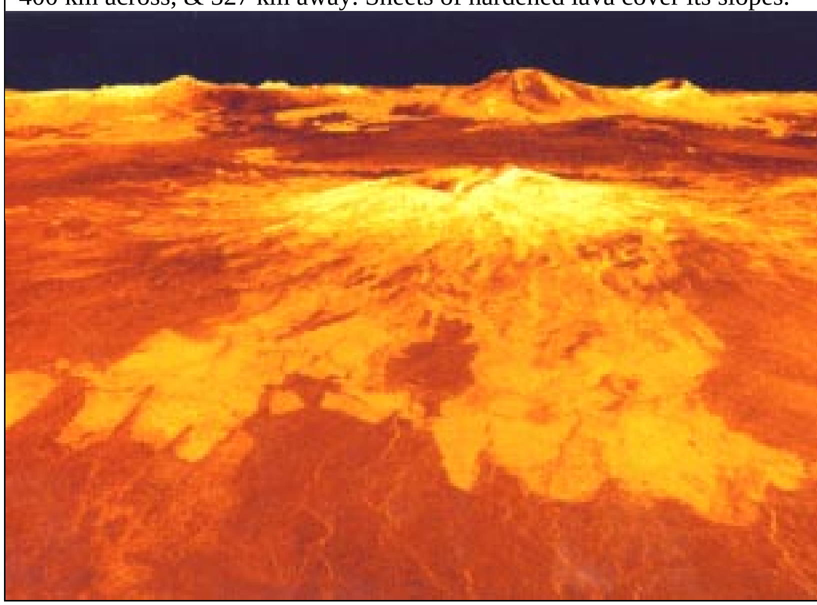


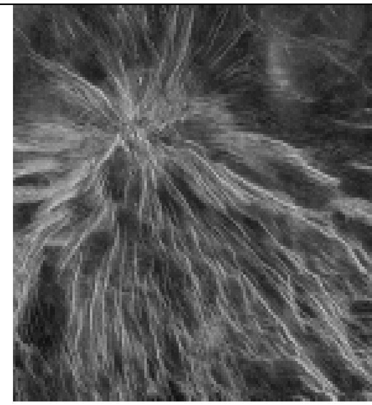
Planetary Parameters		Ratio (Venus/Earth)
Planet Type	Terrestrial (i.e., a solid, rocky planet like Earth)	
Average Distance from Sun (kilometer)	108,200,000 as compared to Earth's 149,600,000	0.72
Equatorial Diameter (kilometer)	12,104 as compared to Earth's 12,756	0.95
Mass (10^{24} kilogram)	4.869 as compared to Earth's 5.9736	0.82
Volume (10^{10} $kilometer^3$)	92.843 as compared to Earth's 108.321	0.86
Average Density ($gram/centimeter^3$)	5.2 as compared to Earth's 5.52	0.94
Surface Gravity ($meter/second^2$)	8.87 as compared to Earth's 9.78	0.91
Magnetic Field ($gauss\text{-}Rh^3$)	None detectable	
Orbital Parameters		
Year Length (One Orbit Around the Sun)	224.7 Earth days	
Day Length (One Rotation on its Axis)	243.7 Earth days	
Inclination of Axis (degrees)	177.3 as compared to Earth's 23.45	
Atmosphere and Climate		
Average Surface Temperature (C)	464 as compared to Earth's 14.8	
Maximum Temperature (C)	484 as compared to Earth's 47	
Minimum Temperature (C)	377 as compared to Earth's -33	
Atmospheric Pressure at Surface	92 bar (Earth = 1 bar). This pressure exerts a force of 65 kg/m^3 as compared to Earth's atmosphere that exerts a force of 1.217 kg/m^3 at sea level.	
Major Atmospheric Gasses	96.5% Carbon Dioxide, 3.5% Nitrogen, 20 ppm Water	
Summary of Water	No surface water or rainfall	
Summary of Climate	Intense greenhouse effect	
Planetary Features		
General Overview	Planet hidden under sulfuric acid clouds. 85% of surface is volcanic rock and lava flows. 15% is mountainous terrain deformed by geologic activity. According to recent reports, the large amount of volcanic surface material suggests that Venus has gotten hot enough to completely melt the surface several times over its history.	
Composition of Poles		
Core Composition		
Known Moons/Rings	No moons, no rings	
Visits to Venus		
1950-69	1962: Mariner 2 (US), fly-by	
1970-79	1970: Venera 7 (USSR), failed landing; 1972: Venera 8 (USSR), lander, sent an hour of data; 1974: Mariner 10 (US), flyby; Venera 9 (USSR), orbiter; 1978: Pioneer Venus Orbiter (US), also dropped four probes.	
1980-99	1984: Veneras 15 & 16 (USSR), orbiters that mapped the surface and analyzed the atmosphere; 1984: Vegas 1 and 2 (USSR), dropped landers & probe; 1989: Magellan (US), orbite	

Some Views of the Planet Venus

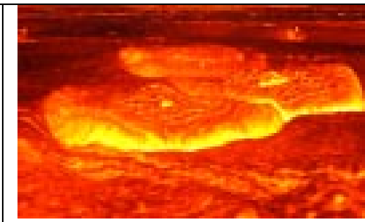


1) The regions of Venus pictured above and below are far apart. Even so, volcanic features such as lava channels, volcanos, and large-scale lava flows predominate. The volcano Gula Mons (above, left) is 3 km high & 1310 km away. The volcano Sapas Mons (below, front) is 1.5 km high, 400 km across, & 527 km away. Sheets of hardened lava cover its slopes.

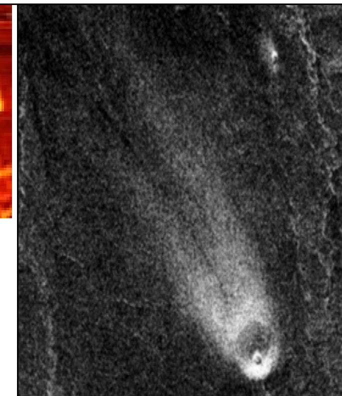




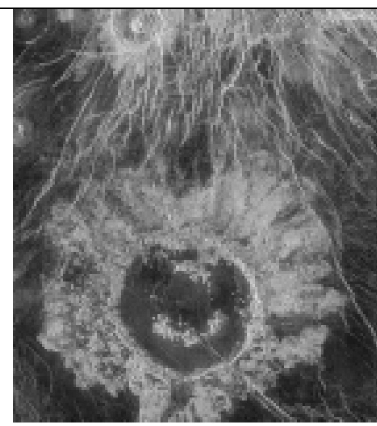
2) This image is 250 km across. It shows a radial fracture pattern (called a *Nova*). Novae occur when magma rises toward the surface, bulging it upward. Fractures radiate out from the center of the bulge. In some places, the magma breaks through the surface, creating lava channels or pancake domes such as the two pictured in Image 3.



3) Round, flat-topped, steep sided hills occur when thick lava is extruded onto level ground and flows slowly and evenly in all directions. Above, the hills are 750 m tall and 25 km across. Below the hills are 62 km across.



4) This volcano is 5 km across. As it erupted, winds blew the ash and materials in its plume, creating a wind streak 10 km wide and 35 km long. Even with its thick atmosphere and high temperatures, Venus' winds as measured by spacecraft are modest (1 to 3.6 km per hour).



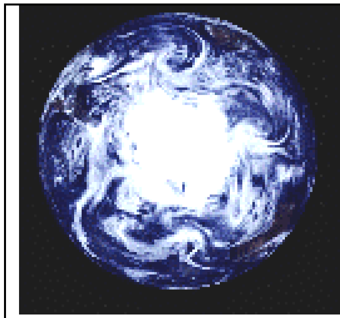
5) Bright lava channels surround 72 km Wheatly crater. Compared to other planets, craters on Venus are rare, supporting the idea that the surface has recently melted.

6) Earth's crust stays solid because its internal heat is dispersed by the cool atmosphere. On Venus, the combination of internal heat and a hot atmosphere can raise surface temperatures to above the melting point of rock. The many volcanic features and lack of craters suggest that Venus' crust has completely melted several times. In this image (70 x 160 km), parts of the surface have melted, creating depressions and lava channels.

