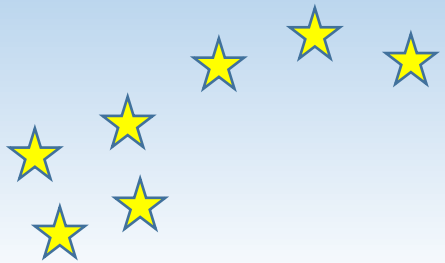


The Planets

Physical Sciences

Broward College

Prepared for AST 1002

Horizons in Astronomy

Terrestrial Planets

What are Terrestrial Planets?

- The terrestrial planets are Mercury, Venus, Earth, and Mars.
- Terrestrial Planets are planets that consist of heavy elements, small in size, and orbit close to the Sun.
- All terrestrial planet surfaces are rocky with many impact, plutonic, and weathered features. All terrestrial planets had water in large quantities on their surfaces but Mercury which has some residual water moisture.
- All terrestrial planets have atmospheres that are small with heavier compounds but Mercury. Venus, Earth, and Mars have weather and climate changes in their dynamic atmospheres.
- Only Earth and Mars have natural satellites.

Cross Sections of Terrestrial Planets

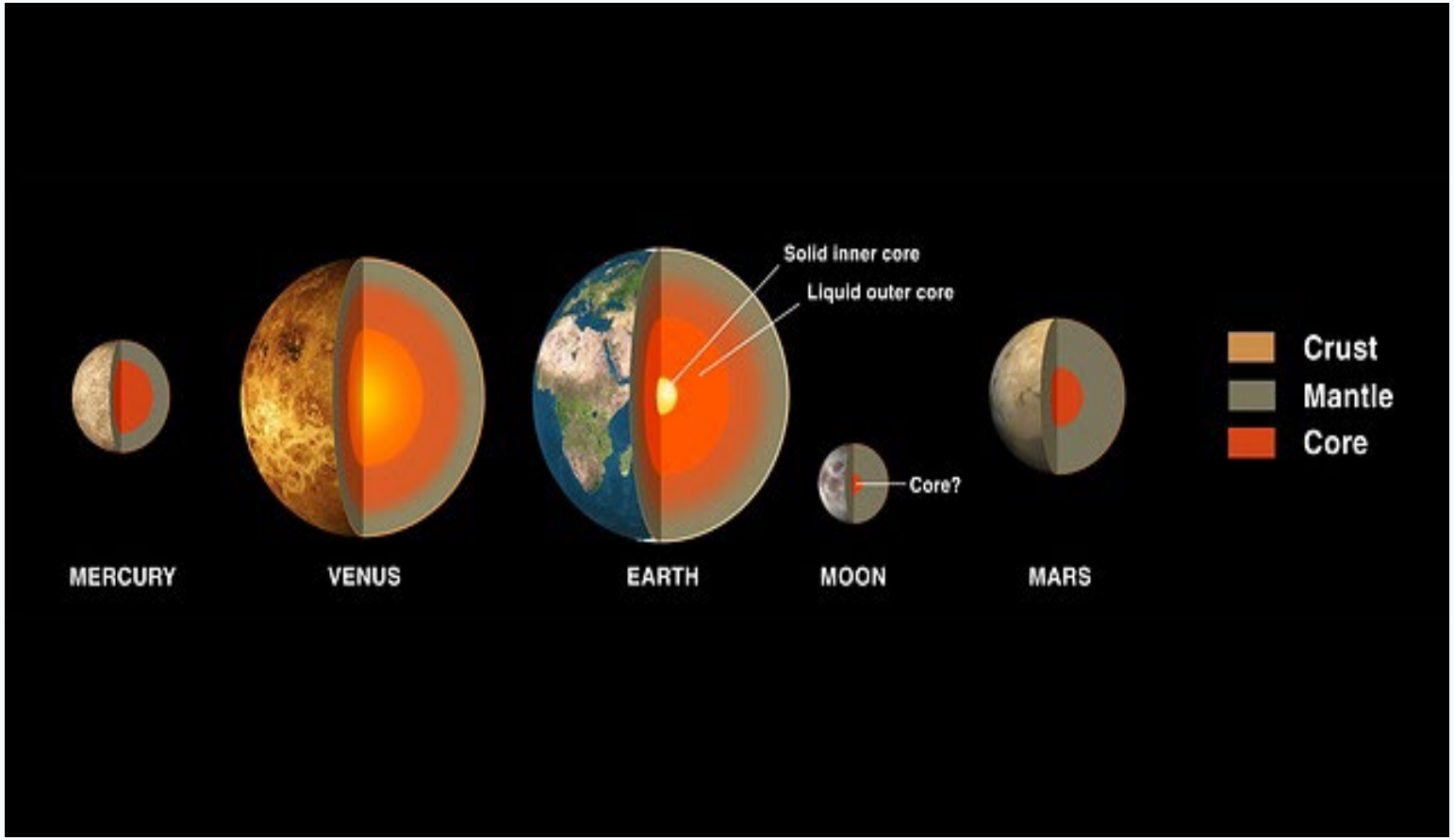


Figure 1. Cross Sections of the Terrestrials (Wiki)

- Mercury, Venus, and Earth have large cores due to impact of large asteroids. Mars has a smaller core because it was not impacted by a large asteroid.
- All terrestrial planets have a core, mantle and crust in their interiors.
- Venus and Earth are still active tectonically while Mercury and Mars are quiet because they have cooled internally.
- All terrestrial planets have some magnetic field. Mercury, Venus, and Earth have fields that extend from the planet, but Mars only has magnetic fields on the surface.

Mercury

- Distance: 5.79 X 10^7 km (0.387 A.U.)
- Albedo: 0.1
- Size (Diameter): 4878 km (0.382 D_E)
- Mass: 3.31 X 10^{23} kg (0.0558 M_E)]
- Density: 5.44 g/cm^3 (0.985 ρ_E)
- Length of Year: 0.24 Earth years
- Length of Day: 59 Earth days
- Surface Temperature: 700 K – 80 K
- Number of Satellites: 0

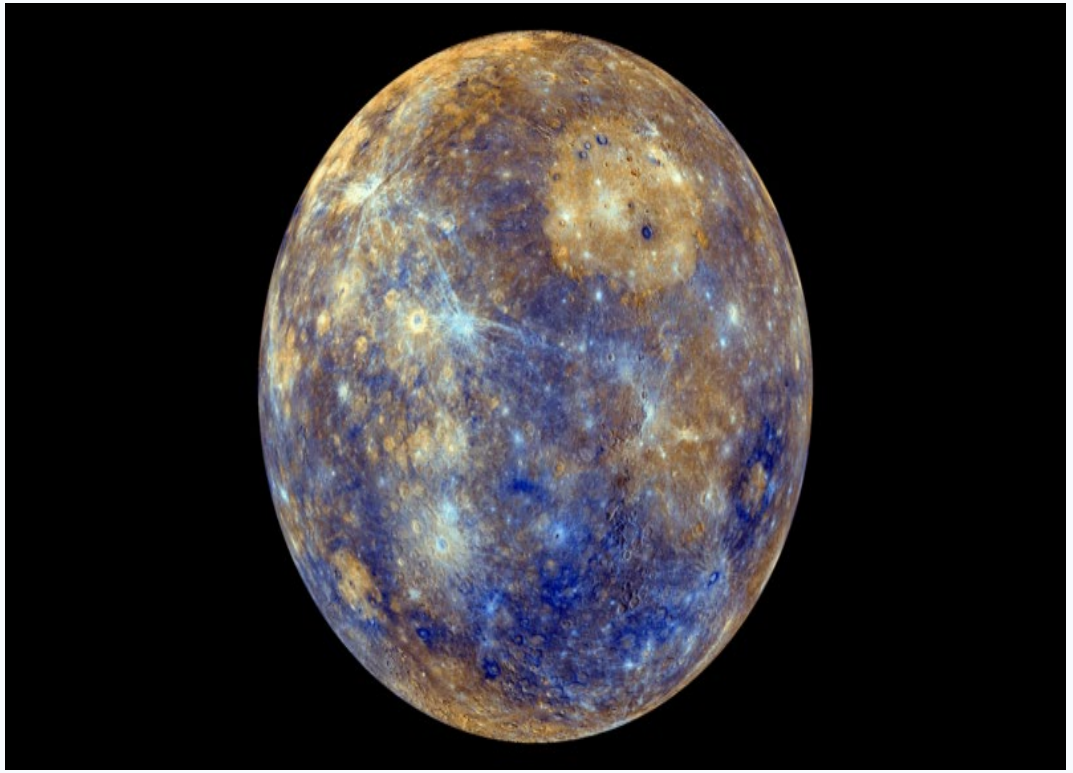


Figure 2. Mercury (Wiki)

Venus

- Distance: 1.082 X 10^8 km (0.7233 A.U)
- Albedo: 0.76
- Size (Diameter): 12,104 km (0.95 D_E)
- Mass: 4.870 X 10^{24} kg (0.815 M_E)
- Density: 5.24 g/cm^3 (0.949 ρ_E)=
- Length of Year: 0.62 Earth years
- Length of Day: 243 Days
- Surface Temperature: 736 K
- Number of Satellites: 0

