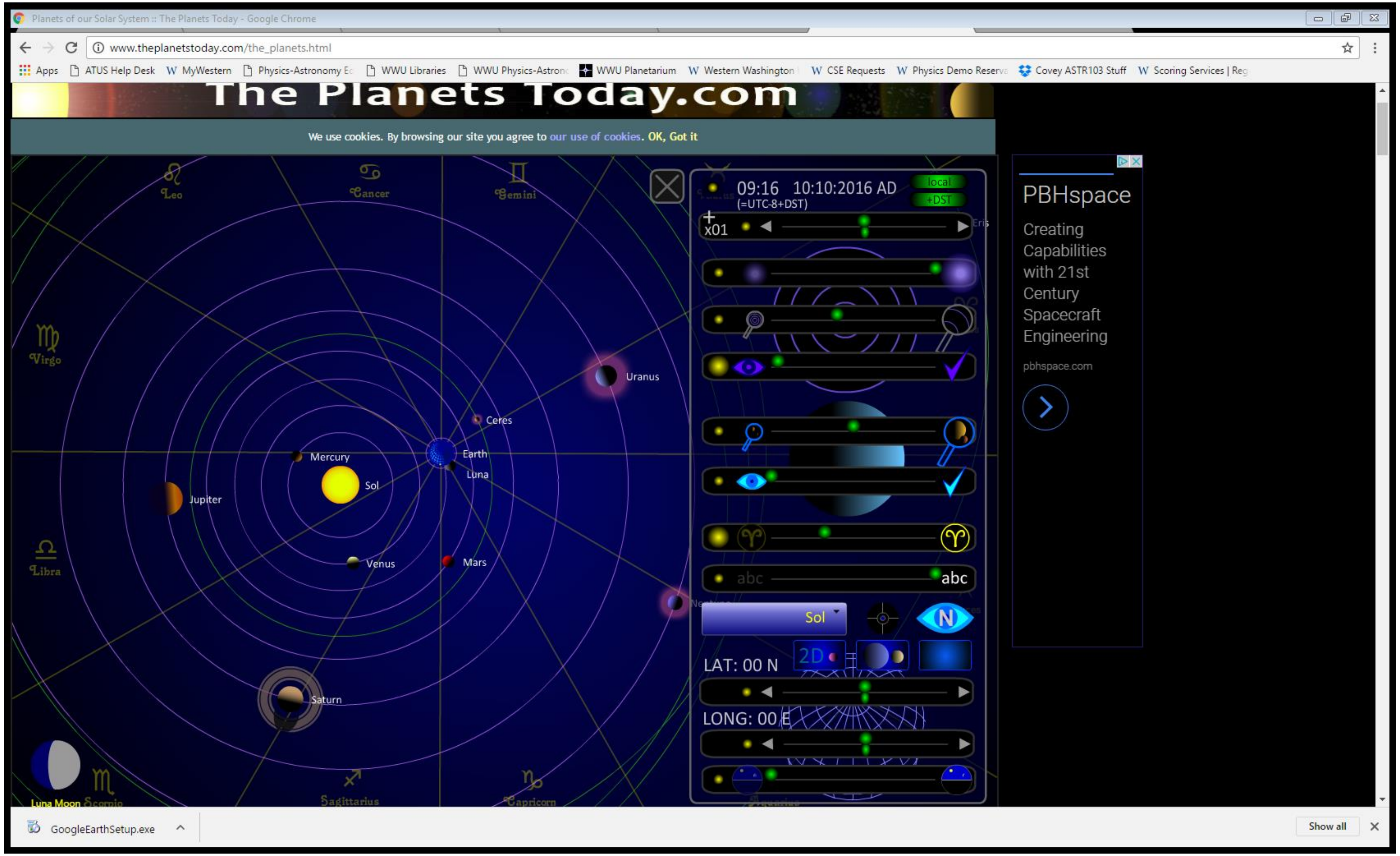
Planets in the sky

Week 4

The Solar System

http://www.theplanetstoday.com/the_planets.html

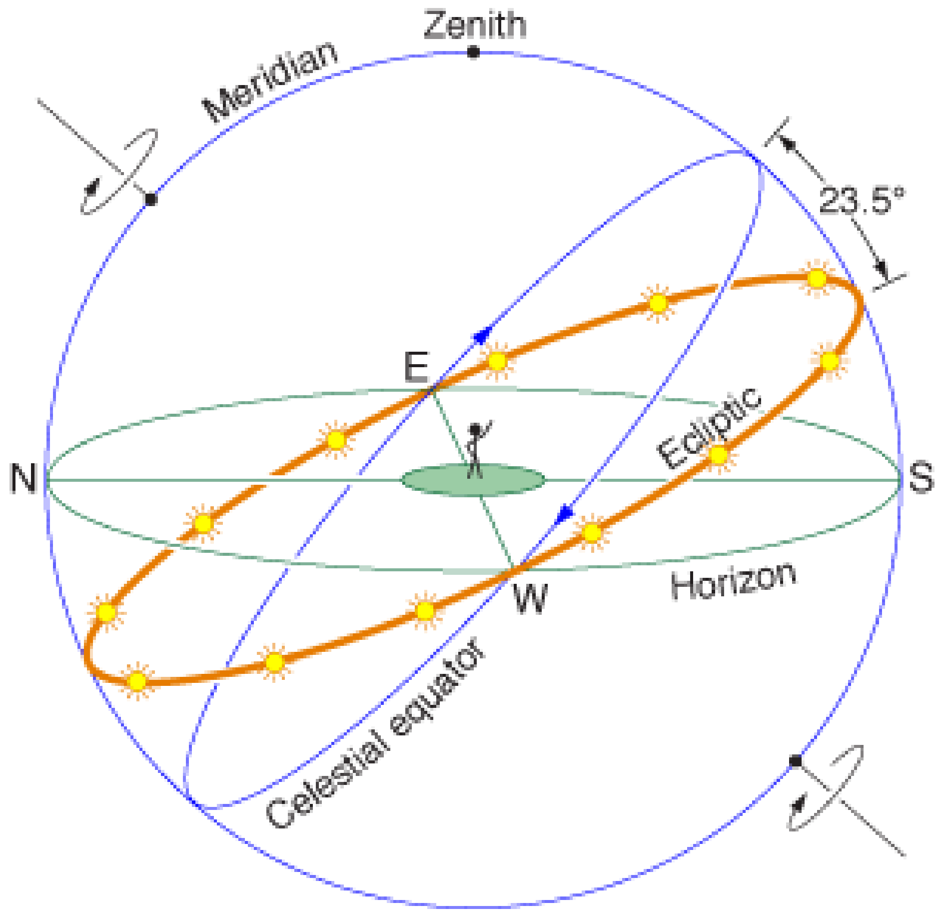


- Planets orbit the Sun according to Kepler's Laws
- All planets orbit in:
  - Nearly circular orbits
  - The same direction (counter-clockwise looking down from the north)