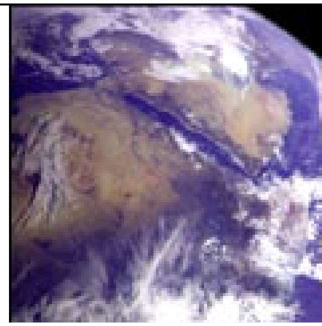
Fast Facts About Earth

Planetary Parameters	
Planet Type	Terrestrial (i.e., a solid, rocky planet)
Average Distance from Sun (kilometer)	149,600,000
Equatorial Diameter (kilometer)	12,756
Mass (10^{24} kilogram)	5.9736
Volume (10^{10} $kilometer^3$)	108.32
Average Density ($gram/centimeter^3$)	5.52
Surface Gravity ($meter/second^2$)	9.78
Magnetic Field ($Gauss\text{-}Re^3$)	0.3076
Orbital Parameters	
Year Length (One Orbit Around the Sun)	365.26 Earth days
Day Length (One Rotation on its Axis)	23.93 Earth hours
Inclination of Axis (degrees)	23.45
Atmosphere and Climate	
Average Surface Temperature (C)	15
Maximum Temperature (C)	47
Minimum Temperature (C)	-33
Atmospheric Pressure at Surface	1,014 millibar. The Earth's atmosphere exerts a force of 1.217 kg/m^3 at se
Major Atmospheric Gasses	78% Nitrogen, 21% Oxygen, 1% Water Vapor, 350 ppm Carbon Dioxide
Summary of Water	Water exists in all three states at the surface and 75% of surface covered
Summary of Climate	There is an active water cycle which circulates water and heat energy around the planet. The water cycle enables processes such as recharging surface ground water supplies, weathering, and erosion to exist. In addition, clouds reflect 30% of the incoming solar radiation.
Planetary Features	
General Overview	The molten mantle enables there to be plate tectonics which is critical for recycling materials in the crust - old crust is continually destroyed and new crust is continually made. In this way, carbon which can exist as carbon dioxide gas or as a solid in carbonate rocks can cycle between the crust and atmosphere and help maintain a stable climate. One reason life was able to arise on Earth is because the conditions have been so stable over the past four-billion years.
Composition of Poles	2 water ice poles. The poles expand and contract in response to long-term global temperature levels, and this change in size influences sea level.
Core Composition	A solid iron and nickel core is surrounded by a molten mantle. A thin, solid crust floats on top of the mantle.
Known Moons/Rings	1 large moon, no rings. Recent reports suggest that the moon was created when a Mars-sized object collided with Earth over four-billion years ago. The large moon helps stabilize Earth's inclination. Large changes in inclination cause large climatic changes and ruin the stability life requires in order to arise.
Visits to Earth	
1950-59	1957: Sputnik (USSR) became first artificial satellite; 1959: Luna 1 (USSR) first successful mission to the moon and first spacecraft to leave Earth's gravity
1960-69	1960: TIROS I (US), first weather satellite; 1961: Vostok 1 (USSR) carried first human into space; 1964: Nimbus 1 (US) began a series of missions to study Earth's atmosphere, geology, and oceans; 1968: Apollo (US) astronauts orbit the moon; 1969: Apollo 11 (US), first manned lunar landing
1970-79	1972: Landsat (US) satellite series begins; 1973: Skylab (US) manned space station; 1976: LAGEOS (US) tracks movement of Earth's surface; 1978: TOMS (US) studies Earth's ozone layer
1980-89	1984: Earth Radiation Budget satellite begins to study Earth's reaction to the Sun's energy.
1990-99	1991: UARS (US) collects data on atmospheric chemistry and physics; 1992: OPEX/Poseidon (US) studies Earth's oceans and climate; 1998: Earth Observing Satellite (EOS) (US) launched, EOS is a 10-year series of satellites.

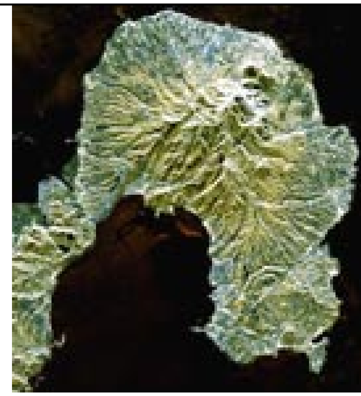
Some Views of Planet Earth



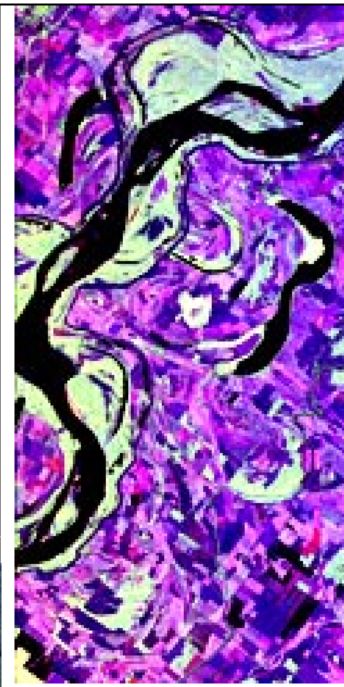
1) Storm systems and oceans surround Earth's South Pole. What elements important to life can you see?



2) Clouds over the Arabian Peninsula, the Indian Ocean, and the Red & Mediterranean Seas. What about this scene suggests that Earth is hospitable to life?

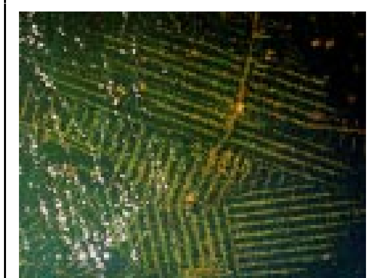


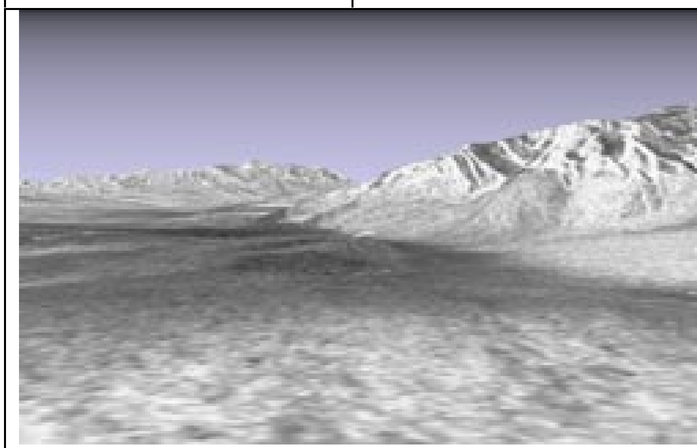
3) This Hawaiian volcano is surrounded by ocean. What processes important to life are visible?



4) A false-color image of meanders & oxbows on the Mississippi. What do these features indicate about how long the river has flowed?

5) How do agricultural patterns in Argentina (above) and deforestation in Brazil (below) indicate life on Earth?



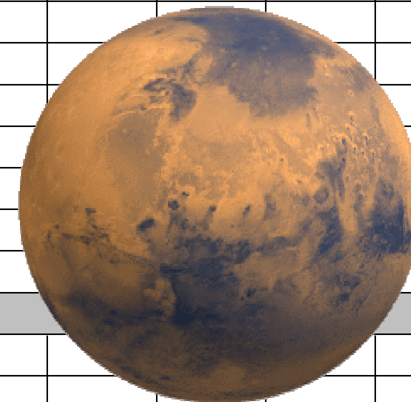


6) This computer-generated view of California's Death Valley is based on elevation data collected by the Galileo spacecraft. Though this scene is dry, what evidence is there for water? Why are there no craters visible? What about this scene is similar to other planets? What is different?

7) Buenos Aires, Argentina is on the left. Rio Parana is in the center, and undeveloped land in Uruguay is on the right. Does anything tell you that this area has been altered from its natural state or that 13 million people live in this city? What man-made features can you recognize?

