Properties of the Planets

Physical Sciences
Broward College
Prepared for AST 1002
Horizons in Astronomy

What is a Planet?

- A planet is rock, icy body that orbits a star, in other words its orbital center of mass is inside of the star.
- A planet can produced energy in its magnetosphere, but does not produce fusion at its core.
- A planet is round due its large mass and clears the path in its particular orbit.
- The major planets are name after Greek/Roman gods and goddesses.
- The distances to planets are in Astronomical Units (A.U.) (1.4960×10^8 km), the distance between the Earth and the Sun.

Types of Planets

Terrestrial	Jovian	Dwarf	Extrasolar
Mercury	Jupiter	Pluto	Many, Many Planets
Venus	Saturn	Eris	
Earth	Uranus	Ceres and many, many more	
Mars	Neptune		

Planetary Orbits

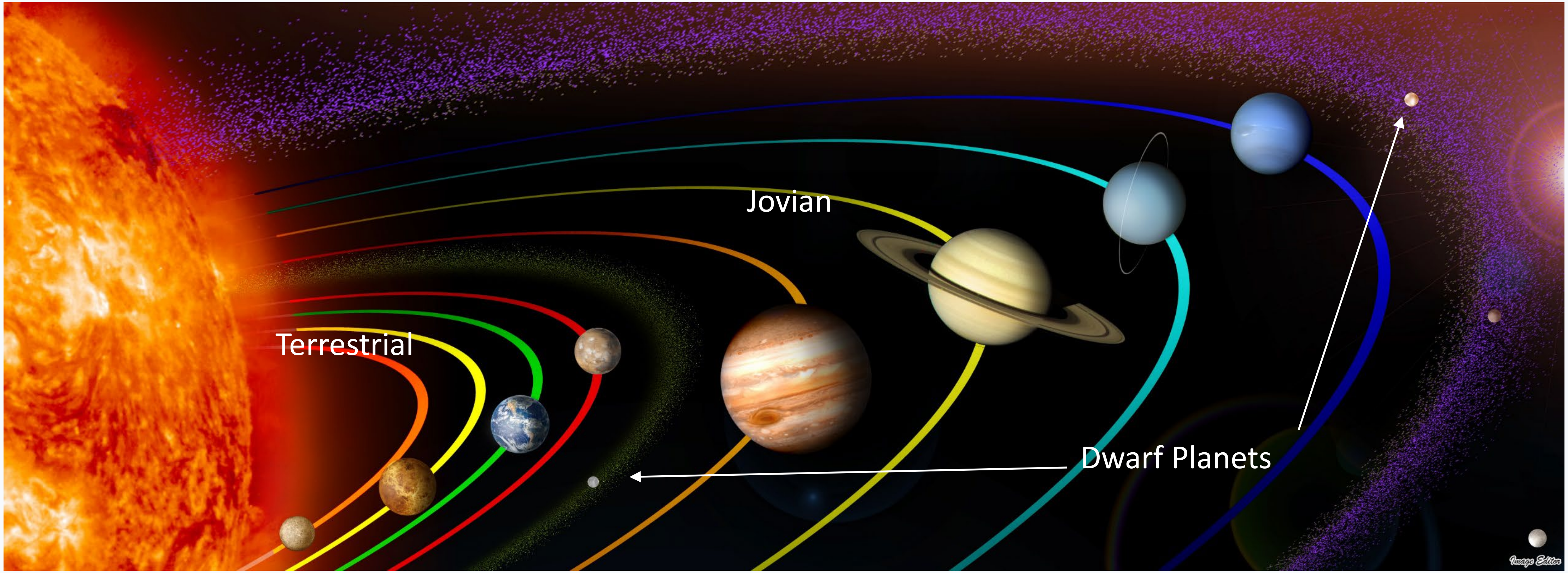
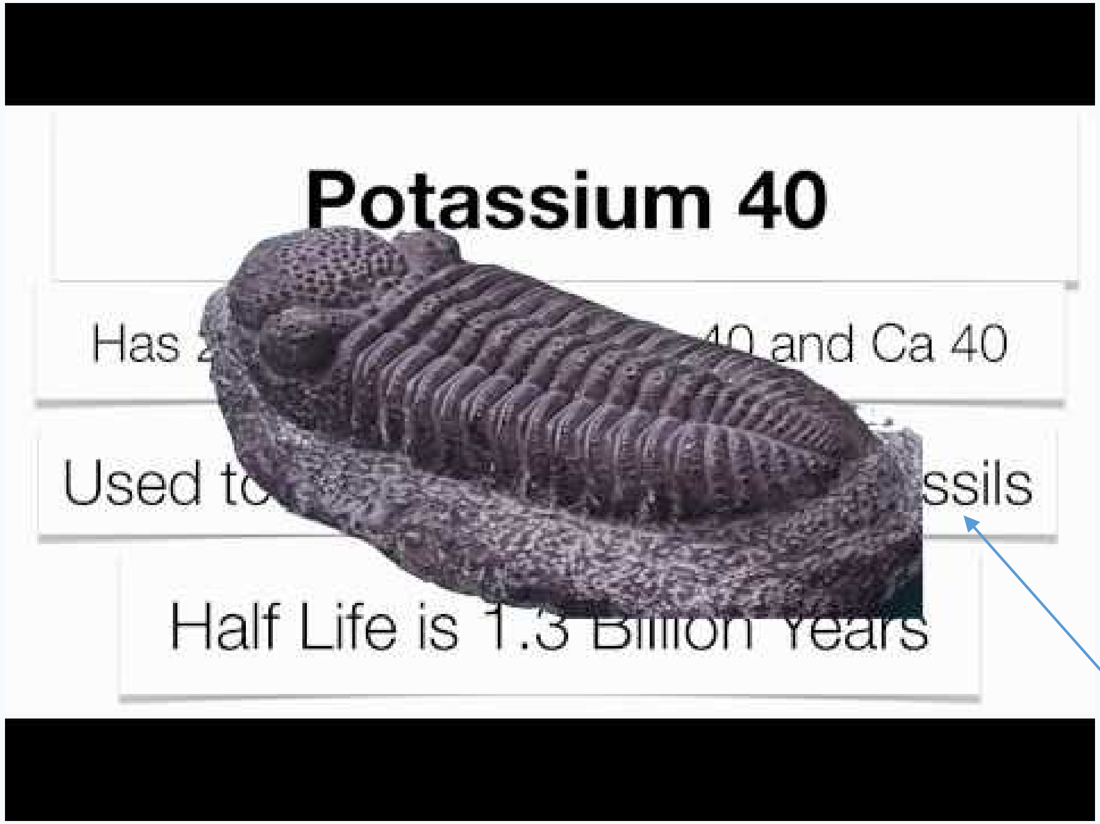