The Solar System: Observing the Sky

- Open-source program: Stellarium

- **Ecliptic**
  a great circle on the celestial sphere representing the Sun's apparent path during the year
- **Celestial equator**
  the projection into space of the earth's equator; an imaginary circle equidistant from the celestial poles
- **Horizon**
  the apparent line that separates earth from sky; the 'skyline'
- **Celestial sphere**
  an imaginary sphere of which the observer is the center and on which all celestial objects are considered to lie
- **Meridian**
  Arc connecting north and south pole



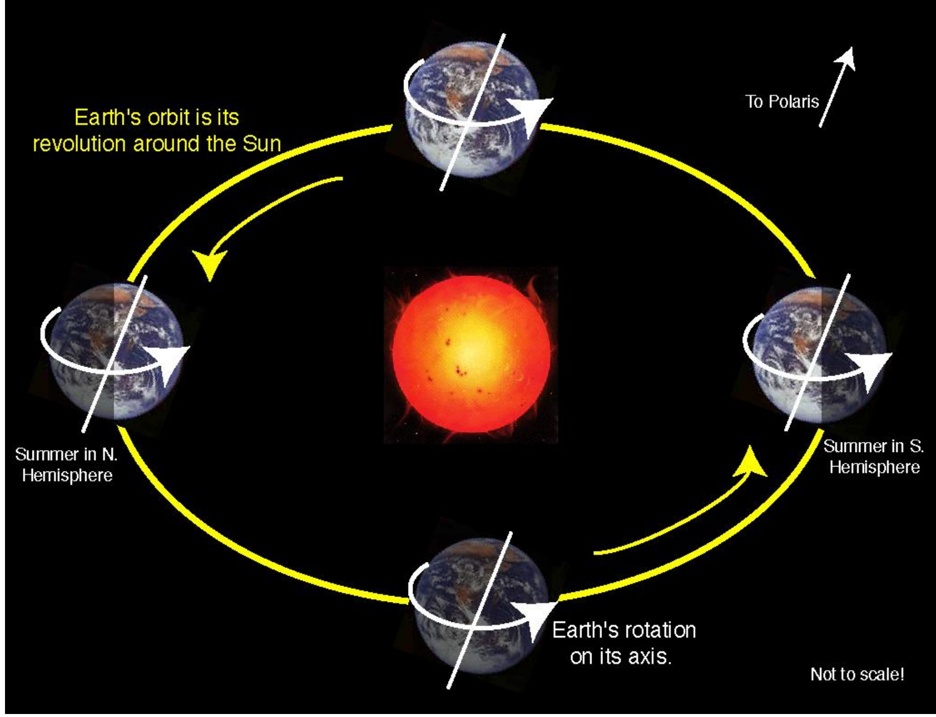
http://astro.unl.edu/classaction/animations/coordsmotion/sunpaths.html

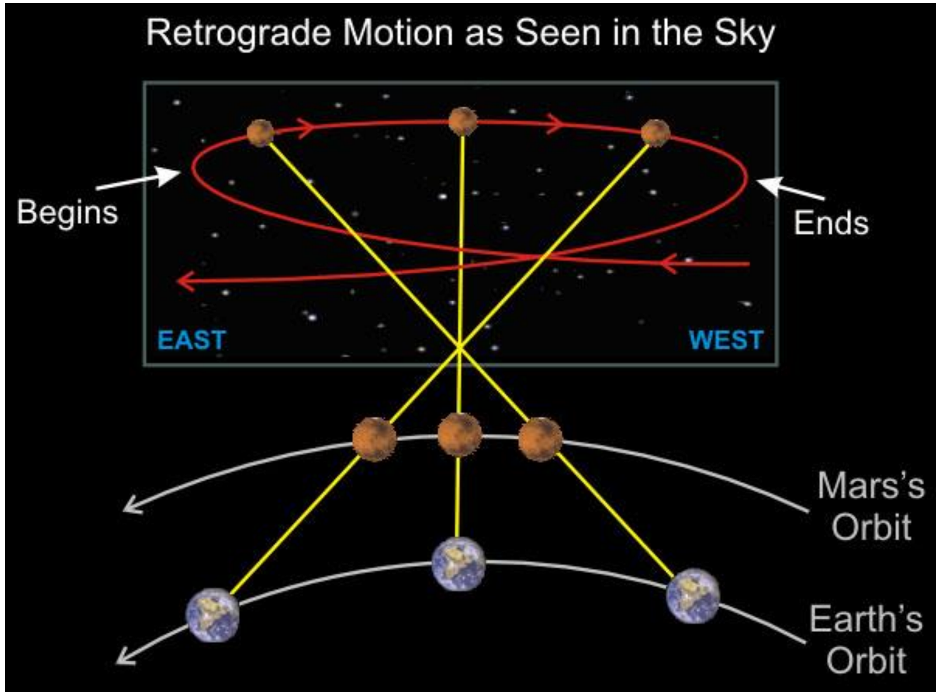
Observing the Sky: Planet Motions

- Over the course of a day, we observe the sun, moon, planets and stars moving east-to-west across the sky due to **Earth's rotation**

- From night-to-night (or month-to-month, or year-to-year) we observe the Sun, Moon and planets moving (changing position) relative to the background stars because the Earth and all those bodies **revolve around the Sun** in their own orbits
    - Planets move W → E relative to the stars over time ("prograde motion")
    - Sometimes they planets appear to reverse direction (moving E → W relative to the stars) which is called "retrograde motion"

    - Remember: Planets and Moon all move relative to the stars over time near to the ecliptic