8) Left is part of the Ganges River delta in Bangladesh. The channels flow through mangrove forests (dark areas) into the Bay of Bengal. The light areas are deforested mangrove areas that now support a very large human population. Why aren't the channels straight? What processes important to life are illustrated here?

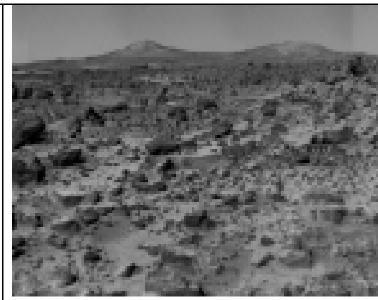
Fast Facts About Mars



Planetary Parameters		Ratio (Mars/Earth)
Planet Type	Terrestrial (i.e., a solid, rocky planet like Earth)	
Average Distance from Sun (kilometer)	227,940,000 as compared to Earth's 149,600,000	1.52
Equatorial Diameter (kilometer)	6,794 as compared to Earth's 12,756	0.53
Mass (10^{24} kilogram)	0.6419 as compared to Earth's 5.9736	0.11
Volume (10^{10} $kilometer^3$)	16.32 as compared to Earth's 108.321	0.15
Average Density ($gram/centimeter^3$)	3.93 as compared to Earth's 5.52	0.71
Surface Gravity ($meter/second^2$)	3.69 as compared to Earth's 9.78	0.38
Magnetic Field ($gauss\text{-}Rh^3$)	0.00002 as compared to Earth's 0.3076	0.00007
Orbital Parameters		
Year Length (One Orbit Around the Sun)	687 Earth days	
Day Length (One Rotation on its Axis)	24.6 Earth hours	
Inclination of Axis (degrees)	25.19 as compared to Earth's 23.45	
Atmosphere and Climate		
Average Surface Temperature (C)	-63 as compared to Earth's 14.8	
Maximum Temperature (C)	24 as compared to Earth's 47	
Minimum Temperature (C)	-143 as compared to Earth's -33	
Atmospheric Pressure at Surface	6 .9-9 millibar (Earth = 1,014 millibar). This pressure exerts a force of 0.02 kg/m^3 as compared to Earth's atmosphere that exerts a force of 1.217 kg/m^3 at sea level.	
Major Atmospheric Gasses	95% Carbon Dioxide, 2.7% Nitrogen, 1.6% Argon, 0.13% Oxygen, 0.03% (210 ppm) Water Vapor, 0.07% Carbon Monoxide	
Summary of Water	Currently no surface water. Channels and ancient shorelines suggest past surface water. A layer of permafrost exists under most, if not all, of the Martian surface.	
Summary of Climate	No water cycle. Each Spring, the South Pole's carbon dioxide sublimates, creating tremendous winds that cause dust storms and global atmospheric circulation.	
Planetary Features		
General Overview	Mars has the solar system's largest volcano, dust storms, canyons, flood channels, and craters. With virtually no atmosphere or water cycle, there is no erosion. So unlike Earth, once Mars solidified, changes to the surface remain forever. While the hot core generates some heat, the mantle is solid and thus, there is no plate tectonics.	
Composition of Poles	North is water ice, South ice covered with frozen carbon dioxide.	
Core Composition	Molten core of 85% iron and nickel and 15% sulfur	
Known Moons/Rings	2 moons, 0 rings	
Visits to Mars		
1950-69	1965: Mariner 4 (US), flyby, made first close-up pictures of the surface; 1969: Mariner 6 and 7 (US) flybys, high resolution images of equatorial and southern region	
1970-89	1971: Mariner 9 (US) , orbiter, first satellite to orbit another planet; 1973: Mars 3 and Mars 5 (USSR), failed attempts to land; 1976: Vikings 1 and 2 (US), two orbiters and two landers, two years of detailed images and data returned. 1988: Phobos (USSR), detailed images of Phobos.	
1990-99	1996: Mars Global Surveyor (US), orbiter, high-resolution mapping; 1996: Mars Pathfinder (US), lander, images and data; 1998: Mars Climate Orbiter (US), orbiter, climate; 1999: Mars Polar Lander (US), climate & water inventory.	

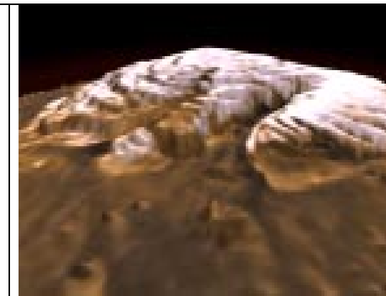
Some Views of Planet Mars

1) The 300 x 200-km Ophir Chasma (top) is the size of Ohio, yet it is just a *side* canyon of Vallis Marineris, Mars' 4,000-km long rift valley. This region bulged up 11 km, opening long cracks and forming canyons which have been further widened by landslides.

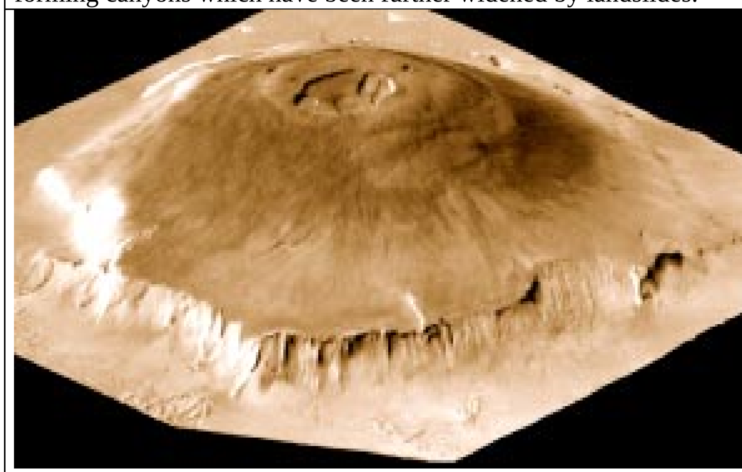


2) The 50-m tall Twin Peaks are 1 km from Pathfinder's landing site. Pathfinder's rover studied several rocks in the foreground.

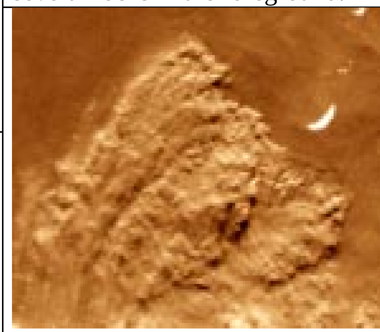
3) Coprates Chasma is a section of Vallis Marineris. The frame is 400 km across and shows several parallel fractures.



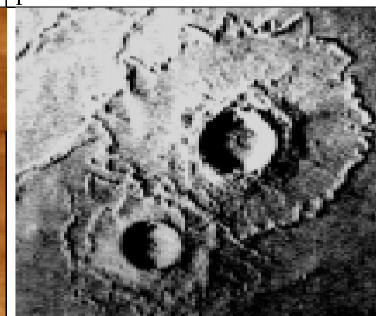
4) The height in this computer-generated image of the North Pole is exaggerated 22 times. Portions of the pole have melted away.



5) At 800-km across and 26-km tall, Olympus Mons is the solar system's largest volcano. By comparison, Earth's largest volcano, Mauna Loa, is 120-km across and 9-km tall. Olympus Mons is one of many volcanoes sitting on Mars' 11-km bulge, suggesting that a magma plume rose to the surface in this region, deforming it by bulging it outward. Where the magma broke through, it created volcanoes. Mars still has a molten core, though it has cooled so much that the Martian crust is very thick. There are no plate tectonics on Mars. However, the internal heat may be enough to melt the permafrost and maintain underground oceans or aquifers.



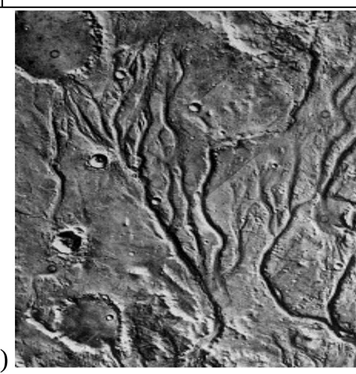
6) Temperature differences between the southern ice cap and the nearby land surface created this 270-km wide dust storm.