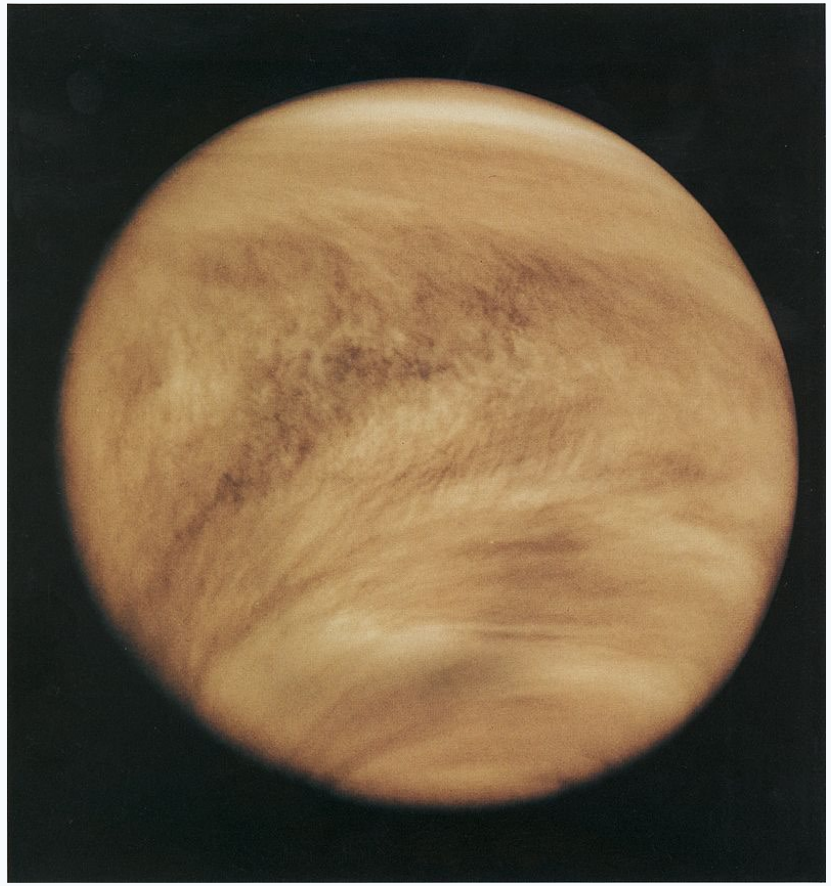


Figure 2. Venus (Wiki)

Earth

- Distance: 1.49 X 10^8 km (1 A.U)
- Albedo: 0.39
- Size (Diameter): 12,758 km (1 D_E)
- Mass: 5.976 X 10^{24} kg (1 M_E)
- Density: 5.497 g/cm^3
- Length of Day: 24 hours (1 Earth Day)
- Length of Year: 365.25 days (1 Earth Year)
- Surface Temperature: 330 K – 184 K
- Number of Satellites: 1

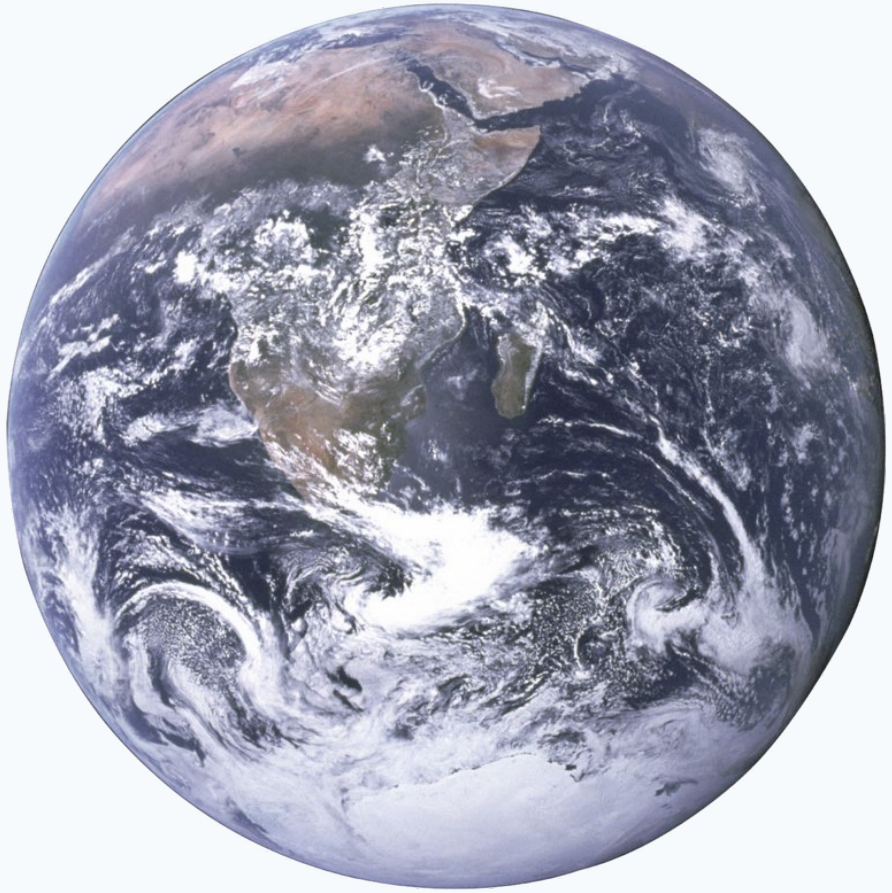


Figure 4. Earth (Wiki)

Mars

- Distance: 2.279 X 10^8 km (1.5237 A.U)
- Albedo: 0.16
- Size (Diameter): 6,796 km (0.53 D_E)
- Mass: 6.424 X 10^{23} kg (0.1075 M_E)
- Density: 3.94 g/cm^3 (0.714 ρ_E)
- Length of Year: 1.88 Earth years
- Length of Day: 1.025 Earth days
- Surface Temperature: 308 K – 130 K
- Number of Satellites: 2

Figure 5. Mars (Ven Werven, 2015)

Terrestrial Planetary Features

Coalescing and Cooling	Impact	Plutonic	Weathering
Rupes Large mountain chains formed by the cooling of a planetary crusts. Scarps Small mountain bluffs formed by either crater formation or cooling of the planetary crusts. Planitia/Terra Large planes that are either continental crust or former oceanic crust.	Craters Craters are formed by impacts by asteroids and comets. Scarps Small mountain bluffs formed by either crater formation or cooling of the planetary crusts.	Volcanoes Mountains that are formed when magma (liquid rock) comes up from the mantel of a planet. Coronae Collapsed mountain that are formed when volcanoes are not supported by the surrounding crust. Valles Large canyons that form at the meeting of surface plate or water erosion. Usually indicative of folding or faulting.	Fossae/Chaos: Large areas of erosion due to water. Dunes Areas of built up material due to wind erosion. Valles Large canyons that form at the meeting of surface plate or water erosion. Usually indicative of folding or faulting.

Planetary Maps – Planitia and Terras

- Planitia (low altitude plains) are present on all terrestrial planets. Only Earth has liquid water on it's planitia. Mercury never had water on its planitia.
- Continents (Terras, high altitude plains) are present on all terrestrial planets. The location is different on each planet due to tectonic activity.
- Also we see several water erosional chaos/fossae (deltas) on Venus, Earth, and Mars; planets where water was present for a long time.

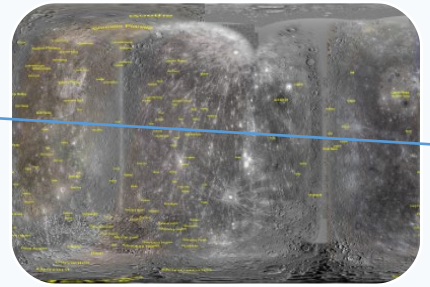


Figure 6. Map of Mercury (NOAA, 2015)

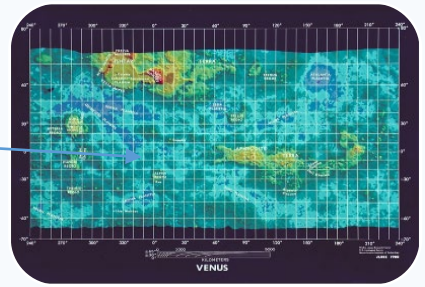


Figure 7. Map of Venus (Wiki)

Figure 8. Map of Earth (Wiki)

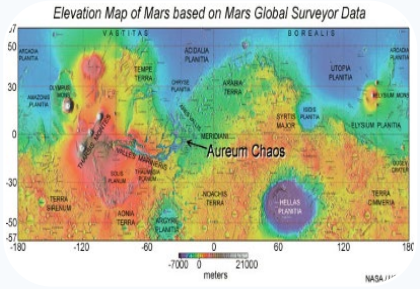


Figure 9. Map of Mars (Martell, 2012)

Rupes and Scarps

- Rupes and Scarps formed on all terrestrial planets.
- Only Mercury and Mars show the presence of these structure due to continued plutonic behavior on Earth and Venus.

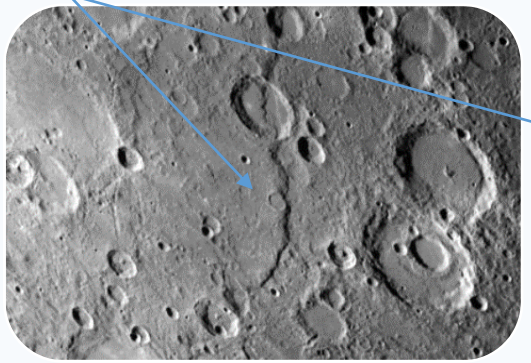


Figure 10. Discovery Rupes on Mercury (Wiki)

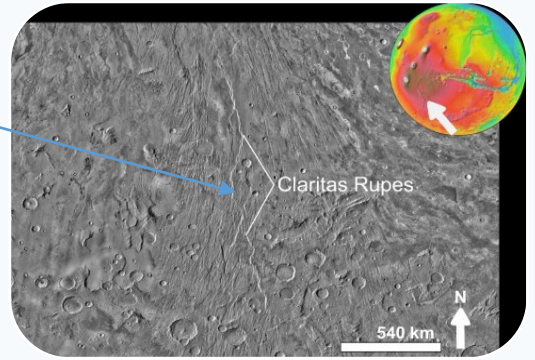


Figure 11. Claritas Rupes on Mars (Wiki)

Craters

- Craters are present on all the Terrestrial planets.
- There are more craters on Mercury and Mars than on Earth and Venus.
- Mars has several impact craters from former moons.