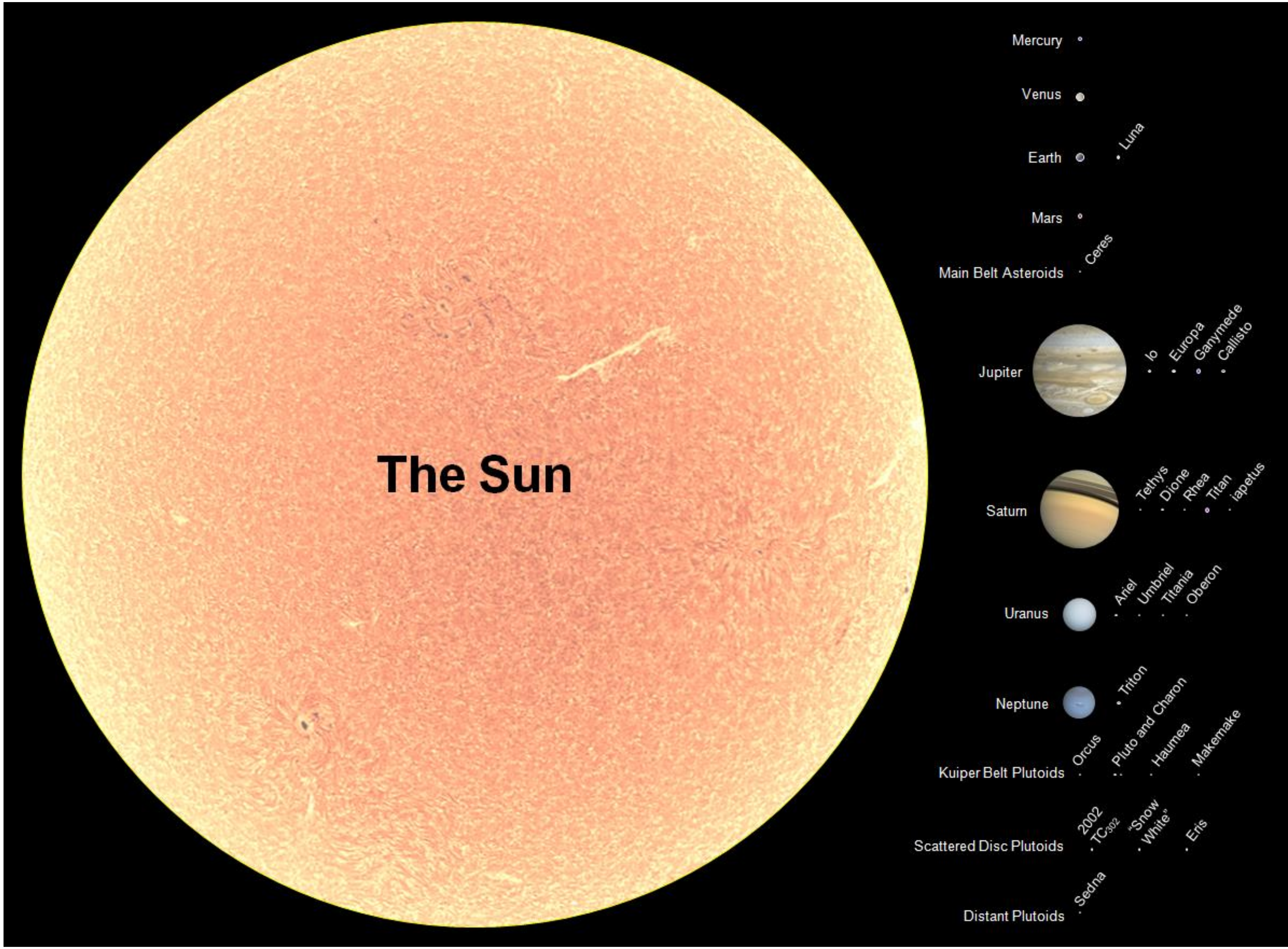




Formation of the Solar System

Week 4

Relative sizes of Solar System objects



Where is matter in the solar system?

- Jupiter is ~3.5 times more massive than Saturn
- Jupiter’s mass is about 0.09% the mass of the Sun
- The Sun comprises about 99.9% of the mass of the solar system
- If we know what the Sun is made of, we can say what the solar system is made of
    - How do we know what the Sun is made of? (We’ll revisit this question in Weeks 5 and 6)

Solar nebula composition

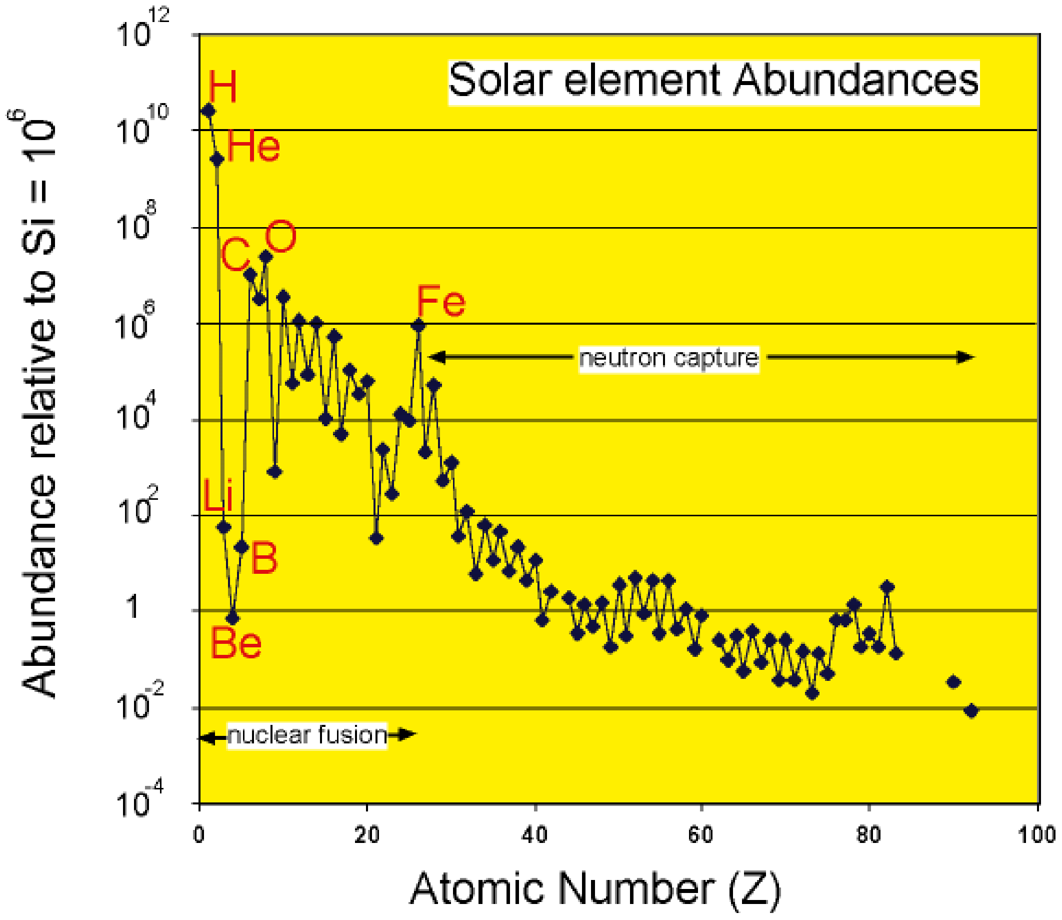
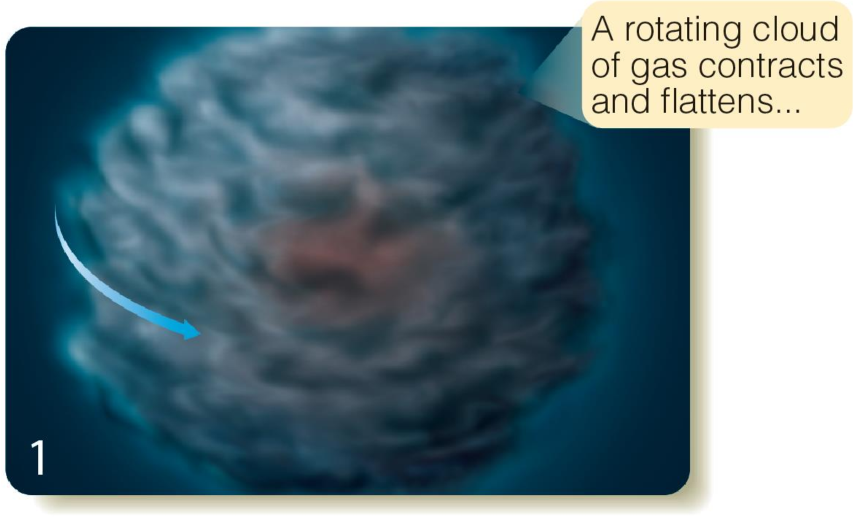