7) The meteorites creating these 30-km craters landed in permafrost, melting the ice and turning the ground into mud.

8) These bacteria-like structures were found inside a rock from Mars, suggesting that Mars may once have been teeming with life.

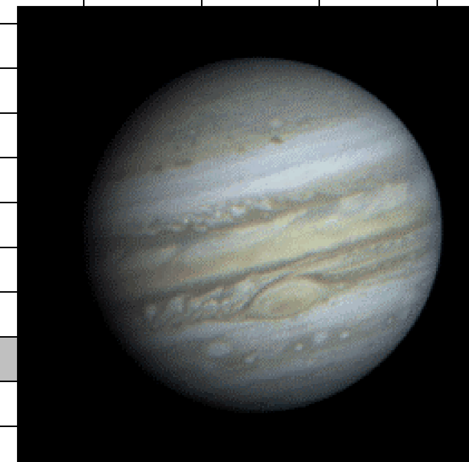
9) 

10) 

11) 

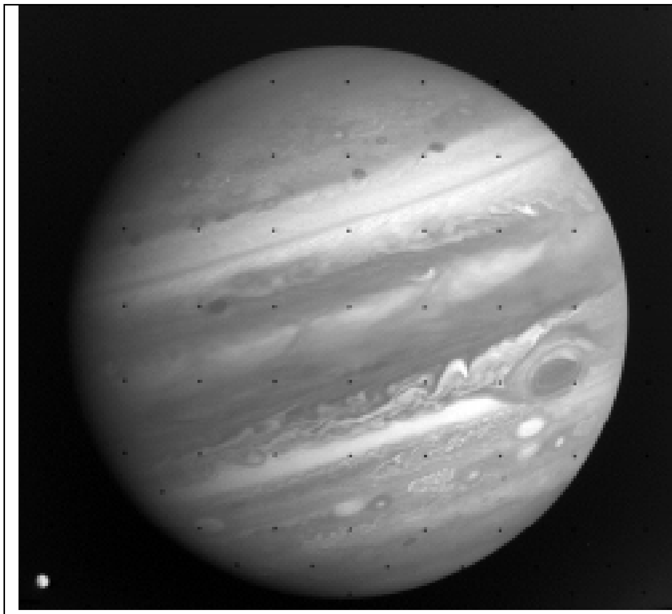
Features related to flowing water suggest that Mars once had a warmer, wetter climate. Supporting the idea that water once flowed freely on Mars are features such as streamlined "islands" (45-km long), channel networks (frame is 125-km tall), and meandering channels (2.5-km wide) which suggest long term flows.

Fast Facts About Jupiter

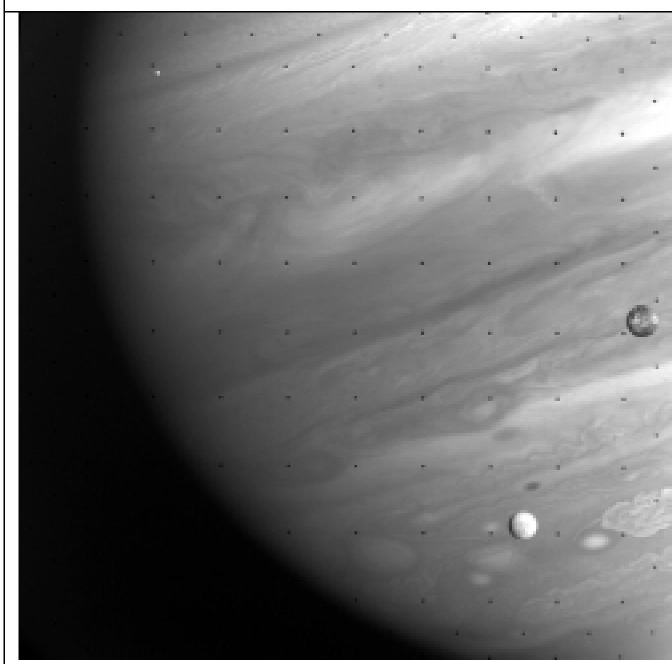


Planetary Parameters		Ratio (Jupiter/Earth)
Planet Type	Gas Giant (unlike a solid, rocky planet like Earth)	
Average Distance from Sun (kilometer)	778,330,000 as compared to Earth's 149,600,000	5.20
Equatorial Diameter (kilometer)	142,984 as compared to Earth's 12,756	11.21
Mass (10^{24} kilogram)	1,899 as compared to Earth's 5.9736	317.90
Volume (10^{10} kilometer^3)	143,128 as compared to Earth's 108.321	1,321.30
Average Density (gram/centimeter^3)	1.33 as compared to Earth's 5.52	0.24
Surface Gravity (meter/second^2)	23.12 as compared to Earth's 9.78	2.36
Magnetic Field (gauss-Rh^3)	4.28 as compared to Earth's 0.3076	The magnetic field is 13.9 times as strong as Earth's and pours billions of watts into Earth's magnetic field each day.
Orbital Parameters		
Year Length (One Orbit Around the Sun)	11.86 Earth years	
Day Length (One Rotation on its Axis)	9.92 Earth hours	
Inclination of Axis (degrees)	3.12 compared to Earth's 23.45	
Atmosphere and Climate		
Average Surface Temperature (C)	-144 as compared to Earth's 14.8	
Maximum Temperature (C)		
Minimum Temperature (C)	-148 (at the top of the clouds) as compared to Earth's -33	
Atmospheric Pressure at Surface	Far above 100 bar (Earth = 1 bar). This pressure exerts a force of 0.16 kg/m^3 at 1 bar compared to Earth's atmosphere which exerts a force of 1.217 kg/m^3 at 1 bar (sea lev	
Major Atmospheric Gasses	90% Hydrogen, 10% Helium, 3,000 ppm Methane, 260 ppm Ammonia, 4 ppm Water Vapor	
Planetary Features		
General Overview	Red Spot is a storm that has lasted at least 300 years. Jupiter contains nearly 2/3 of the solar system's planetary mass. In composition, it resembles a small star. It's interior pressure may reach 100 million times Earth's surface pressure.	
Core Composition	Slush or liquid	
Known Moons/Rings	4 large and 12 small moons, several rings so thin they were only discovered when Voyagers 1 and 2 visited Jupiter.	
Visits to Jupiter		
1950-79	1973: Pioneer 10 (US), flyby, imaged cloud tops and moons; 1974: Pioneer 11 (US), flyby, imaged polar regions; 1979: Voyager 1 (US), flyby, discovered faint ring and three moons; 1979: Voyager 2 (US), flyby, detailed images of ring and Io volcanism.	
1980-99	1995: After a six-year journey from Earth, the Galileo orbiter (US) arrives at Jupiter. Galileo's instruments study Jupiter's weather, atmosphere, magnetic field, composition, and internal structure. After successfully completing its initial mission, Galileo's mission was extended, enabling it to study Jupiter's rings, moons, and magnetosphere.	

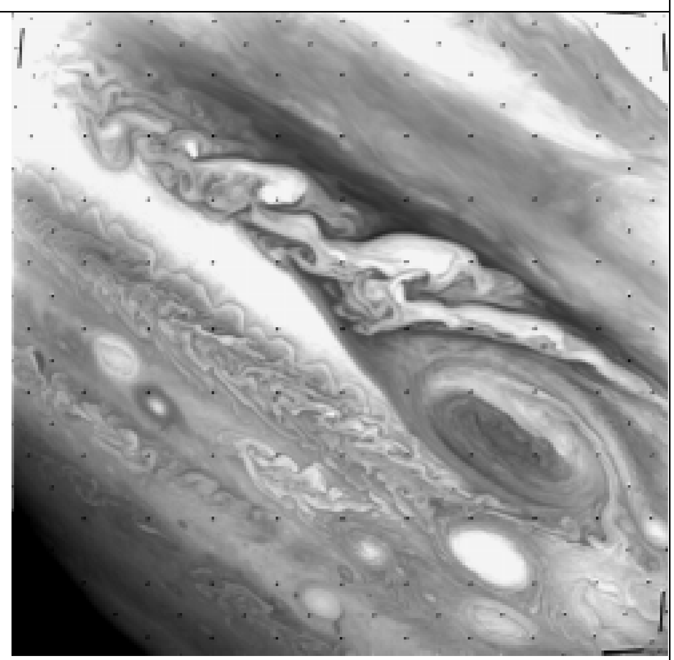
Some Views of the Planet Jupiter



Jupiter is comprised of gas. Had it been four times larger, it would have had enough gravity to compress its gas, start the proscess of nuclear fusion, and become our solar system's second sun. Even though it is the solar system's largest planet, it only takes about ten hours to make one complete rotation. This fast spin creates banding and other features in the flowing gasses. These patterns change in response to the atmosphere's incessent churning.