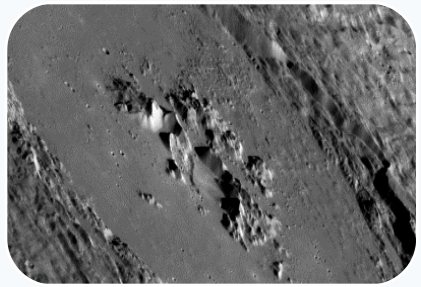


Figure 12. Abedin Crater on Mercury (Wiki)

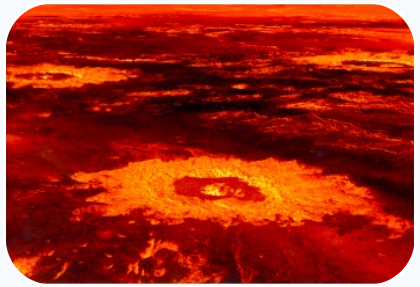


Figure 13. Crater on Venus (Wiki)

Figure 14. Berringer Crater in Arizona (Wiki)

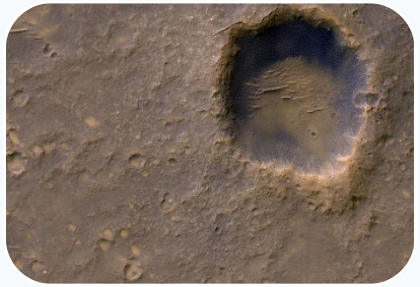


Figure 15. Bonneville Crater on Mars (Wiki)

Volcanoes and Corona

- Volcanoes existed on all the terrestrial planets. Some are alive and some are dead.
- They transplant material from the mantle to the surface and recycle the material to refresh the crusts.
- Corona: Some have collapse due to the crust being soft under the basin of the volcano; these are present on Earth and Venus.

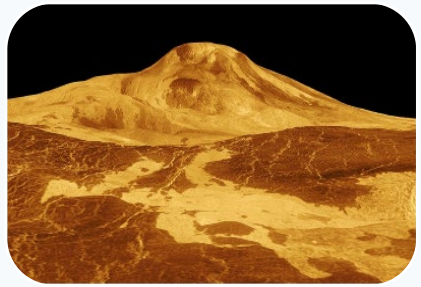


Figure 16. Mat Mons on Venus (Wiki)

Figure 17. Mount Saint Helens on Earth (Wiki)

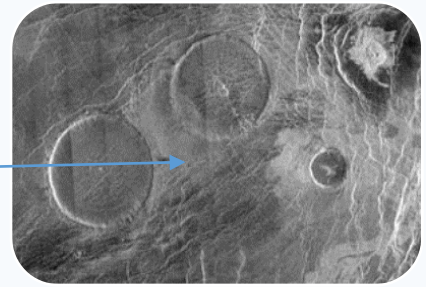


Figure 18. Corona on Venus (Wiki)

Figure 19. Olympus Mons on Mars (Wiki)

Atmospheres for Terrestrial Planets

- Venus, Earth, and Mars have extended atmospheres.
- All of the terrestrial atmospheres have a troposphere and stratosphere; but Earth has a mesosphere layer.
- The atmospheres are composed of oxygen and carbon dioxide while Venus has significant sulfur and Earth has significant argon component.
- The pressure in the atmosphere changes and causes weather on Venus, Earth, and Mars.

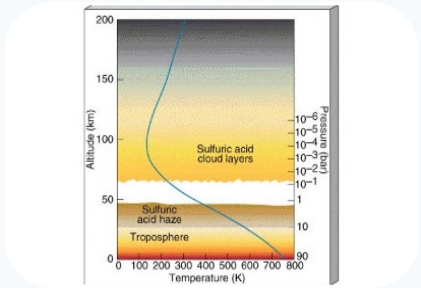


Figure 20. Atmospheric Profile for Venus (Close, 2015)

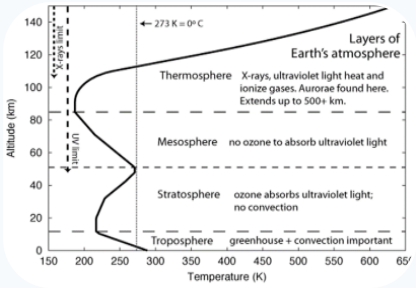


Figure 21. Atmospheric Profile for Earth (Strobel, 2014)

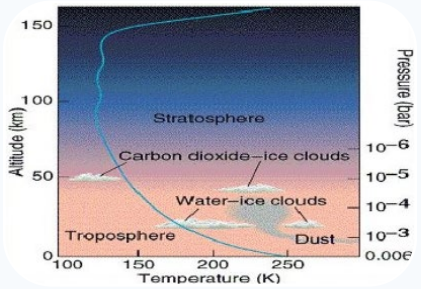


Figure 22. Atmospheric Profile for Mar (Harrison, 2015)

Weather – Winds on Earth and Mars

- Weather occurs on Venus, Earth, and Mars.
- Weather tends to be global for Venus and Mars, i.e. when there is a windstorm it occurs for the whole planet. On Earth, it is highly localize with different types of weather occurring at different location.
- Also, Earth and Mars experience seasons.

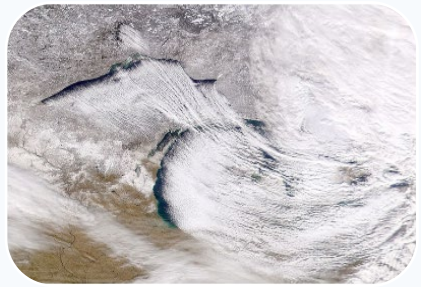


Figure 23. Weather on Earth (Wiki)

Figure 24. Winds on Mars (Wiki)

Figure 25. Frost on the Earth (Higget, 2015)

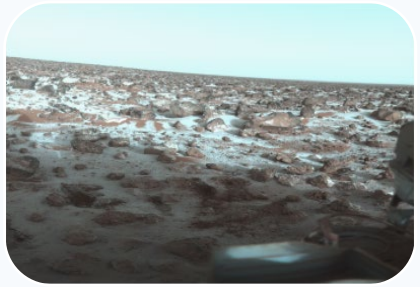


Figure 26. Frost on Mars (Wiki)

Dunes – Consequence of the Weather

- Dunes are built up on Earth and Mars due to wind storms.
- The dunes are consequence of wind erosion.
- Mars and Earth also share the existence of “dust devils”, swirling vortexes of dust due to rotational winds.

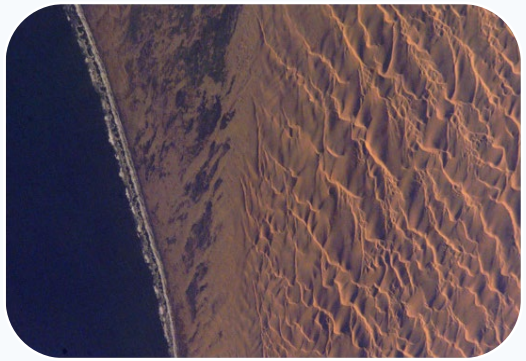


Figure 27. Dunes on Earth (Wiki)

Figure 28. Dunes on Mars (Wiki)

Moons of the Terrestrial Planets

Earth's Moon – Formed due to impact from asteroid.

Figure 29. Earth's Moon (Van Werven, 2015)

Phobos and Demos: Captured asteroids from the Asteroid belt.

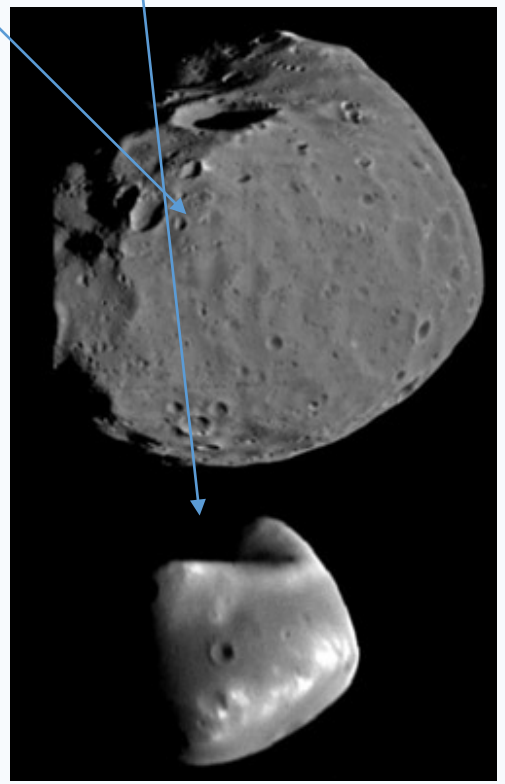


Figure 30. Phobos and Demos of Mars (Wiki)

Goldilock's Theorem – Habitable Zones

- The Goldilock's theorem states that only planets that exist a certain distance can support life. The type and state of a star determines which planets will create and sustain life.
- Venus is too hot: The planet did have water, but did not develop organic compounds. This situation did not allow for absorption of excess carbon. The carbon stayed around absorbed more heat; the more heat, the more the water evaporated releasing carbon into the air to absorb more heat. This cycle continued until the water was all evaporated leaving a scorched surface and sulfuric atmosphere.
- Mars is too cold: The planet started out with water and organic molecules. It was smaller and the interior cooled leaving little magma. Once the tectonic processes stopped, the planet could not sustain its thick atmosphere. The water boiled off into space releasing carbon dioxide into the thin atmosphere; but since it was further from the sun, it grew cold. Any life died or hibernated after such a period of the cool.
- Earth is just right: Earth has maintained a balance of all these objects; life has emerged and been sustained.

Jovian Planets

What are Jovian Planets?

- Jovian planets are Jupiter, Saturn, Uranus, and Neptune.
- Jovian Planets are planets with lighter elements, large in size, and orbit further away from the Sun.
- Jovian planets have icy, rocky cores that are under great pressures from large extended atmospheres.
- Jovian planets have many atmospheric layers with some being electrically conductive creating large magnetospheres around the planet. They produce more energy than they receive from the Sun.
- Jovian planets all have many natural satellites.