Figure 1. Planetary Orbits (Image Editor/NASA/JPL, 2008)

Abundance

- Abundance is the percentage of a particular material that comprises an object.
- Can be 100% or 0%
- Elemental abundances are based on observations taken from the universe via spectroscopy.
- Elemental abundances are the percentage of the universe that particular element comprises.
- The planets that are made of hydrogen and helium are larger than the planets made of iron and oxygen.
- Also the heavier elements are less abundant so they suggest a second generation star.
- Primary atmospheres are made of hydrogen and helium while second atmospheres are made of other elements.

Radioactive Decay



- Some atomic configurations (isotopes) are unstable and they decay into other elements or isotopes.
- The decay is predictable; we can calculate the age of a planet from its abundance of its elements.
- Please click on the image to learn more about radio dating.

Escape velocities – Atmospheric Living

- It is when K.E. (Kinetic Energy) = P.E. (Potential Energy) or K.E. (Internal) = K.E. (External) in the conservation of energy.
- It is the velocity required to escape from the gravitational pull of an object (planet, star, and galaxy).
- Two types:
  - Molecular escape velocities – When the K.E. (Molecular) of the particle is equal the K.E. (External).
  - Gravitational escape velocities – When the P.E. (Gravitational) of the particle is equal to the general K.E. (External).
- If the gravitational is much greater than the molecular escape velocity, the molecule is trapped in this particular planet's atmosphere.
- If the situation is reversed or the velocities are close, the molecule escapes.
- The inner planets have small escape velocities and higher temperatures therefore they have the heavier (oxygen, nitrogen) elements, molecules
- The outer planets have large escape velocities and low temperatures therefore they have the lighter elements (hydrogen, helium).