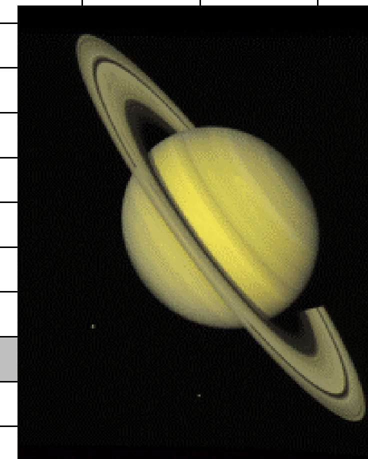


Io and Europa, the two innermost of Jupiter's 16 moons, are seen passing between Jupiter and the Voyager 1 spacecraft. Io, the darker of these two moons, is the most active volcanic body in the solar system. Europa's surface is mostly water ice, and there is strong evidence that it may be covering an ocean of liquid water or slushy ice.



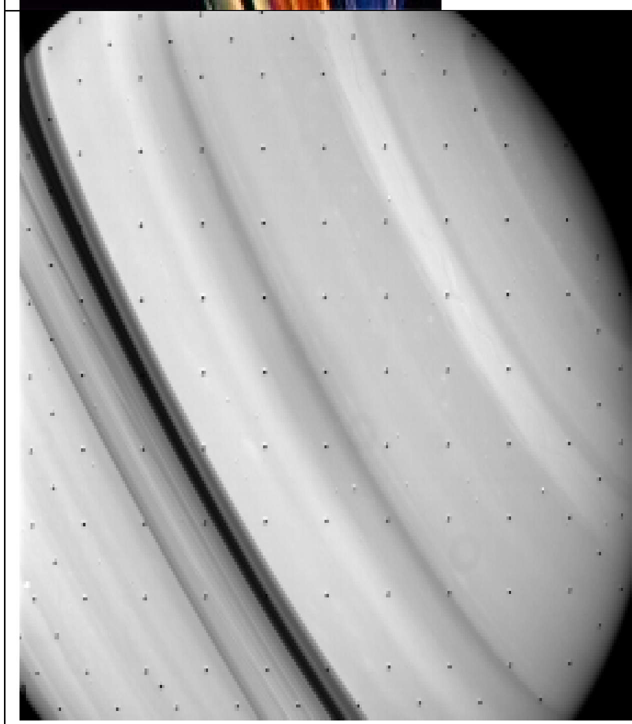
The Red Spot is a hurricane-like storm twice the diameter of Earth that has lasted over 300 years. The gasses swirl counterclockwise around this "eye," and Jupiter's typical banding pattern is broken into turbulent eddies that drift away from the Red Spot. Below the Red Spot are smaller storms, creating bright white vorticies of ammonia ice. The white oval below the Red Spot has lasted over 40 years.

Fast Facts About Saturn

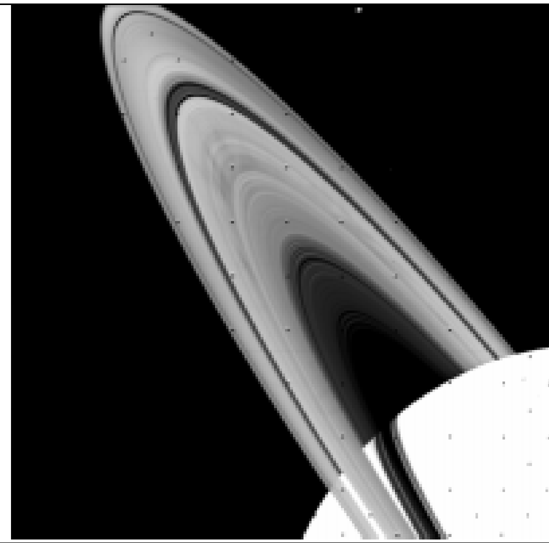


Planetary Parameters		Ratio (Saturn/Earth)
Planet Type	Gas Giant (unlike a solid, rocky planet like Earth)	
Average Distance from Sun (kilometer)	1,426,800,000 compared to Earth's 149,600,000	9.54
Equatorial Diameter (kilometer)	120,536 as compared to Earth's 12,756	9.45
Mass (10^{24} kilogram)	568.46 as compared to Earth's 5.9736	95.16
Volume (10^{10} $kilometer^3$)	82,713 as compared to Earth's 108.321	763.60
Average Density ($gram/centimeter^3$)	0.69 as compared to Earth's 5.52	0.12
Surface Gravity ($meter/second^2$)	8.96 as compared to Earth's 9.78	0.92
Magnetic Field ($gauss\text{-}Rh^3$)	0.21 as compared to Earth's 0.3076	0.68
Orbital Parameters		
Year Length (One Orbit Around the Sun)	29.46 Earth years	
Day Length (One Rotation on its Axis)	10.5 Earth hours	
Inclination of Axis (degrees)	26.73 compared to Earth's 23.45	
Atmosphere and Climate		
Average Surface Temperature (C)	-180 as compared to Earth's 14.8	
Maximum Temperature (C)	-113 at one bar as compared to Earth's 47	
Minimum Temperature (C)	-153 at one bar as compared to Earth's -33	
Atmospheric Pressure at Surface	Greater than 100 bars (Earth = 1 bar). This pressure exerts a force of 0.19 kg/m3 at 1 bar compared to Earth's atmosphere which exerts a force of 1.217 kg/m3 at 1 bar (sea	
Major Atmospheric Gasses	96% Hydrogen, 3.3% Helium, 4,500 ppm Methane, 125 ppm Amm	
Summary of Water	Although Saturn is water ice-rich (suspended as crystals in the gaseous planet and at its core), it has no known liquid water or water vapor.	
Planetary Features		
General Overview	Saturn rotates so fast, it is flattened at the poles. Winds up to 1600 kilometers per hour create a banded appearance of the surface clouds. Extensive ring system made mostly of ice crystals. The moon, Titan, is larger than Mercury, has an atmosphere rich in nitrogen, and is enveloped in a hydrocarbon-rich haze.	
Core Composition	Superheated water or rock and ice	
Known Moons/Rings	18 moons, seven over 400 km in diameter; Thousands of rings in six major groupings.	
Visits to Saturn		
1950-79	1979: Pioneer 11 (US), flyby, imaged polar regions and Titan. Detected internal source of heat	
1980-99	1980: Voyager 1 (US), flyby, sent back 17,500 images of planet, rings, and moons. Measured wind speeds. 1982: Voyager 2 (US), detailed imagery of rings and moons. Studied Titan's atmosphere. 1997: Cassini/Huygens orbiter launched for a 2004 arrival.	

Some Views of Planet Saturn

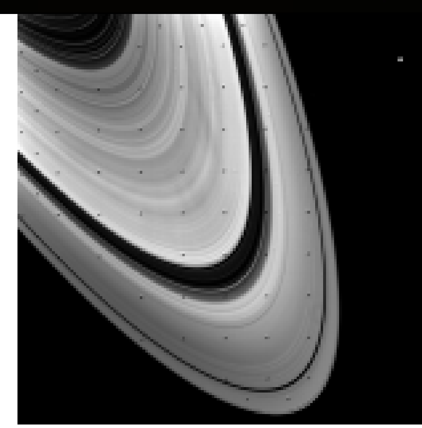


The dots above are artifacts of the imaging process.