TABLE 8-1 The Most Abundant Elements in the Sun

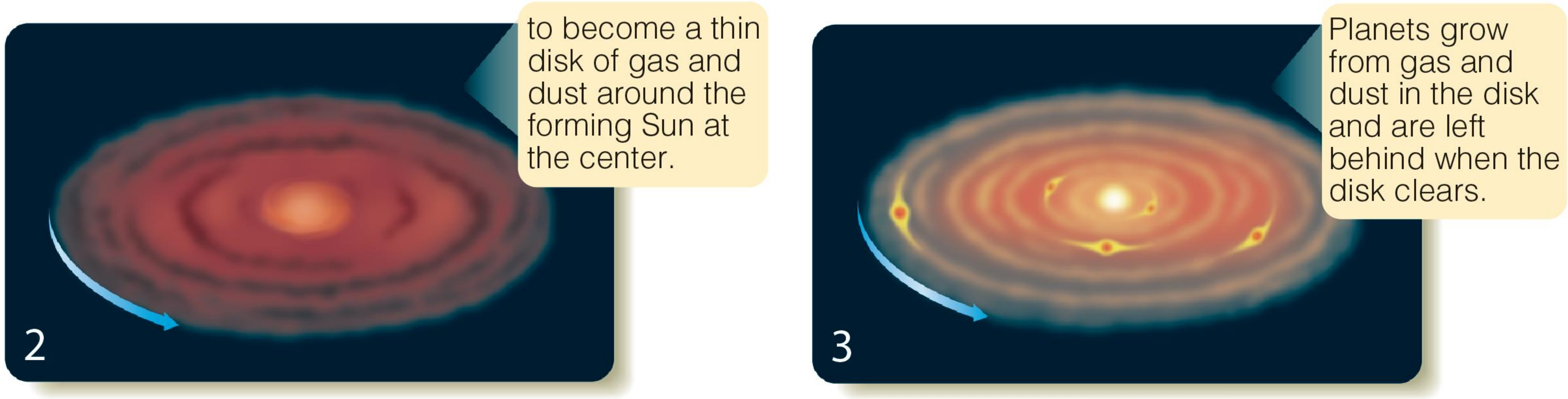
Element	Percentage by Number of Atoms	Percentage by Mass
Hydrogen	91.0	70.6
Helium	8.9	27.5
Carbon	0.03	0.3
Nitrogen	0.01	0.1
Oxygen	0.05	0.6
Neon	0.01	0.2
Magnesium	0.003	0.07
Silicon	0.003	0.07
Sulfur	0.002	0.04
Iron	0.003	0.1

Estimated from composition of the Sun

Solar Nebula Theory



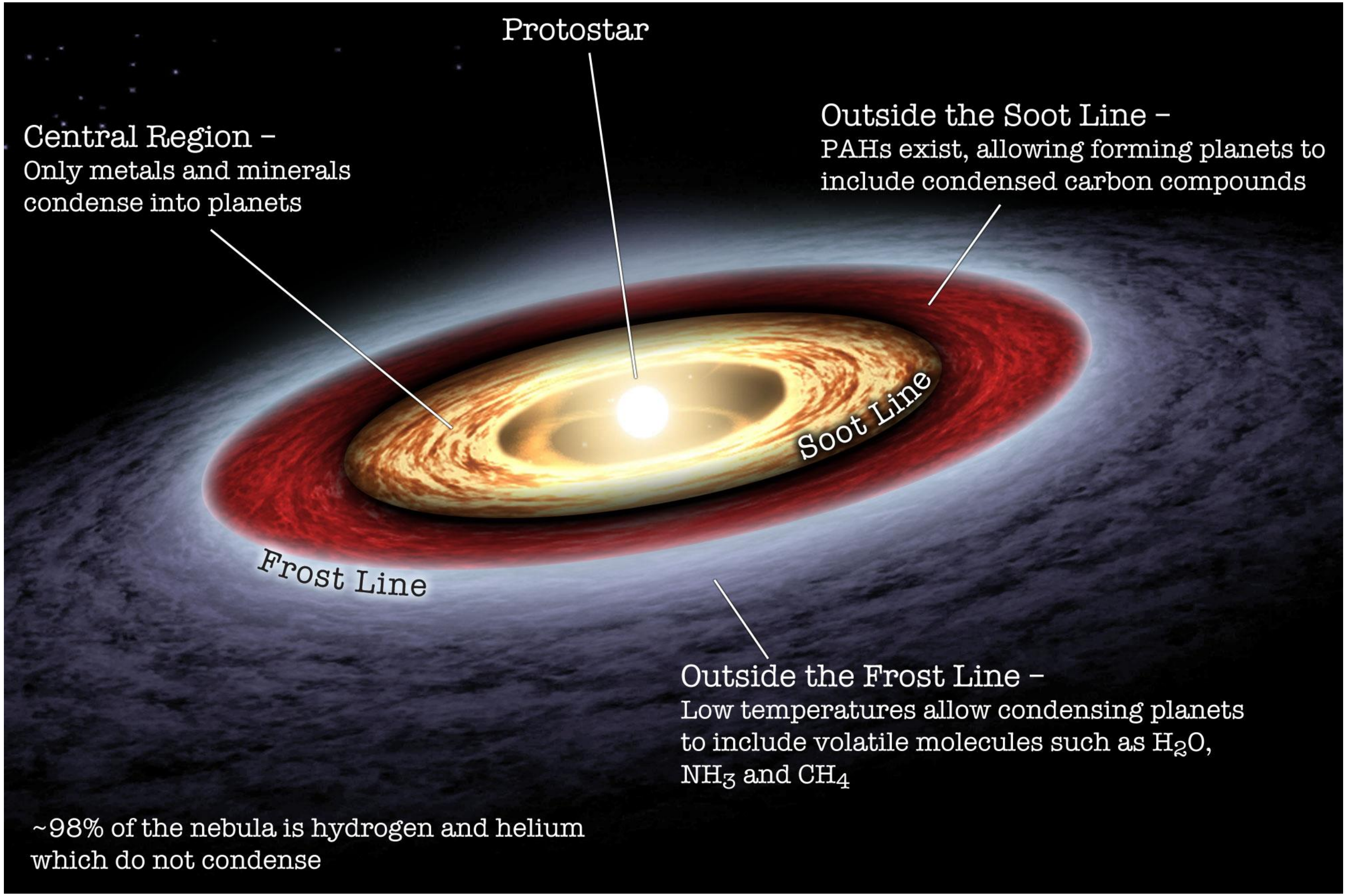
- Describes how the Sun and solar system formed
- Everything forms from the same starting stuff (the nebula was originally homogeneous)
- 99.9% of material goes to form the Sun



Steps of planet formation

1. Condensation of gas
    - Gaseous materials condense to form solids ("dust")

The "frost line": Outer planets form where lower temps allowed volatile materials to condense (water, methane, etc.)