Molecular Escape Velocities

$$KE_{Molecular} = \frac{3}{2}kT \text{ (or } \frac{8}{2\pi}kT)$$

$$KE = \frac{1}{2}mv^2$$

$$KE = KE_{Molecular}$$

$$\frac{1}{2}mv^2 = \frac{3}{2}kT$$

$$mv^2 = 3kT$$

$$\sqrt{v^2} = \sqrt{\frac{3kT}{m}}$$

$$v = \sqrt{\frac{3kT}{m}}$$

$$m_H = 1.6735X10^{-27}kg$$

$$T = 293.0K$$

$$k = 1.3805X10^{-23}J/K$$

$$v = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.3805X10^{-23}J/K)(293.0K)}{1.6735X10^{-27}kg}}$$

$$v = 2{,}693\,m/s$$

The molecular escape velocity of hydrogen at Earth. We use the mass of hydrogen with the blackbody temperature of the Earth in Kelvins. And k is the Boltzmann constant.

Molecular Escape Velocities

To calculate the molecular escape velocity we heat elements/compounds and allow the atoms/molecules to hit a target. The speed at which most of the atoms/molecules hit the target is the escape velocity.

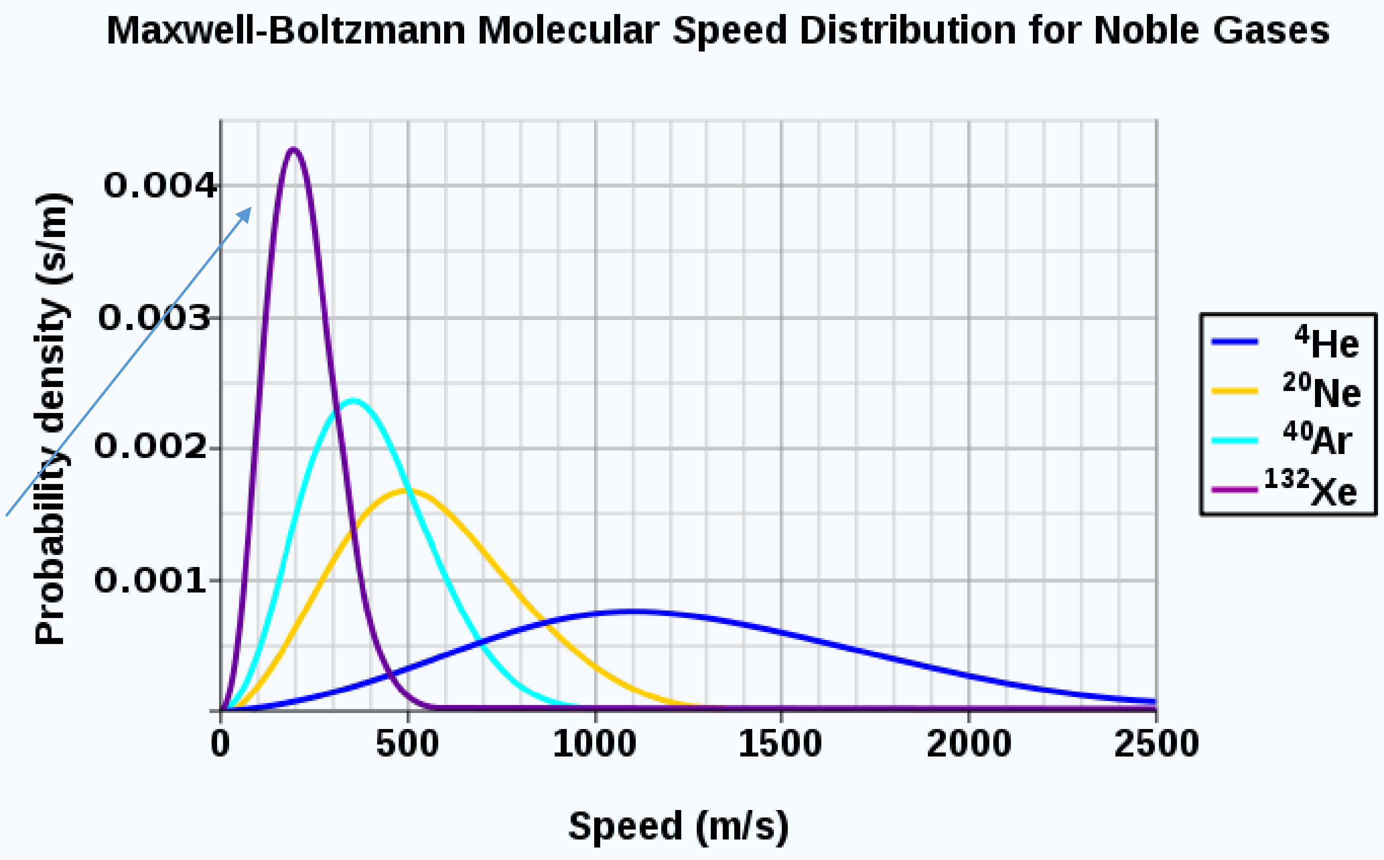


Figure 2. Molecular Escape Velocities of Different Elements (Wiki)

Gravitational Escape Velocity of Earth

$$KE = \frac{1}{2}mv^2$$

$$PE_{Gravitational} = \frac{GMm}{r}$$

$$KE = PE$$

$$\frac{1}{2}mv^2 = \frac{GMm}{r}$$

$$\sqrt{v^2} = \sqrt{\frac{2GM}{r}}$$

$$v = \sqrt{\frac{2GM}{r}}$$

$$M = 5.98X10^{24}\,kg$$

$$r = 6.378X10^{6}\,m$$

$$v = \sqrt{\frac{2GM}{r}}$$

$$v = \sqrt{\frac{2(6.67X10^{-11}\,Nm^2/kg^2)(5.98X10^{24}\,kg)}{6.378X10^{6}\,m}}$$