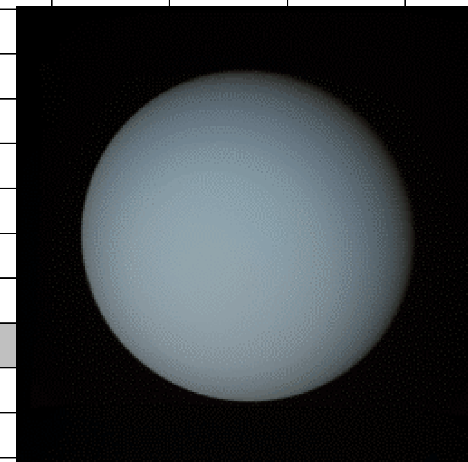
Saturn's ring system was first seen from Earth through a telescope in 1675, though the two Voyager spacecraft have given us our best views to date. There are thousands of rings in six major groupings. They are made mostly of water ice crystals and were likely produced when Saturn's gravity ripped apart a moon. Saturn is made of gas, and it spins so fast that it is flattened at the poles. In many ways, Saturn's atmosphere is similar to Jupiter's, with similar banding, high winds, and chemistry.

Enceladus (left) & Titan are 2 of Saturn's larger moons. Titan is enveloped in a thick, dense atmosphere of argon, methane, and nitrogen. There may be oceans of methane and ethane, making Titan an intriguing candidate for life



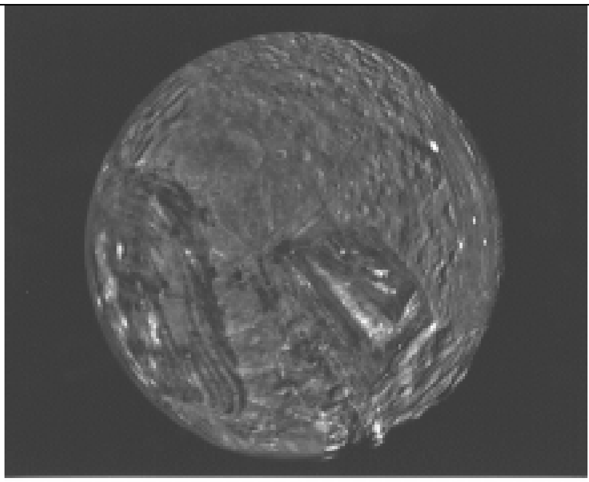
Several of Saturn's moons are visible in the above views.

Fast Facts About Uranus

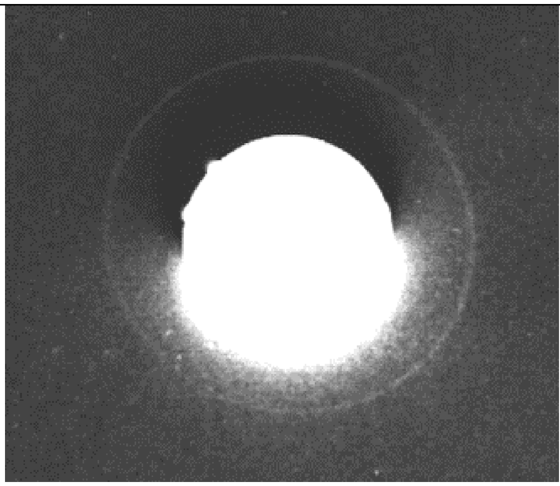


Planetary Parameters		Ratio (Uranus/Earth)
Planet Type	Gas Giant (unlike a solid, rocky planet like Earth)	
Average Distance from Sun (kilometer)	2,870,990,000 compared to Earth's 149,600,000	19.19
Equatorial Diameter (kilometer)	51,118 as compared to Earth's 12,756	4.01
Mass (10^{24} kilogram)	86.83 as compared to Earth's 5.9736	14.54
Volume (10^{10} kilometer^3)	6,833 as compared to Earth's 108.321	63.08
Average Density (gram/centimeter^3)	1.318 as compared to Earth's 5.52	0.24
Surface Gravity (meter/second^2)	8.69 as compared to Earth's 9.78	0.89
Magnetic Field (gauss-Rh^3)	0.228 as compared to Earth's 0.3076	0.74
Orbital Parameters		
Year Length (One Orbit Around the Sun)	84.01 Earth years	
Day Length (One Rotation on its Axis)	17.24 Earth hours	
Inclination of Axis (degrees)	97.86 compared to Earth's 23.45	
Atmosphere and Climate		
Average Surface Temperature (C)	-195 at one bar as compared to Earth's 14.8	
Maximum Temperature (C)		
Minimum Temperature (C)	-215 at one bar as compared to Earth's -33	
Atmospheric Pressure at Surface	Greater than 100 bars (Earth = 1 bar) This pressure exerts a force of 0.42 kg/m^3 at 1 bar compared to Earth's atmosphere which exerts a force of 1.217 kg/m^3 at 1 bar (sea	
Major Atmospheric Gasses	82.5 % Hydrogen, 15.2% Helium, 2.3% Methane	
Summary of Water	There is no liquid water or water vapor	
Planetary Features		
General Overview	Uranus is a blue-greenish ball of gas. Voyager measured winds up to 200 meters per second. Uranus' spin axis is tipped almost 90 degrees from the normal orientation of planets in the solar system. Its magnetic field is not centered on its spin axis.	
Core Composition		
Known Moons/Rings	All the moons are made primarily of water ice. Four of them are over 1,000 km, one is about 500 km, and 10 are below 150 km. Uranus has 11 thin, widely spaced, dark-colored rings, fewer than half of which have circular orbits.	
Visits to Uranus		
1950-99	1986: Voyager 2 (US), flyby, discovers 10 small moons and two more rings. Detected magnetic field and length of Uranian day.	

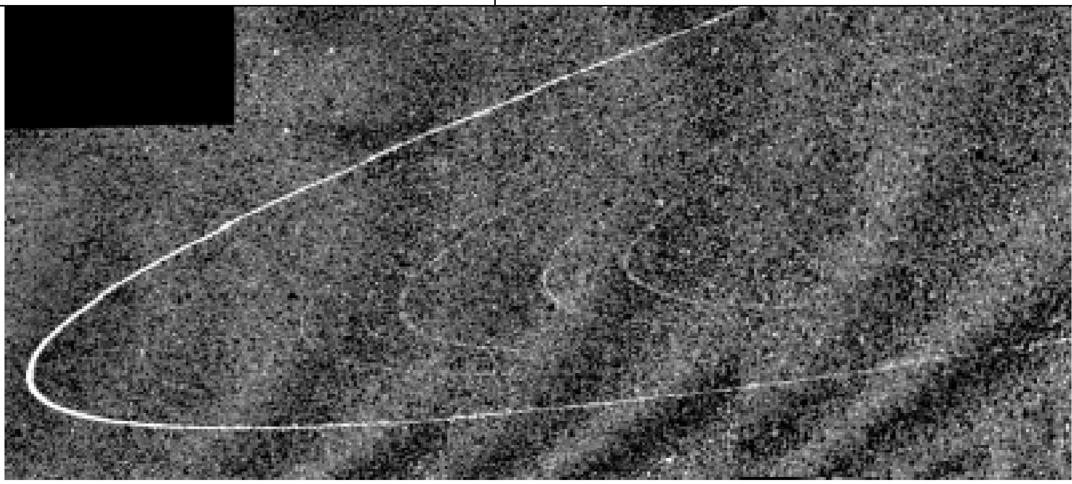
Some Views of the Planet Uranus



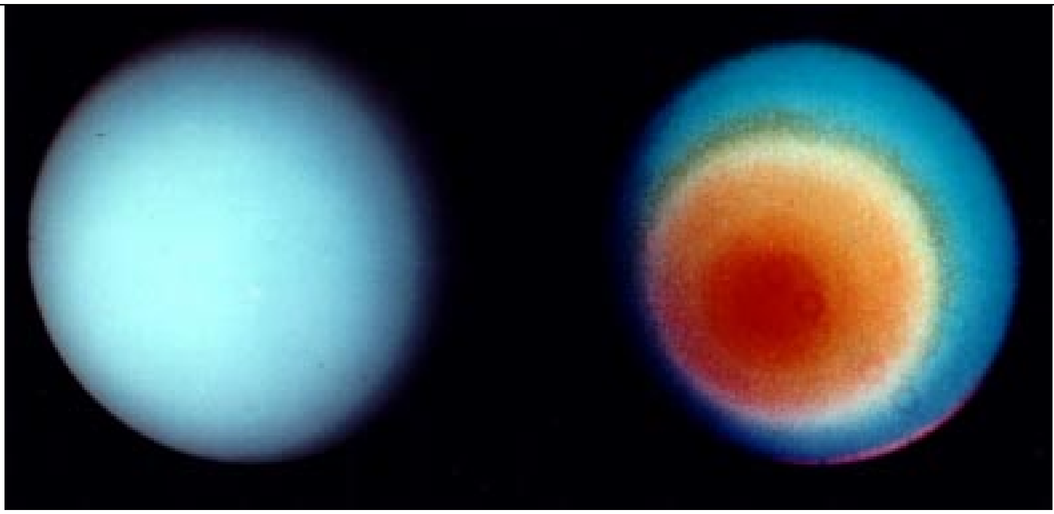
1) Miranda, one of Uranus's 15 moons. Do the terrestrial or gaseous planets have more moons?