Cross Sections of Jovian Planets

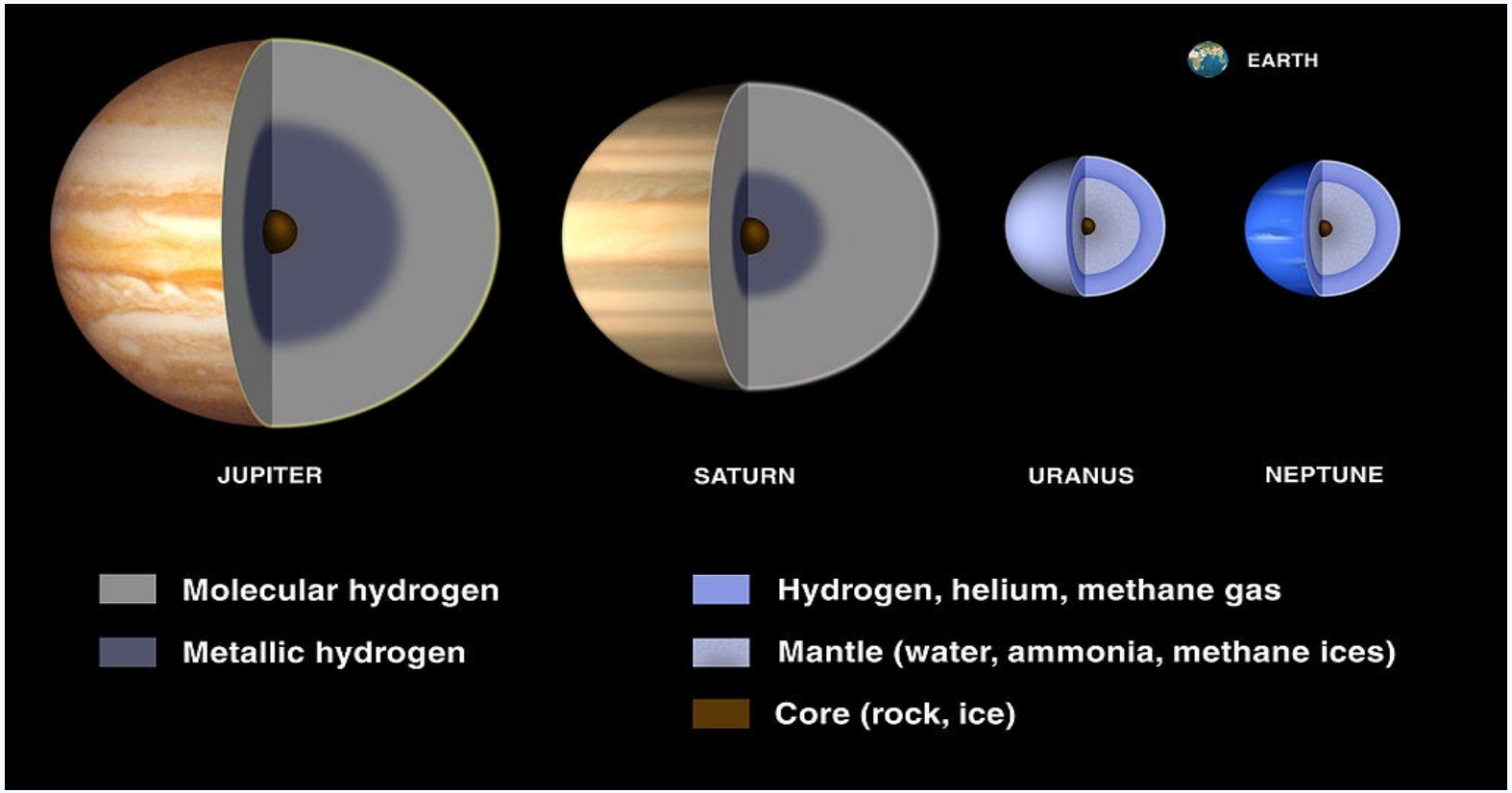


Figure 31. Cross Sections of the Jovian Planets (Wiki)

- Jovian Planets all have solid cores that either carbonaceous or icy.
- Jupiter and Saturn are massive enough to create enough pressure on their hydrogen to make it behave like a conductor thus producing a large amount of heat.
- Uranus and Neptune have been victims of the collisions from outer Solar System objects and have layers of ices that have not settled.

Jovian Magnetospheres

- Jovian planets have magnetospheres that are many times the size of the planet.
- Jupiter and Saturn have magnetospheres that are aligned with axis of rotation while Uranus and Neptune have magnetospheres that are not aligned and are off center from the planet.

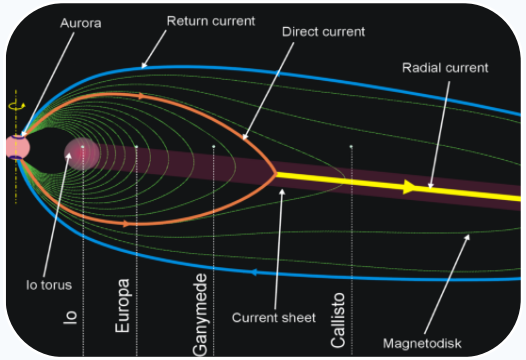


Figure 32. Jupiter's Magnetosphere (Wiki)

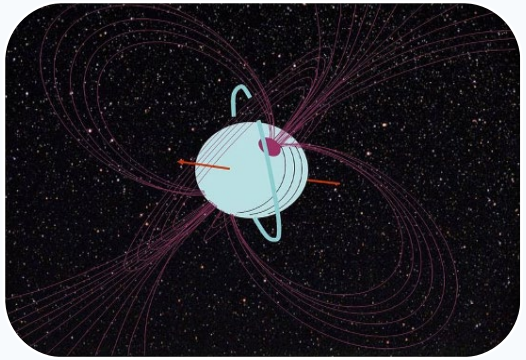


Figure 33 Uranus' Magnetosphere (Wiki)

Jupiter

- Distance: 7.783 X 10^8 km (7.783 A.U.)
- Albedo: 0.51
- Size (Diameter): 143,800 km (11.18 D_E)
- Mass: 1.889 X 10^{27} kg (317.83 M_E)
- Density: 1.34 g/cm^3 (0.243 ρ_E)
- Length of Year: 11.87 Earth years
- Length of Day: 0.417 Earth days
- Temperature: 165 K
- Number of Satellites: 67

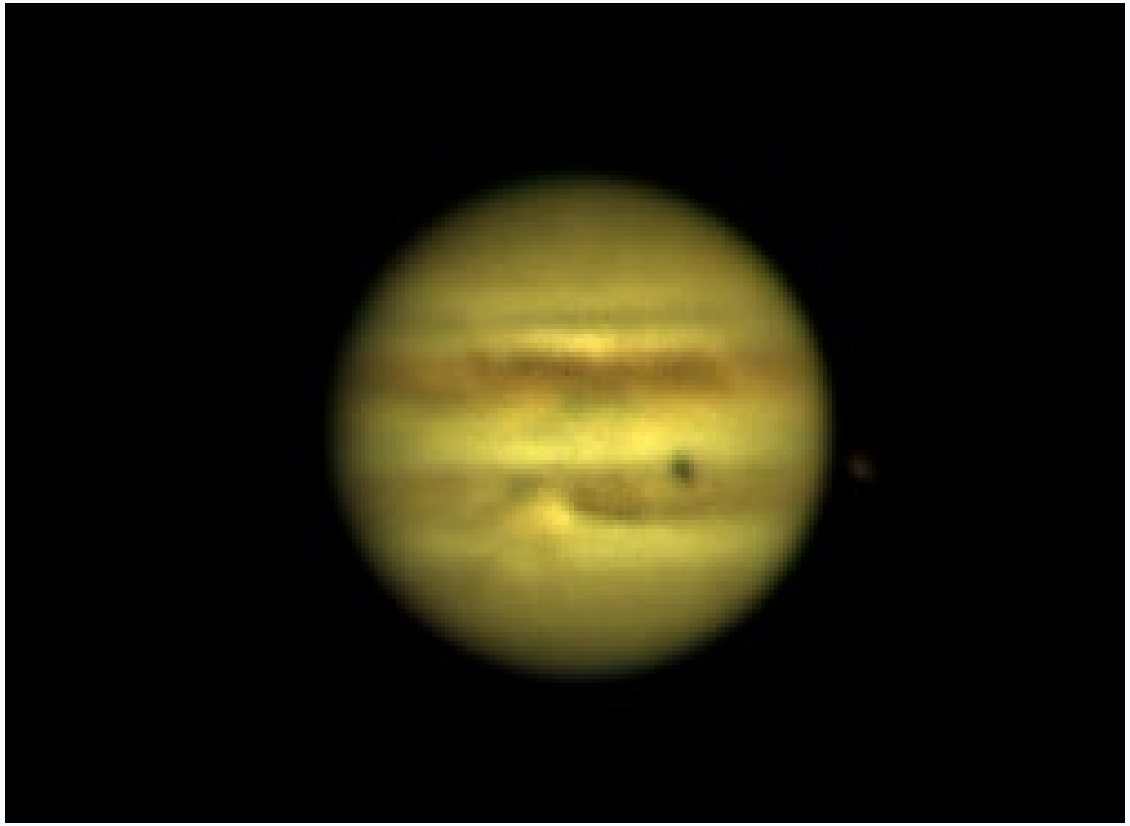


Figure 34. Jupiter (Van Werven, 2015)

Saturn

- Distance: 1.4 X 10^9 km (9.5 A.U.)
- Albedo: 0.47
- Size (Diameter): 120,536 km (9 D_E)
- Mass: 5.68 X 10^{26} kg (95.2 M_E)
- Density: 0.69 g/cm^3 (0.125 ρ_E)
- Length of Year: 29.5 Earth years
- Length of Day: 0.446 Earth days
- Temperature: 134 K
- Number of Satellites: 62