Uncompressed Density

TABLE 19-2 The Condensation Sequence

Temperature (K)	Condensate	Object; Estimated Temperature of Formation (K)
1500	Metal oxides	Mercury; 1400
1300	Metallic iron and nickel	
1200	Silicates	
1000	Feldspars	Venus; 900
680	Troilite (FeS)	Earth; 600
		Mars; 450
175	H_2O ice	Jovian; 175
150	Ammonia-water ice	
120	Methane-water ice	
65	Argon-neon ice	Pluto; 65

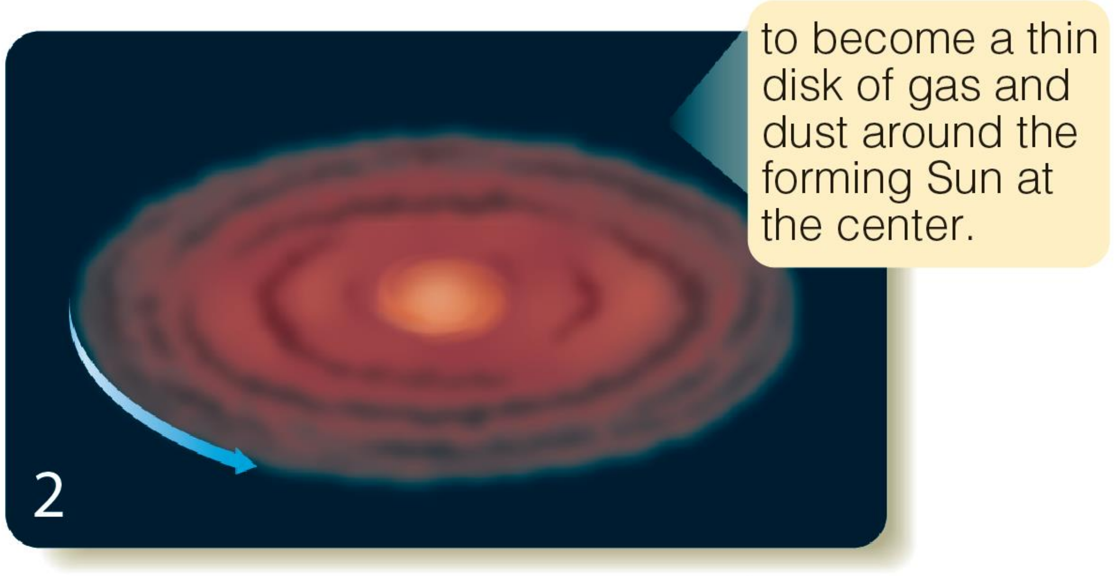
- Densest materials condensed from the solar nebula near the newly formed Sun
- Temperature controlled where different materials could condense
- Light, volatile materials condensed in the outer solar system, beyond the 'frost line'

Steps of planet formation

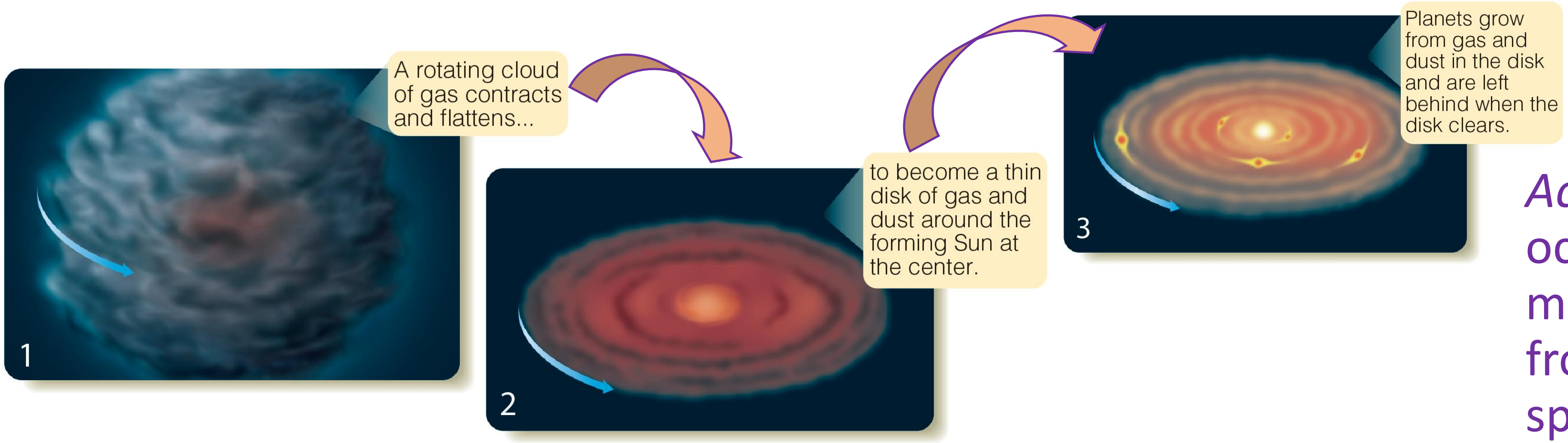
1. Condensation of gas
   - Gaseous materials condense to form solids (“dust”)
2. Accretion of particles
   - Dust particles are attracted by gravity and clump together to form larger particles (going from invisibly small particles to meter-size particles)

Accretion

- Dust particles grow large enough to attract each other
- Growing particles "sweep up" smaller dust particles that are near their orbit
- All particles from a particular orbit have the same composition