$$v = 11{,}183\,m/s$$

The molecular escape of hydrogen is close to gravitational escape velocity of Earth so the likelihood of hydrogen in our atmosphere is low.

Albedo versus Blackbody Temperatures – Surface Living

- Albedo is the amount of sunlight a planet reflects.
- It is determined as a ratio of the amount of light received to the amount of sunlight reflected.
- Planets that have bright surfaces and/or clouds have large albedos.
- Planets that have dim surfaces and/or clouds have small albedos.

- A simplified picture:
- When the albedo is large and the blackbody temperature is small, then much of the light is not making it down to the surface. Therefore a cold planet. (Uranus, Neptune, Pluto)
- When the albedo is large and the blackbody temperature is large then much of the light reaches the surface (Mercury, Venus)
- When the albedo is large and the blackbody are balanced then just the right amount of light is reaching the planet. (Earth)

Albedo Temperature of Venus

$$T = T_{Sun}\sqrt{\frac{R}{2d}\sqrt{(1 - a)}}$$

T_{Sun} is the temperature of the sun

d is the distance to the planet in m

R is the radius of the sun in m

a is the albedo

$$R = 6.960 X 10^{8}\ m$$

$$d = 108.2 X 10^{9}\ m$$

$$a = 0.65$$

$$T_{Sun} = 5{,}700\ K$$

$$T = (5{,}700\ K)\sqrt{\frac{(6.960 X 10^{8}\ m)\sqrt{1-0.65}}{2(108.2 X 10^{9}\ m)}}$$