Figure 35. Saturn (Van Werven, 2015)

Uranus' Properties

- Distance: 3.0 X 10^9 km (19.2 A.U.)
- Albedo: 0.51
- Size (Diameter): 57,118 km (4 D_E)
- Mass: 8.722 X 10^{25} kg (14.6 M_E)
- Density: 1.29 g/cm^3 (0.234 ρ_E)
- Length of Year: 84.0 Earth years
- Length of Day: 0.717 Earth days
- Temperature: 76 K
- Number of Satellites: 27

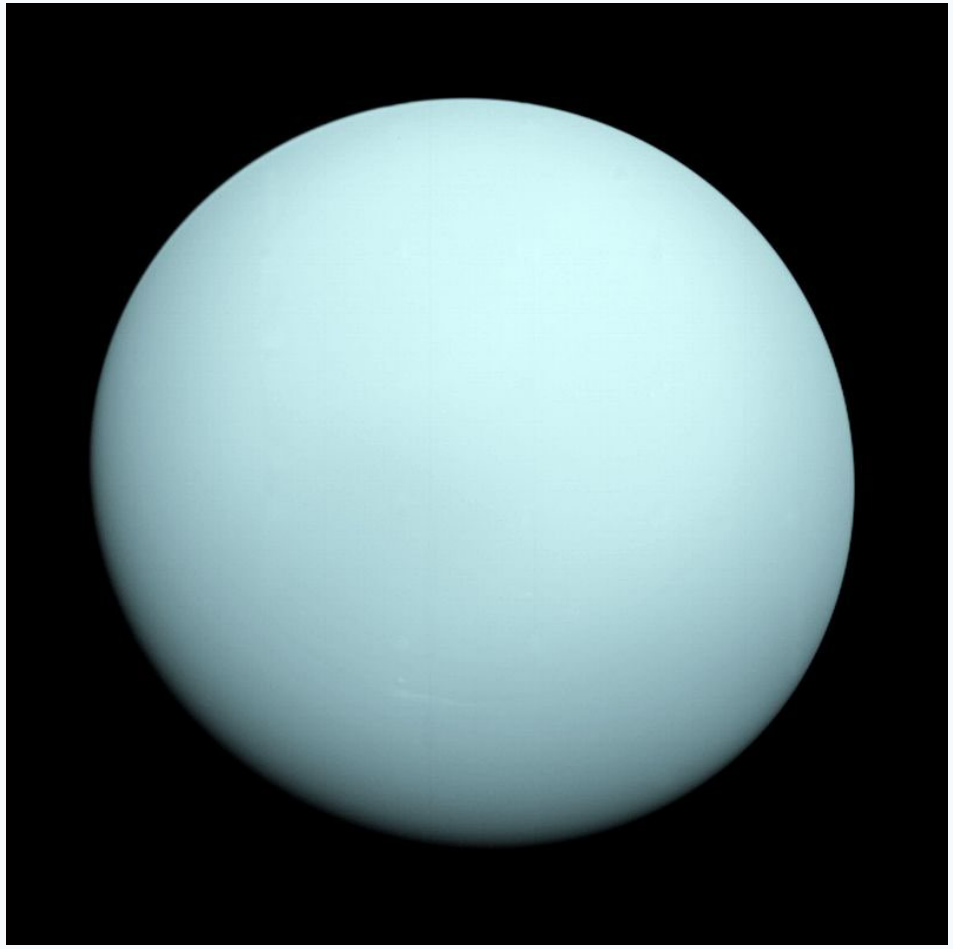


Figure 36. Uranus (Wiki)

Neptune's Properties

- Distance: 4.497 X 10^9 km (30.1 A.U.)
- Albedo: 0.35
- Size (Diameter): 49,528 km (4 D_E)
- Mass: 1.027 X 10^{26} kg (17.2 M_E)
- Density: 1.64 g/cm^3(0.297 ρ_E)
- Length of Year: 164.8 Earth years
- Length of Day: 0.670 Earth days
- Temperature: 72 K
- Number of Satellites: 14

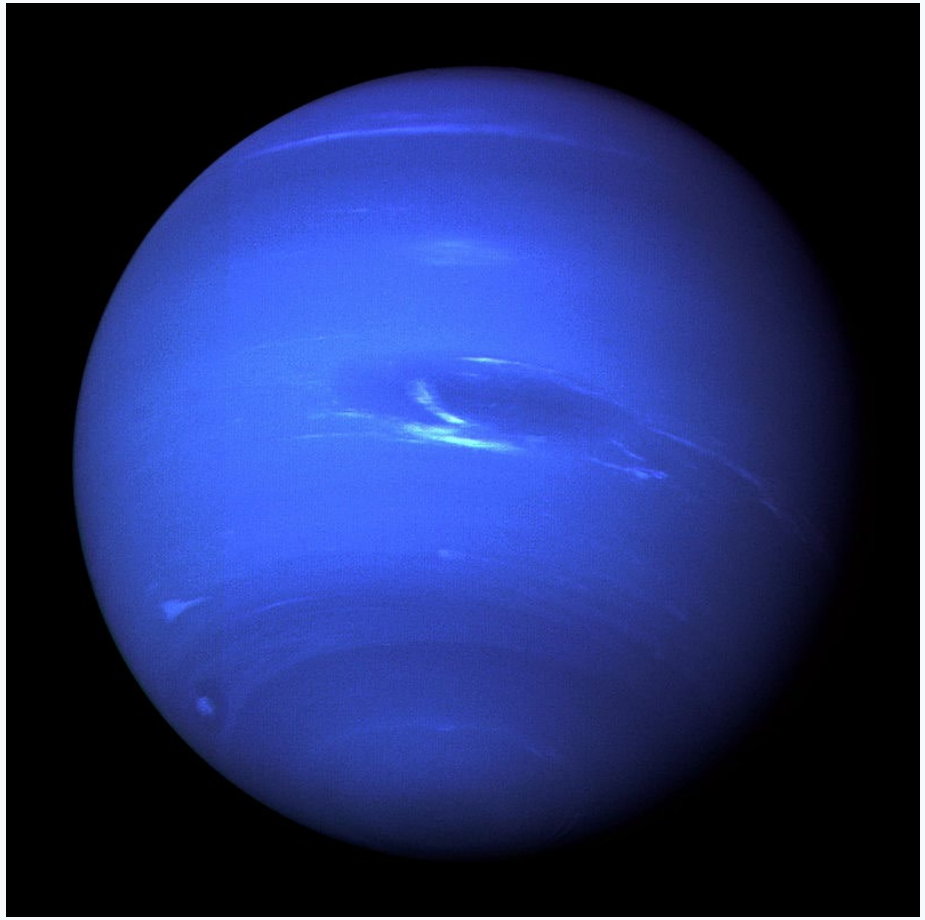


Figure 37. Neptune (Wiki)

Upper Atmospheric Storms

- All the Jovian planets have storms in their active upper atmospheres.
- Belts (high pressure) and Zones (low pressure) move past each other spinning off Storms.
- In the case of Jupiter, the Red Spot was spun off 10,000 years ago. In the case of Saturn, a vortex called the Hexagonal Vortex has formed.
- We have tried to resolve these on Uranus, but a methane haze is making imaging these difficult.

Figure 38. Jupiter's Belts and Zones (Wiki)

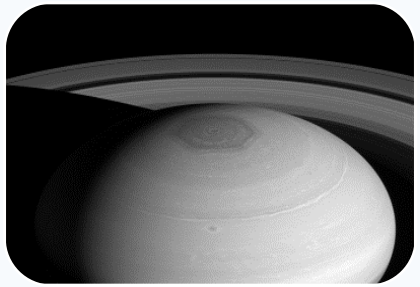


Figure 39. Saturn's Belts and Zones (Wiki)

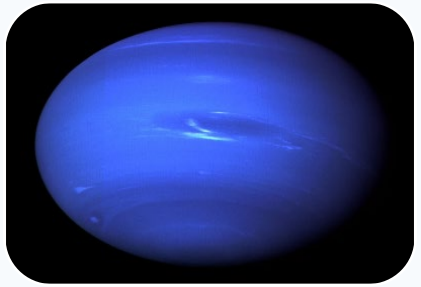


Figure 40. Neptune's Storms (Wiki)

Jovian Planet Rings

- All the Jovian planets have rings.
- The rings are a product of either moons were broken up due to impacts or charged material caught in the magnetosphere of the planets.
- The objects are guided into the equatorial plane of the planet and kept in place by shepherd moons that gravitationally.
- Note that Uranus rolls around on it equatorial plane as opposed to the other Jovian planets.