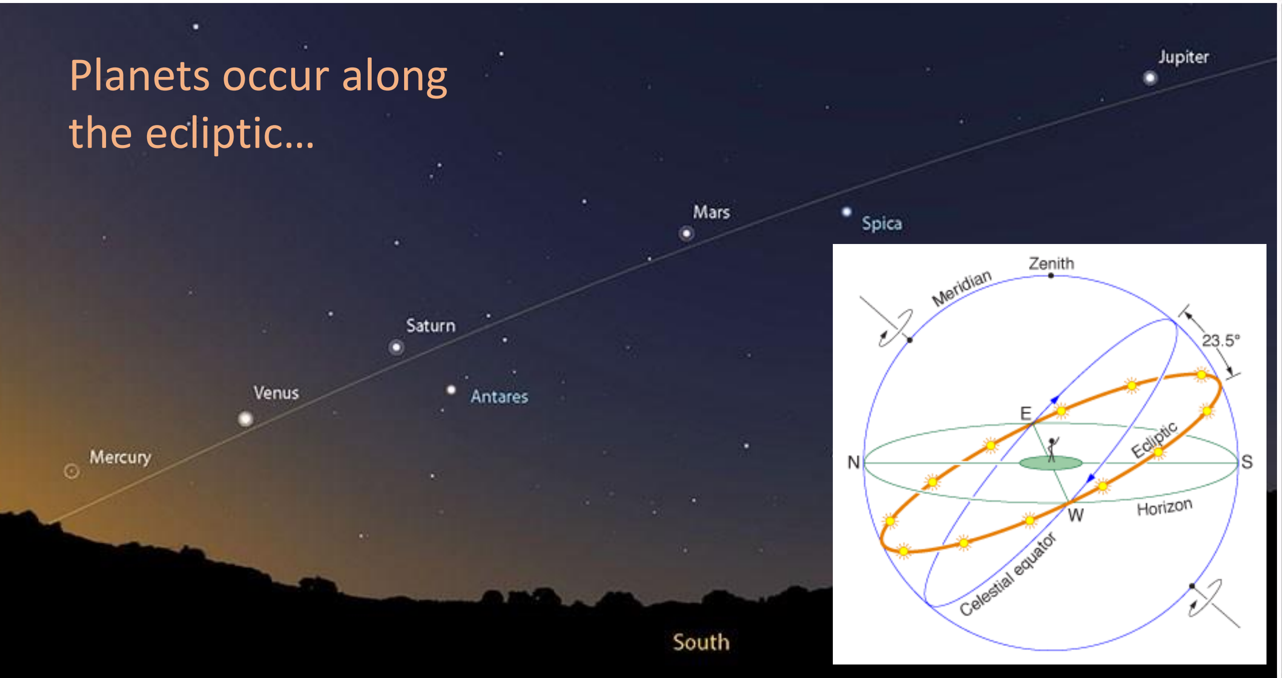


Accretionary Disk (protoplanetary disk)

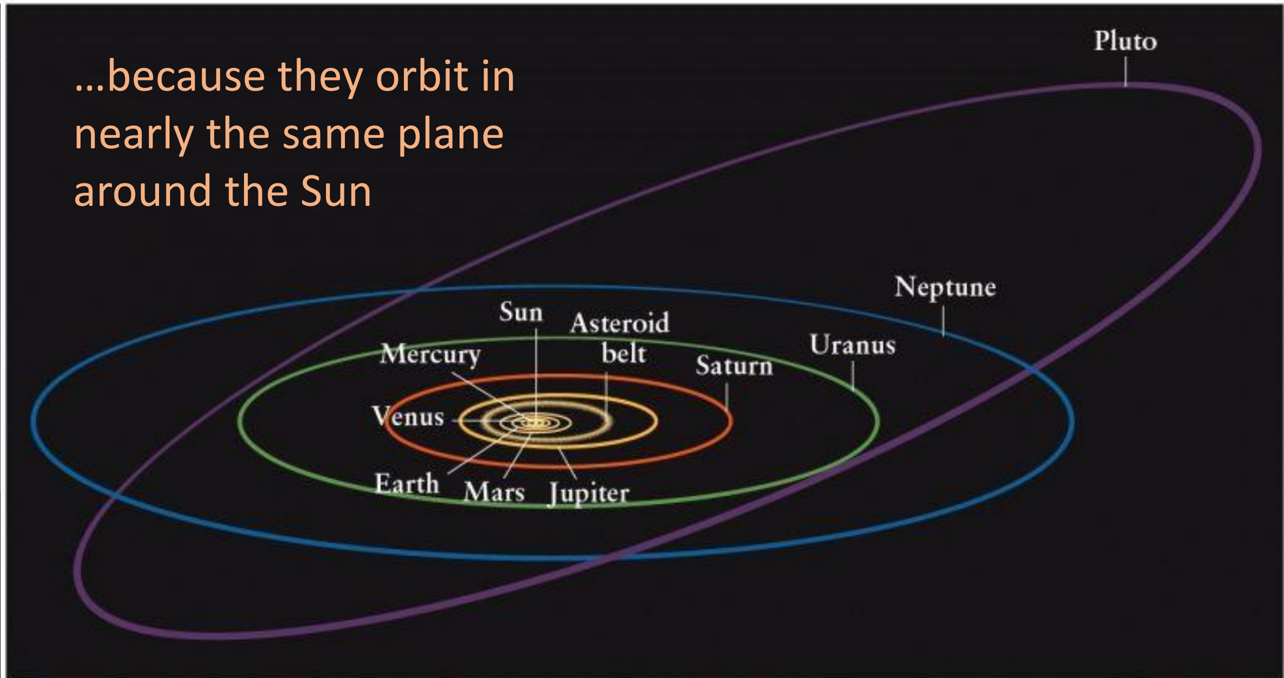


Accretion of particles occurs in a disk of material that collapses from gravity and spinning

Planets occur along the ecliptic...



...because they orbit in nearly the same plane around the Sun



Steps of planet formation

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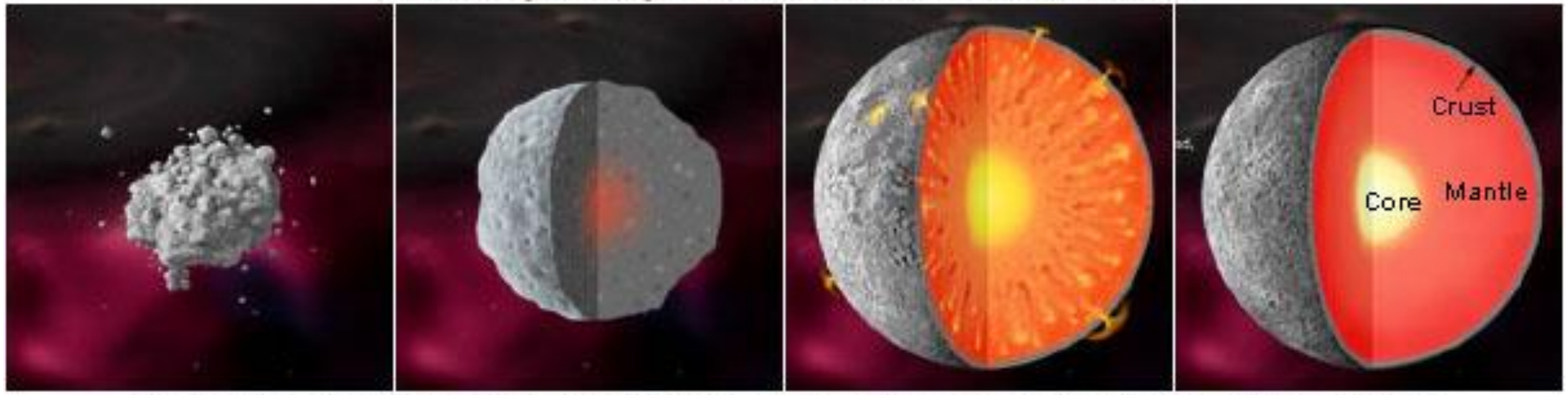
3. Planetesimals form, continued accretion leads to protoplanets
   - Protoplanets are big enough to *differentiate*

Protoplanets differentiate

A Rocky Body Forms and Differentiates



(From Smithsonian National Museum of Natural History - http://www.mnh.si.edu/earth/text/5_1_4_0.html)