$$T = (5{,}700\ K)\sqrt{\frac{4.117 X 10^{8}\ m}{2.164 X 10^{11}\ m}}$$

$$T = 249\ K$$

Blackbody Temperatures of the Planets

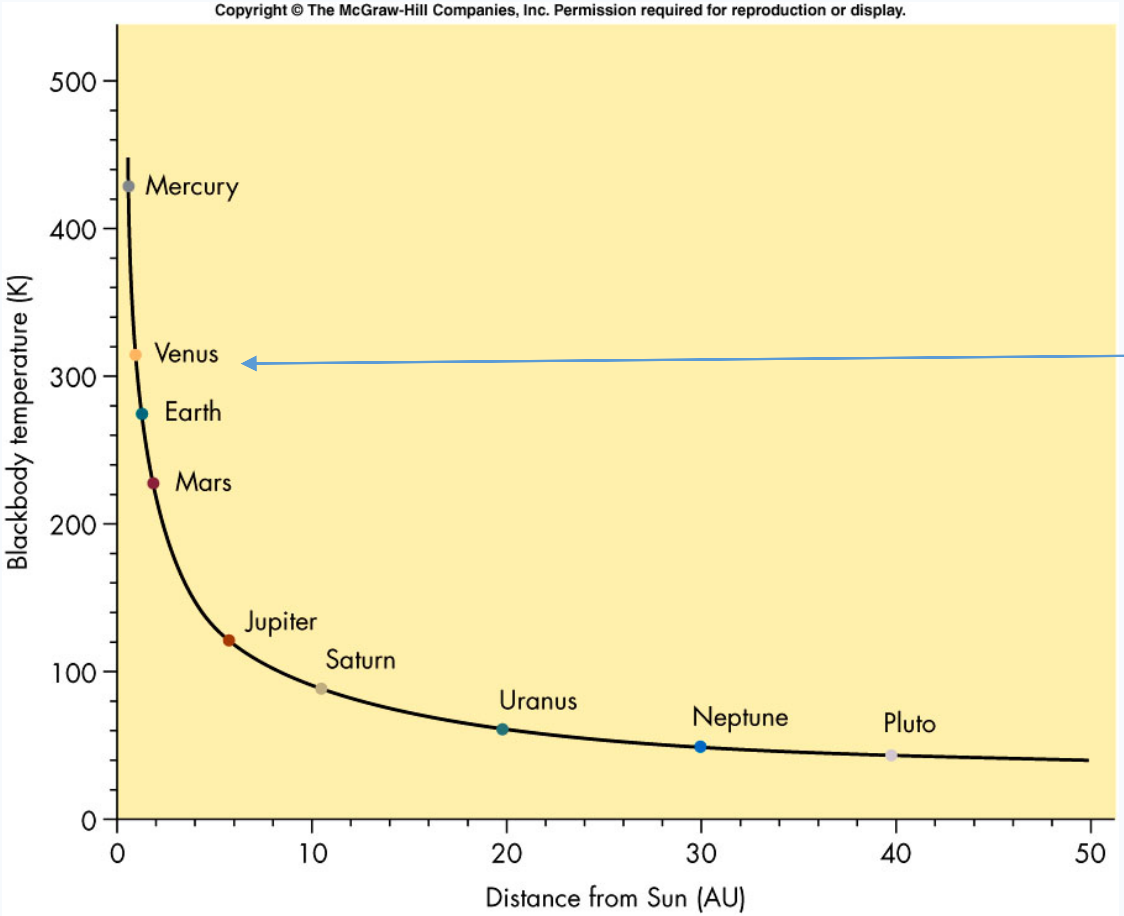


Figure 3. Blackbody temperature of the Planets (Fix, 2004)

Venus has a larger blackbody temperature than albedo temperature. The interpretation is that it has a great Greenhouse Effect and keeps most of the heat it receives from the Sun; it is very hot on the surface.

Book/Course Image References

- Fix, J. D. (2004) *Astronomy: Journey to the Cosmic Frontier,* New York, McGraw-Hill Higher Education
- Image Editor/NASA/JPL (2008) *01 The Solar System PIA10231, mod02* Retrieved from: https://www.flickr.com/photos/11304375@N07/2818891443

Wiki Image References

- Molecular Escape Velocities for Different Elements: "MaxwellBoltzmann-en" by Original uploader was Pdbailey at en.wikipediaLater versions were uploaded by Cryptic C62 at en.wikipedia.Convert into SVG by Lilyu from Image:MaxwellBoltzmann.gif. - Originally from en.wikipedia; description page is/was here.. Licensed under Public Domain via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:MaxwellBoltzmann-en.svg#/media/File:MaxwellBoltzmann-en.svg