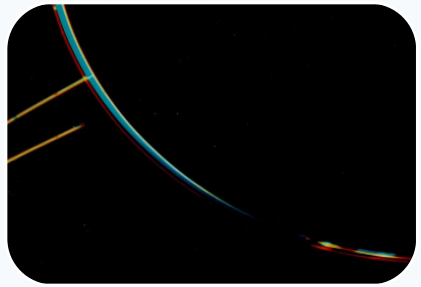


Figure 41. Jupiter's Rings (Wiki)

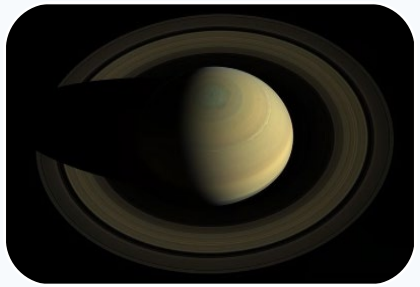


Figure 42. Saturn's Rings (Wiki)

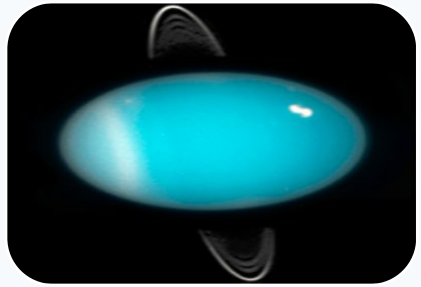


Figure 43. Uranus' Rings (Wiki)

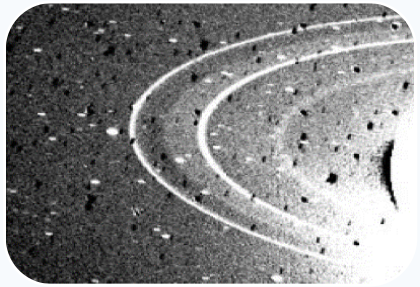


Figure 44. Neptune's Ring (Wiki)

Jupiter’s Moons

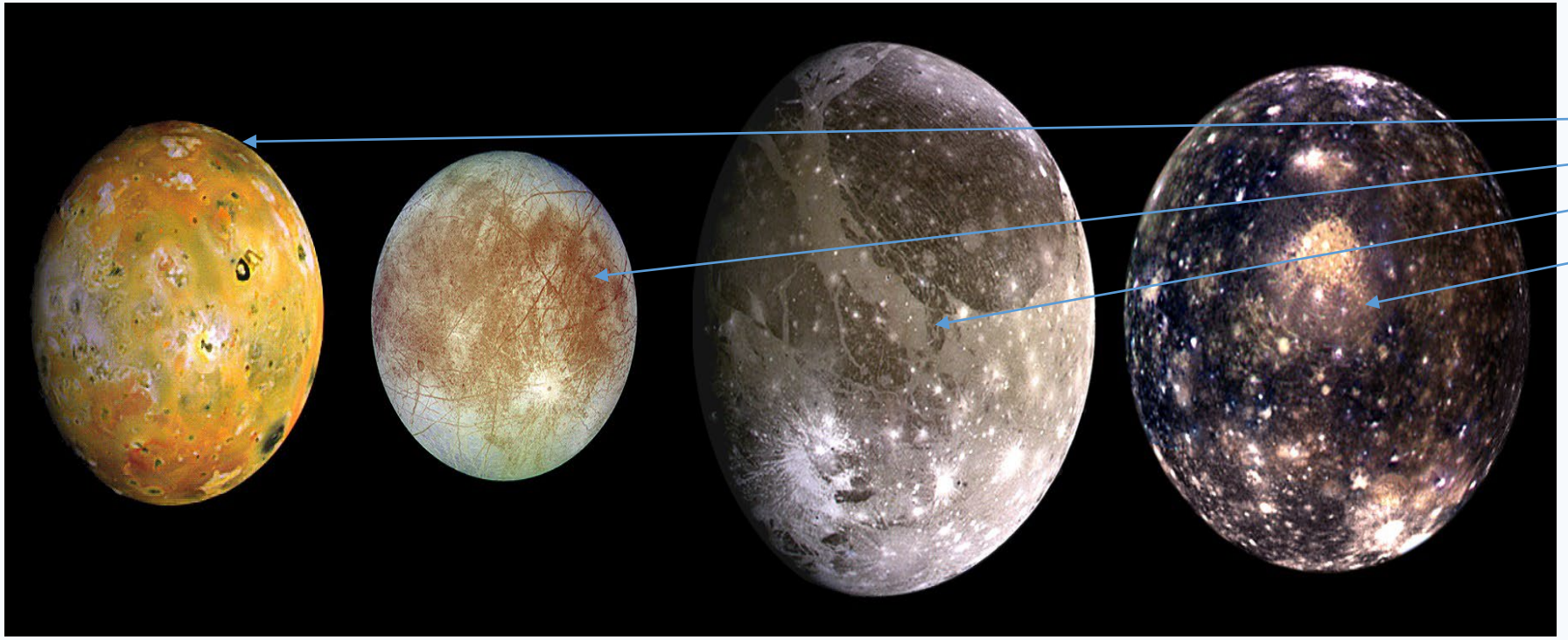
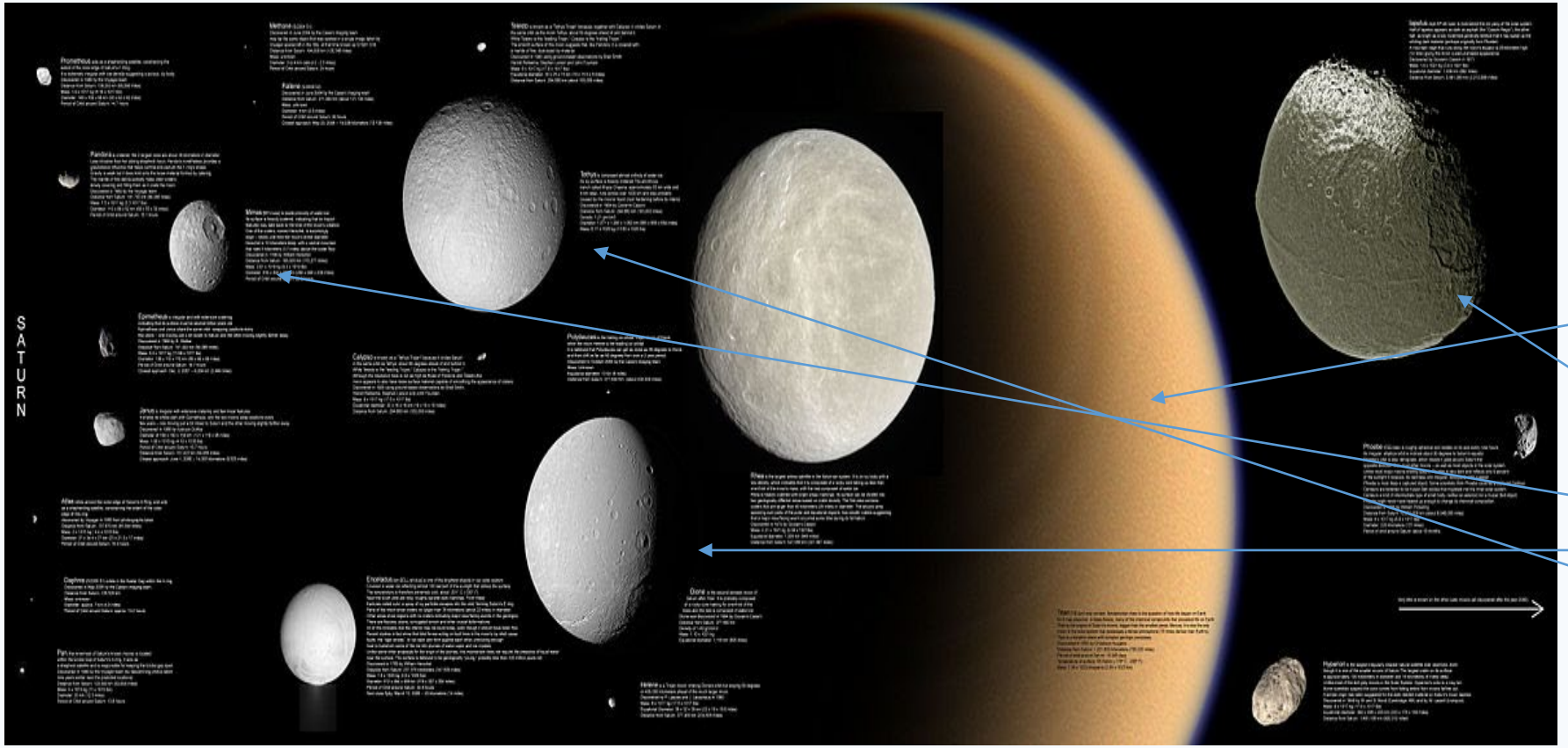


Figure 45. Jupiter’s Moons (Wiki)

- The four main moons for Jupiter are Io, Europa, Ganymede, and Calisto.
- Io and Europa are kneaded by the magnetosphere of Jupiter and have fluid surfaces.
- Ganymede and Calisto have been greatly impacted and have many craters.

Saturn's Moons



- The main moons of Saturn are Titan, Mimas, Enceladus, Rhea, Tethys, Phoebe, and Dione.
- Titan has an atmosphere of methane very much like the ancient Earth.
- Mimas, Enceladus, Rhea, Dione, Phoebe, and Tethys are icy planets that are kneaded by the magnetosphere of Saturn.

Figure 46. Saturn's Moons (Wiki)

Uranus' Moons

- The five main Uranian moons are Miranda, Ariel, Umbriel, Titania and Oberon.
- Miranda has a complex geology that is thought to be due to the influence of magnetospheres of Uranus.