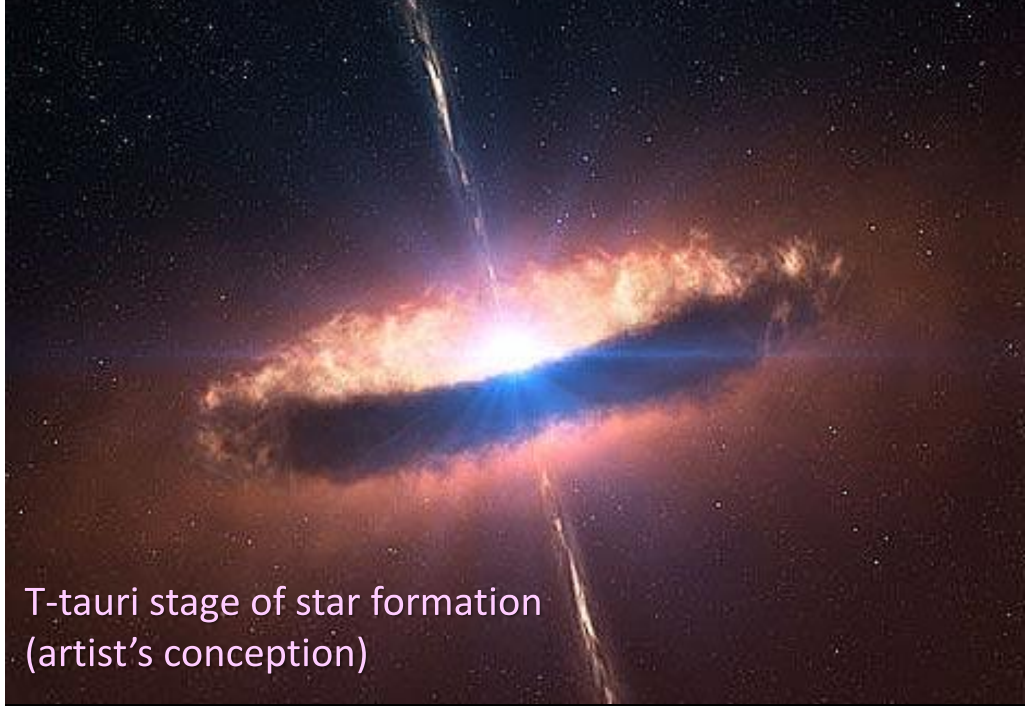
- Heated planet from
  - Gravitational energy from forming planet (heat of formation)
  - Nuclear fission (decay of unstable atomic isotopes)
- Dense materials sink to center (metallic cores)
- Light materials form a crust on rocky planets

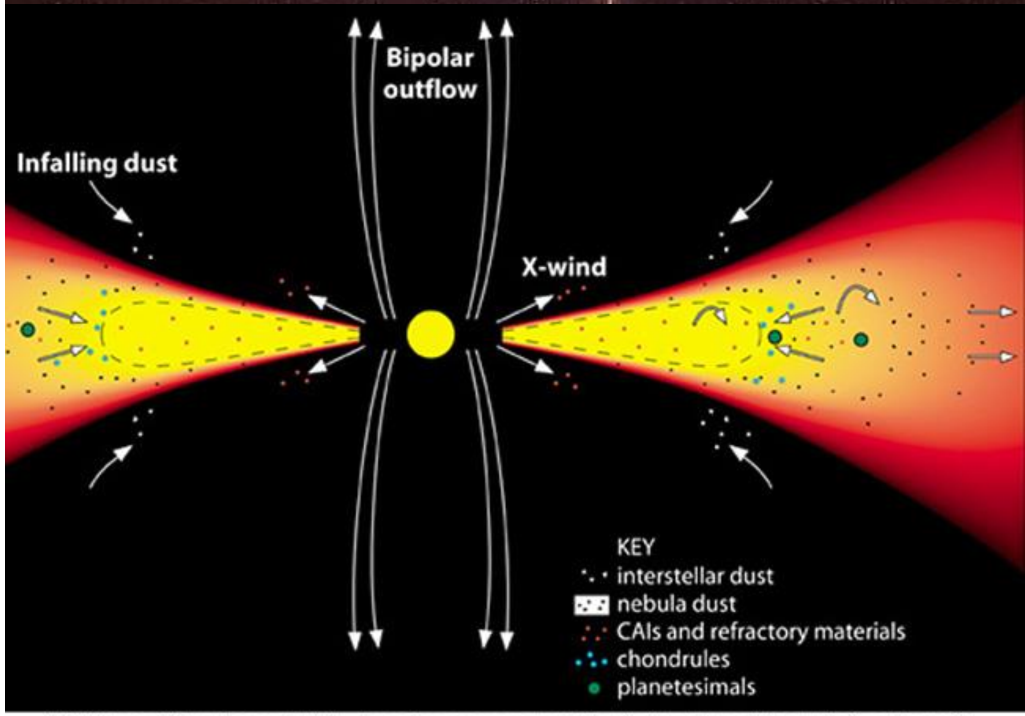
Steps of planet formation

1. Condensation of gas
   - Gaseous materials condense to form solids (“dust”)
2. Accretion of particles
   - Dust particles are attracted by gravity and clump together to form larger particles (going from invisibly small particles to meter-size particles)
3. Planetesimals form, continued accretion leads to protoplanets
   - Protoplanets are big enough to *differentiate*
4. Gravitational collapse
   - Large planets had enough gravity to attract hydrogen and helium gas, forming gas giant (Jovian) planets

The last stages

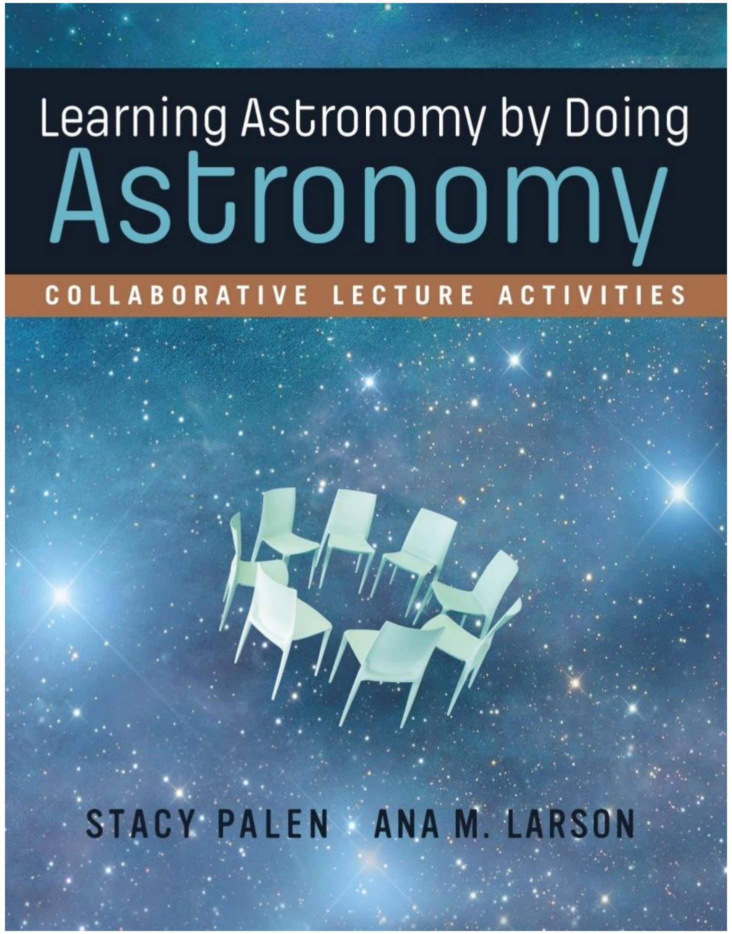
- "Excess gases" and tiny dust particles are blown away by solar wind
- Small planetesimals and larger dust particles are mostly swept up by planets soon after the planets form
  - "Late heavy bombardment"
  - Heavily craters planet surfaces around 4 billion years ago
- There are still rogue materials orbiting the Sun
  - Asteroids, comets, particles in the Oort cloud


T-tauri stage of star formation (artist's conception)



(PSRD graphic by Nancy Hulbirt, based on a conceptual drawing by Edward Scott, Univ. of Hawaii.)