2) Until Voyager 2 flew past in 1986, nobody knew that Uranus had rings. How are the planets with rings similar?

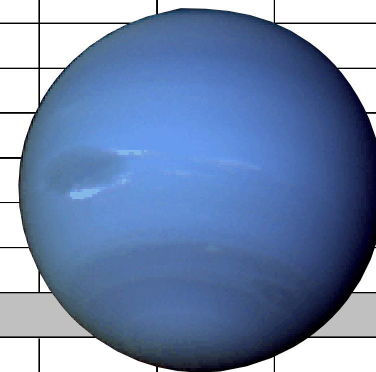


3) This grainy image was assembled from several smaller images. How many of Uranus's 11 rings can you see?



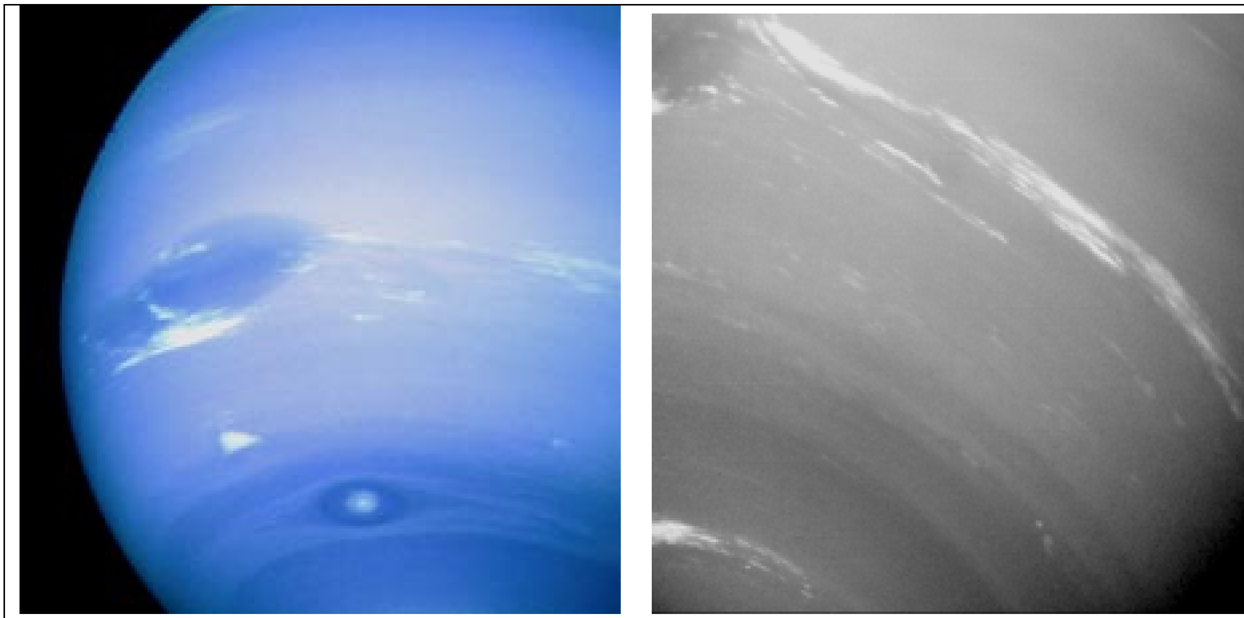
4) Uranus is primarily hydrogen gas, similar to the other gaseous planets. Uranus is 2.3% methane, a gas that absorbs red light. As a result, Uranus looks blue. Uranus has few visible atmospheric features and lacks any significant internal heat source. An odd feature about Uranus is that it is tipped on its side so, unlike all the other planets, its axis of rotation is in the same plane as its orbital plane. This means that in winter, the North Pole points directly at the sun, and in summer the South Pole points directly at the sun. Since it takes Uranus 84 years to orbit the sun, winter and summer each last 21 years!

Fast Facts About Neptune

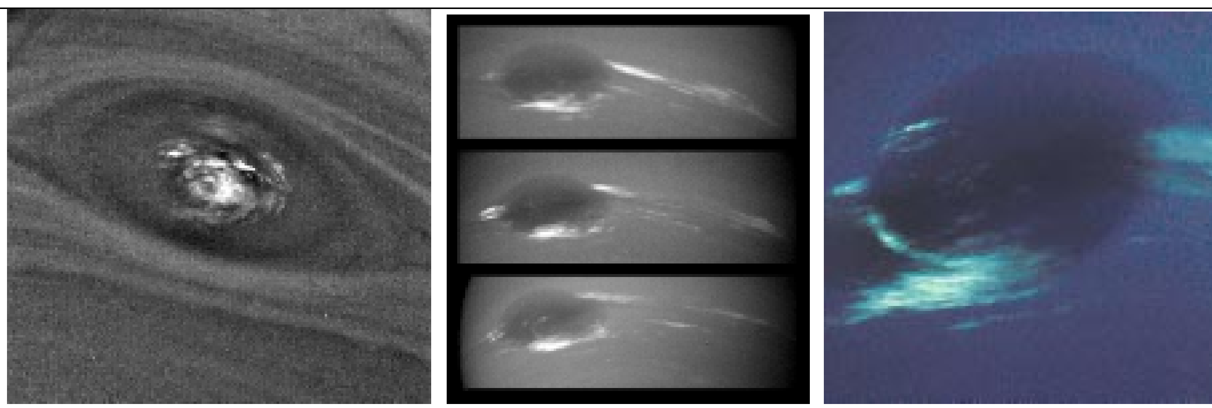


Planetary Parameters		Ratio (Neptune/Earth)
Planet Type	Gas Giant (unlike a solid, rocky planet like Earth)	
Average Distance from Sun (kilometer)	4,498,300,000 compared to Earth's 149,600,000	30.07
Equatorial Diameter (kilometer)	49,532 as compared to Earth's 12,756	3.88
Mass (10^{24} kilogram)	102.43 as compared to Earth's 5.9736	17.15
Volume (10^{10} kilometer^3)	6,254 as compared to Earth's 108.321	57.74
Average Density (gram/centimeter^3)	1.64 as compared to Earth's 5.52	0.30
Surface Gravity (meter/second^2)	11.2 as compared to Earth's 9.78	1.13
Magnetic Field (gauss-Rh^3)	0.142 as compared to Earth's 0.3076	0.46
Orbital Parameters		
Year Length (One Orbit Around the Sun)	164.79 Earth years	
Day Length (One Rotation on its Axis)	16.11 Earth hours	
Inclination of Axis (degrees)	29.56 compared to Earth's 23.45	
Atmosphere and Climate		
Average Surface Temperature (C)	-204 at one bar as compared to Earth's 14.8	
Maximum Temperature (C)		
Minimum Temperature (C)	-215 at one bar as compared to Earth's -33	
Atmospheric Pressure at Surface	Greater than 100 bars (Earth = 1 bar) This pressure exerts a force of 0.45 kg/m^3 at 1 bar compared to Earth's atmosphere which exerts a force of 1.217 kg/m^3 at 1 bar (sea	
Major Atmospheric Gasses	80.0 % Hydrogen, 19.0% Helium, 1.5% Methane	
Summary of Water	There is no liquid water or water vapor	
Planetary Features		
General Overview	Neptune is a gaseous ball with a banded blue atmosphere decorated with white clouds of methane ice. It has several large dark spots like Jupiter's Red Spot.	
Core Composition		
Known Moons/Rings	Triton is 2,700 km in diameter. Also, there are two 300-400 km moons, two 150-200 km moons, and three 50-100 km moons. Neptune's four rings and several diffuse sheets of particles are made of dark materials, are discontinuous, and are thicker in certain sections.	
Visits to Neptune		
1950-99	1989: Voyager 2 (US), flyby, discovers six small moons.	