Figure 47. Uranus' Moons (Wiki)

Neptune's Moons

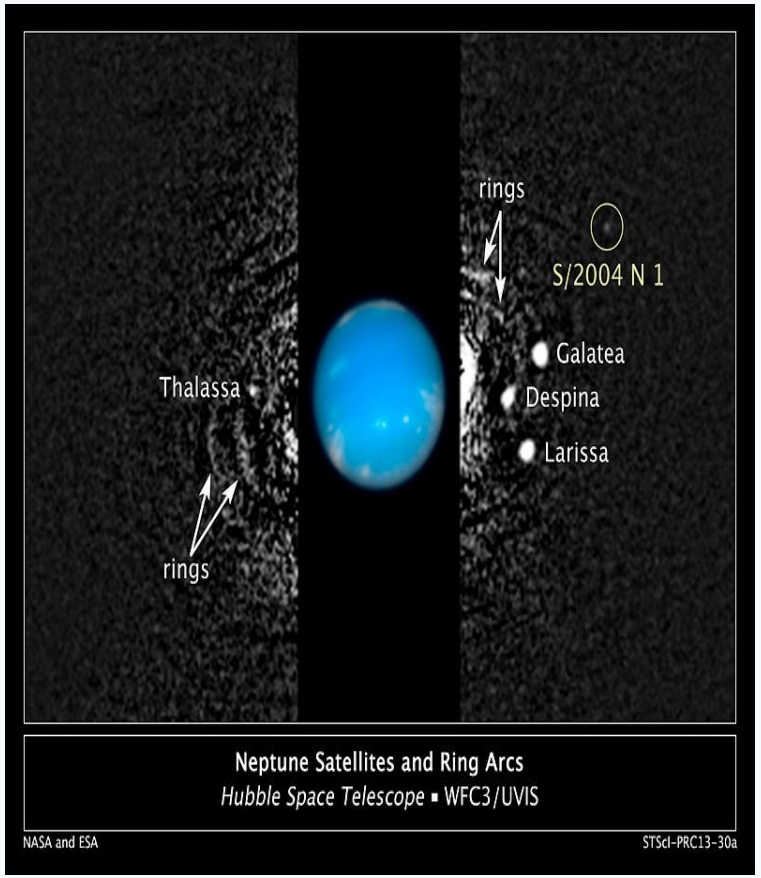


Figure 48. Neptune's Inner Moons (Wiki)

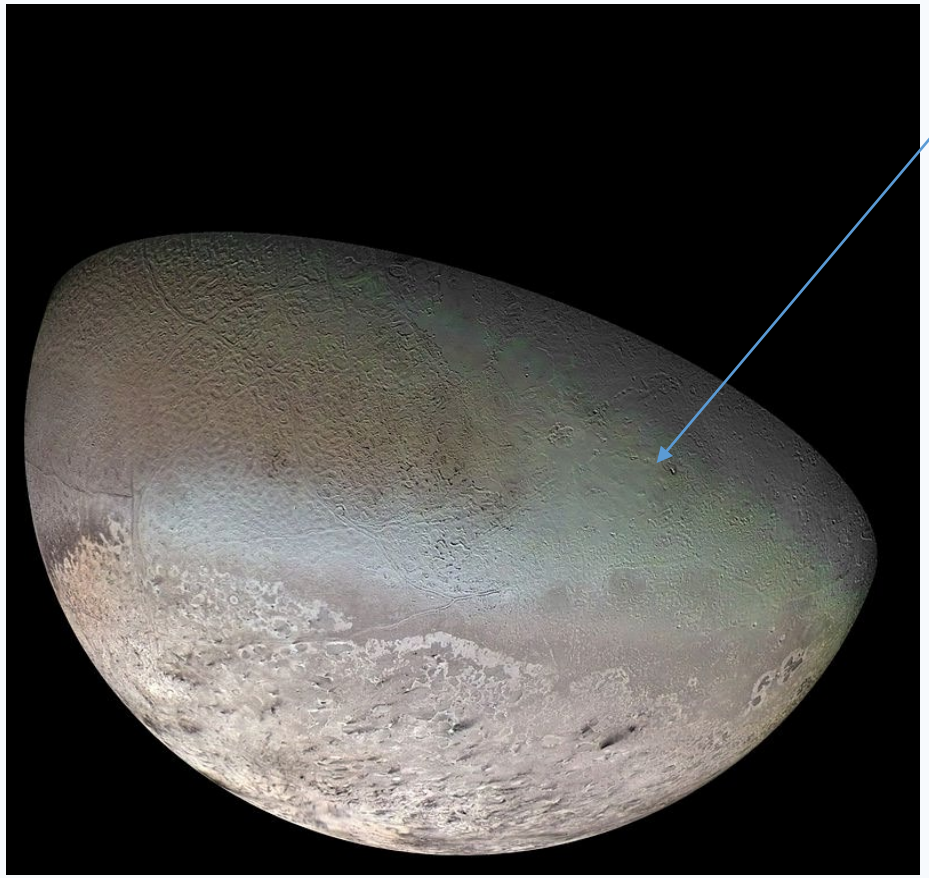


Figure 49. Triton (Wiki)

- The main moon of Neptune is Triton.
- Triton is active due to the magnetosphere of Neptune and has a small atmosphere.
- Most of the moons of the Jovian Planets are captured asteroids or Solar System debris.

Dwarf and Extrasolar Planets

What are the Dwarf Planets?

- Dwarf Planets are small rocky, icy bodies that have enough gravity for roundness and do not clear their paths.
- Dwarf planets orbit in belts, clouds, and between planets.
- Dwarf planets can be comprised of many different materials.
- Some dwarf planets have moons.

Dwarf Planets – Ceres, Pluto, and Eris

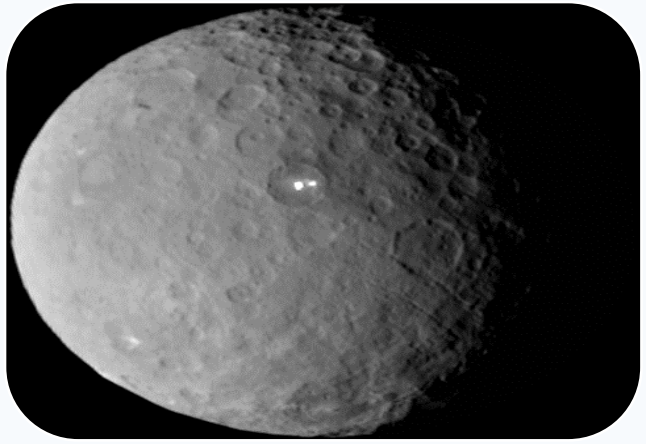


Figure 50. Ceres (NASA/JPL-Caltech/UCLA/MPS/DLR/IDA,2015)

Figure 51. Pluto (NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute,2015)

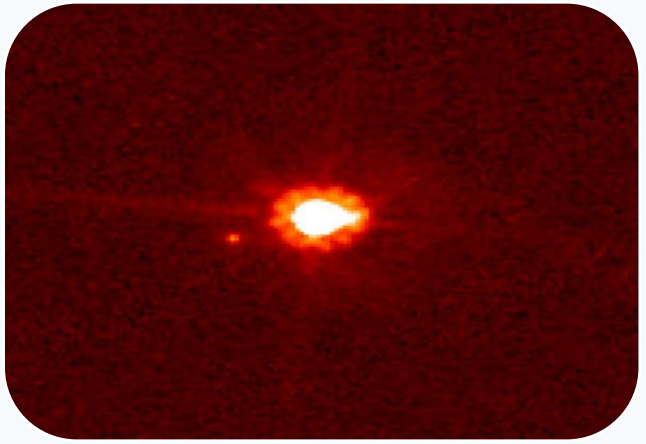
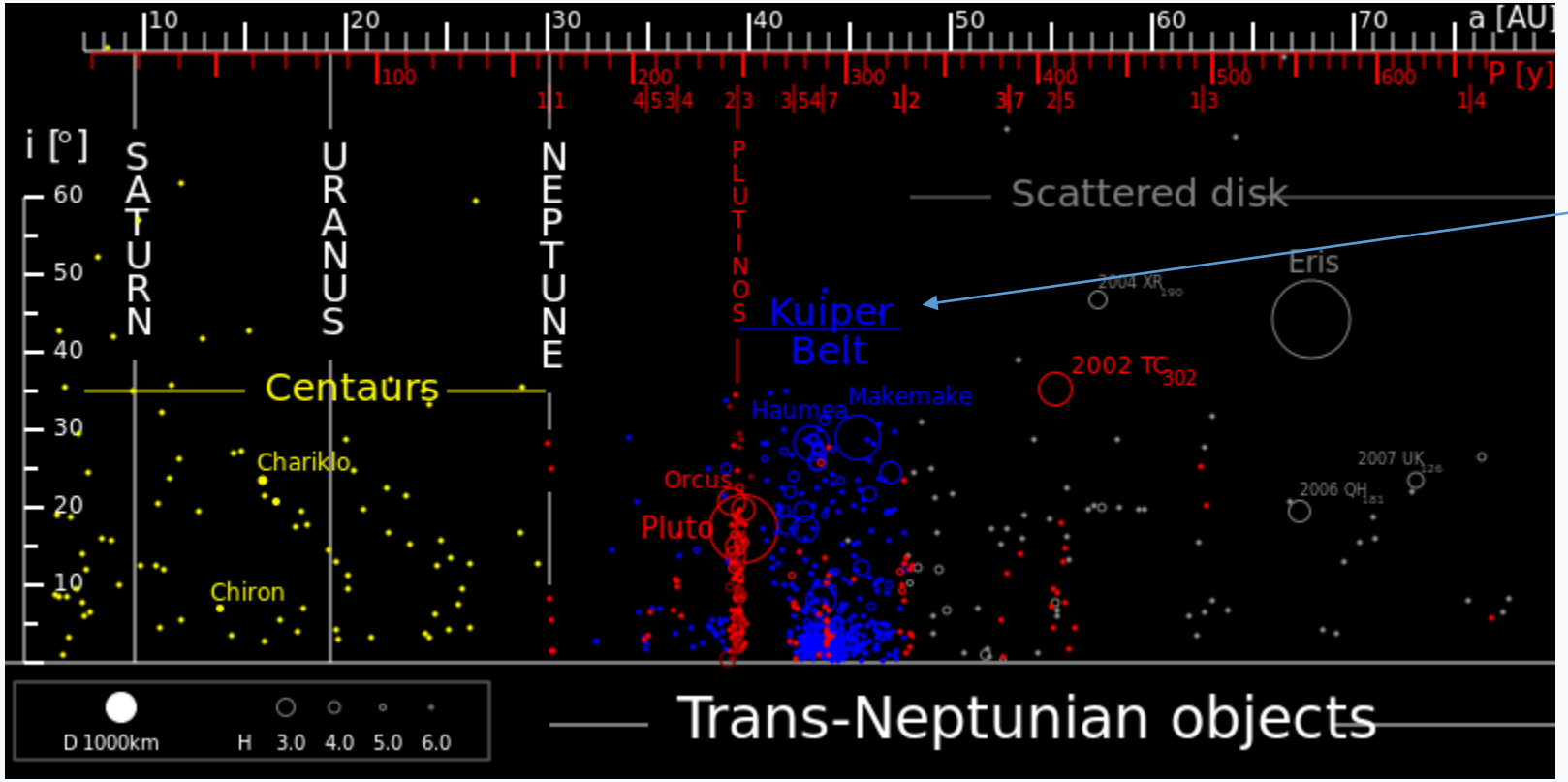


Figure 52. Eris (Wiki)

These are three examples of the dwarf planets. Ceres is inside the asteroid belt between Mars and Jupiter while Pluto and Eris frame the inner and outer Kuiper Belt (a belt near the orbit of Neptune). Some have moons and are planetary systems as much as the major planets.

Outer Solar System Dwarf Planet Orbits



- Most Dwarf planets are outer solar System objects that orbit in a group of icy planetsimals called the Kuiper Belt .
- Ceres is the exception orbiting at 2.5 A.U. in the main asteroid belt.

Figure 53. Orbits of the Outer Solar System Dwarf Planets (Wiki)

Extrasolar Planets

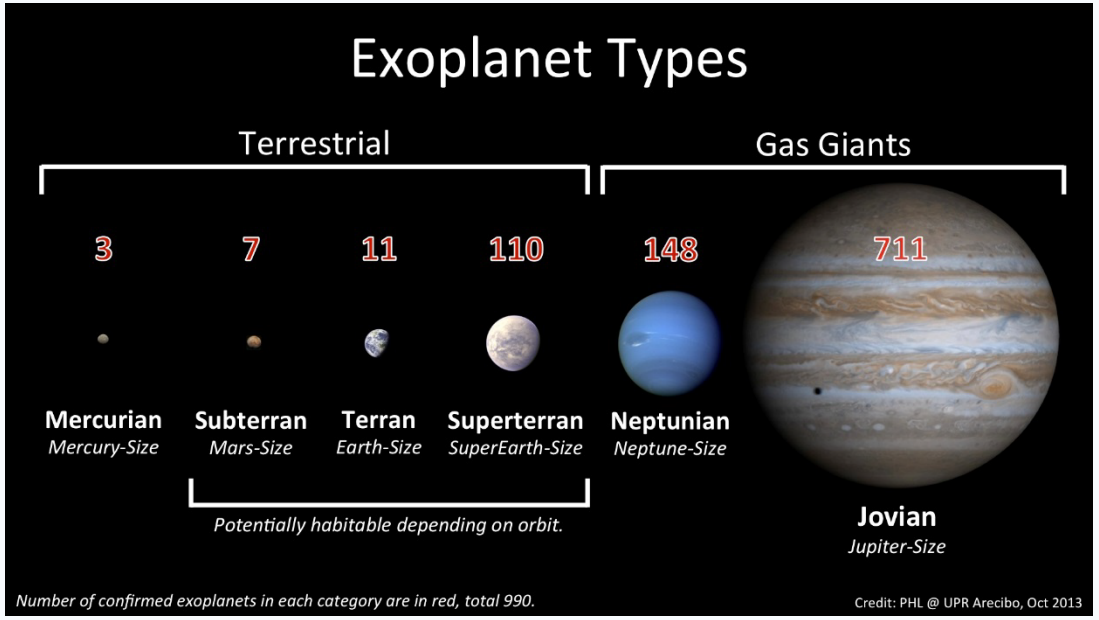


Figure 54. Types of Extrasolar Planets (Mendez, 2015)

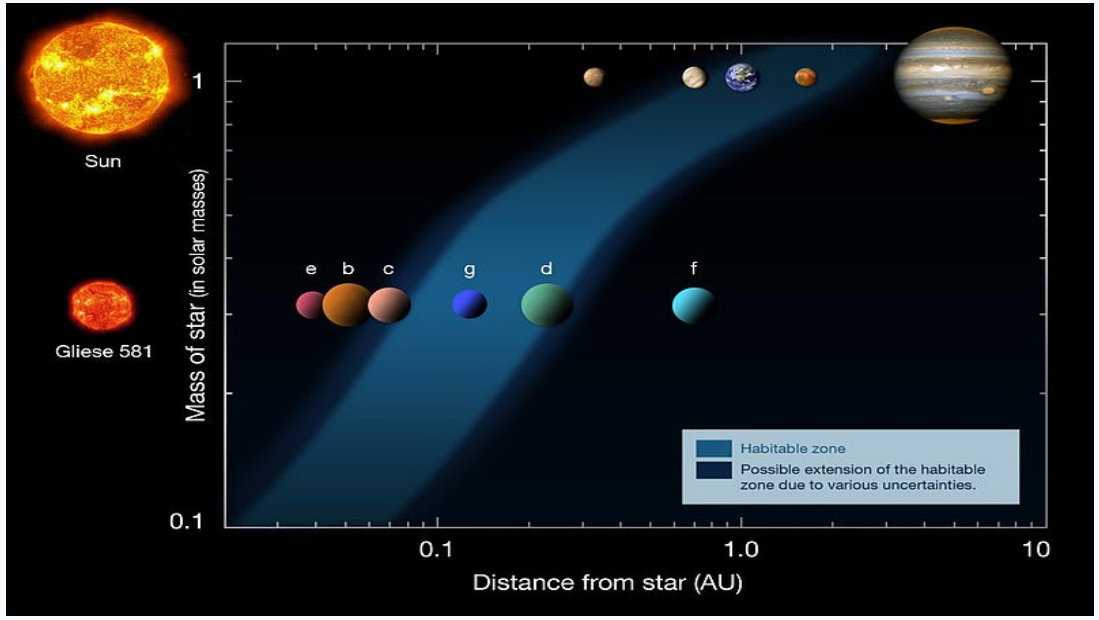


Figure 55. Habitable Zones of Extrasolar Planets (Wiki)

Extrasolar planets are planets found orbiting stars other than our Sun. Extrasolar planets can be either Jovian or Terrestrial. They orbit in different areas than the planets in our Solar System. They are classified by size and orbit.

Number of Extrasolar Planet Candidates

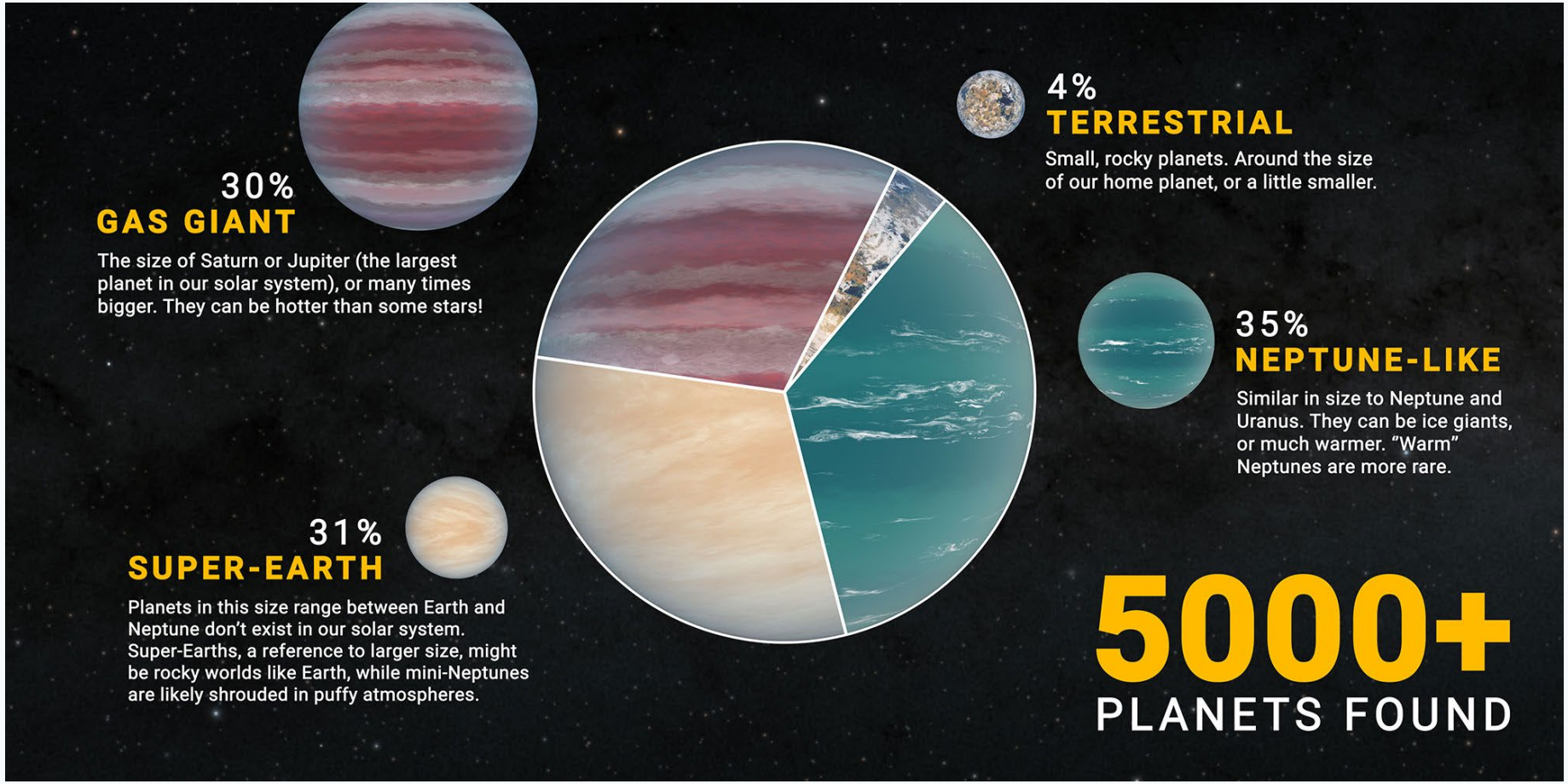


Figure 56. Current Extrasolar Planet Candidates (Brennon, 2022)

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