Some Views of the Planet Neptune



1-2) Neptune's clouds show more variety and contrast than Uranus's. Even though it is farther from the sun, Neptune is slightly warmer than Uranus. This warmth, thought to be from the compression of gasses when Neptune formed, creates layers in the atmosphere. This layering creates banding and white frozen methane clouds. The warmth also generates winds up to 2,000 km per hour. Oddly, these winds blow in the opposite direction to Neptune's rotation. Astronomers theorize that Neptune may have "slushy" interiors containing thick layers of water clouds.

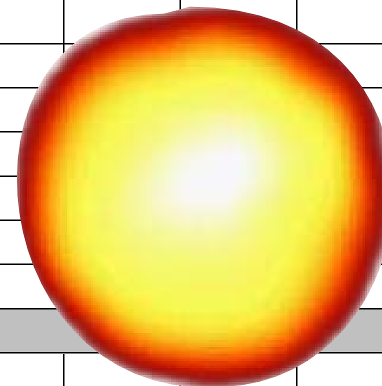


3-5) Neptune has several storm systems similar to Jupiter's. The largest, called the Great Dark Spot, is the size of Earth. The storm stays in the same general spot, presumably over a plume of rising warm gas. The disruption and turbulence it causes to the cloud bands encountering it make the storm visible (see the center set of sequenced images above).

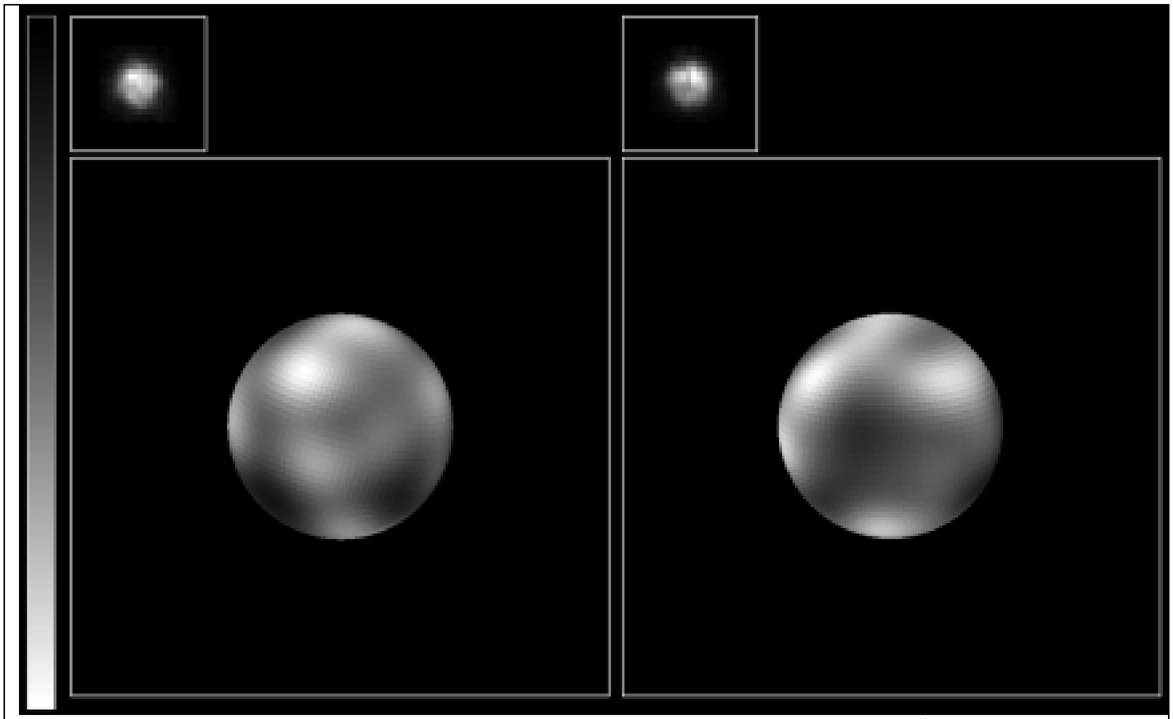
6-8) Neptune has eight moons. Triton (center, above), is the largest. Neptune's four rings are not even -- they are thicker in some places and so thin in others that there are openings, making for discontinuous rings. On the right, the brightly reflecting Neptune has been masked so that the camera could image the faint rings.

Fast Facts About Pluto

Planetary Parameters		Ratio (Pluto/Earth)								
Planet Type	Terrestrial (i.e., a solid, rocky planet like Earth)									
Average Distance from Sun (kilometer)	5,906,400,000 compared to Earth's 149,600,000	39.48								
Equatorial Diameter (kilometer)	2,247 as compared to Earth's 12,756	0.18								
Mass (10^{24} kilogram)	0.0125 as compared to Earth's 5.9736	0.002								
Volume (10^{10} kilometer^3)	0.616 as compared to Earth's 108.321	0.006								
Average Density (gram/centimeter^3)	2.06 as compared to Earth's 5.52	0.37								
Surface Gravity (meter/second^2)	0.66 as compared to Earth's 9.78	0.07								
Magnetic Field (gauss-Rh^3)										
Orbital Parameters										
Year Length (One Orbit Around the Sun)	248 Earth Years									
Day Length (One Rotation on its Axis)	6.4 Earth days									
Inclination of Axis (degrees)	122 compared to Earth's 23.45									
Atmosphere and Climate										
Average Surface Temperature (C)	-225 at one bar as compared to Earth's 14.8									
Maximum Temperature (C)	-213 as compared to Earth's 47									
Minimum Temperature (C)	-236 at one bar as compared to Earth's -33									
Atmospheric Pressure at Surface	0.001 to 0.003 millibar (Earth = 1,014 millibar)									
Major Atmospheric Gasses	Nitrogen, Methane									
Summary of Water	Permanently frozen water ice									
Summary of Climate	Nitrogen atmosphere alternates between completely freezing out as nitrogen ice and sublimating to form a tenuous atmosphere.									
Planetary Features										
General Overview	Discovered in 1930, Pluto is the smallest, most distant, coldest, and darkest planet. During its winter, the entire atmosphere freezes onto the planet's surface as nitrogen ice. Its highly elliptical orbit and high density suggest that Pluto may be a Sun-orbiting, icy planetesimal.									
Composition of Poles	2 poles of unknown composition									
Core Composition	Rocky core									
Known Moons/Rings	1 moon, Charon, half as large as Pluto.									
Visits to Pluto										
1950-99	1994: first Hubble Space Telescope maps of Pluto.									



Some Views of the Planet Pluto



1-2) The Hubble Space Telescope, a telescope that orbits the Earth, took the images of Pluto (right) and Charon (left), Pluto's large moon -- half the size of Pluto! Because no spacecraft has ever visited this planet, these are our BEST images of Pluto and Charon. Computers enhanced the Hubble Space Telescope's images, but even so, almost no details are visible. It is so cold, that during the winter (which lasts 82 years!), the entire nitrogen atmosphere freezes onto the planet's surface as nitrogen ice. Some astronomers question whether Pluto is even a planet. They think it is more like the rocky, icy objects (called planetesimals) orbiting at the outer edge of our solar system.

2) This is another image of Pluto and Charon taken by the Hubble Space Telescope. Every few years, Charon comes between Earth and Pluto, eclipsing it. When Charon passes in front, it blocks parts of Pluto and the atmospheres show up against the blackness of space. In this way, astronomers can study the composition and characteristics of the atmospheres of these distant objects.