Activity 14: The Clearing and Herding of Saturn's Ring Particles



Pre-14.1: Kepler's 3rd law says $P^2 \alpha a^3$. What does this tell us about orbits?

a. The orbits of planets around the Sun and the orbits of moons around planets are ellipses.
b. Planets orbit the Sun differently that moons orbit planets.
c. The farther a planet is from the Sun and the farther moons are from their planets, the slower they orbit.
d. There is a limit to how small a moon can be to follow Kepler's laws

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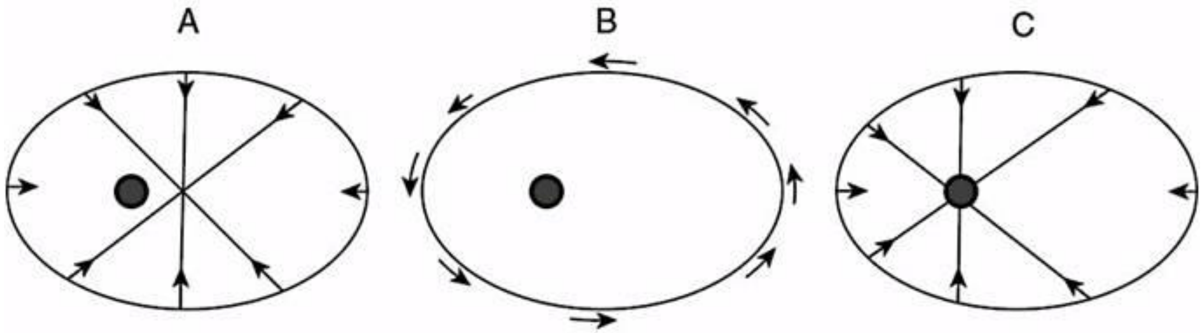
b. Planets orbit the Sun differently that moons orbit planets.
c. **The farther a planet is from the Sun and the farther moons are from their planets, the slower they orbit.**
d. There is a limit to how small a moon can be to follow Kepler's laws

Pre-14.2: Here are sketches of a moon (or ring particle) orbiting a planet. The arrows indicate the direction of the force of gravity felt by the moon. Which sketch correctly shows the direction of the gravitational force?



a. A: The force of gravity is directed toward the center of the orbit.
b. B: The force of gravity acts tangential to the orbital path.
c. C: The force of gravity goes between the center of the planet and the object.

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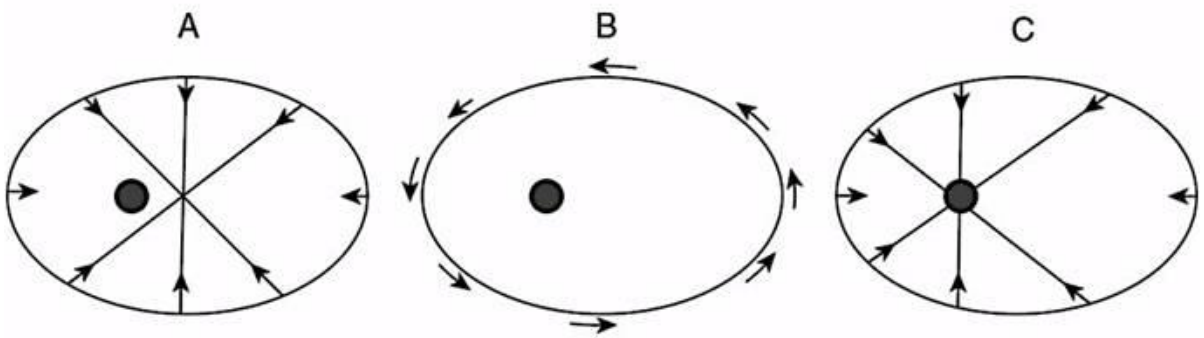
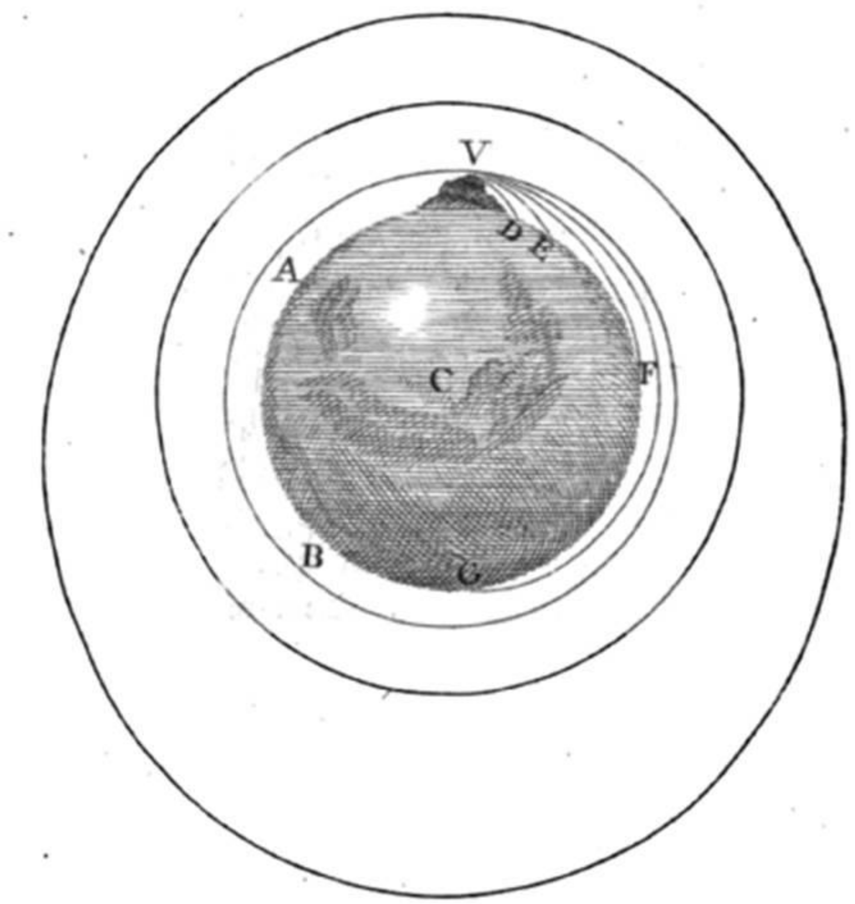


a. A: The force of gravity is directed toward the center of the orbit.

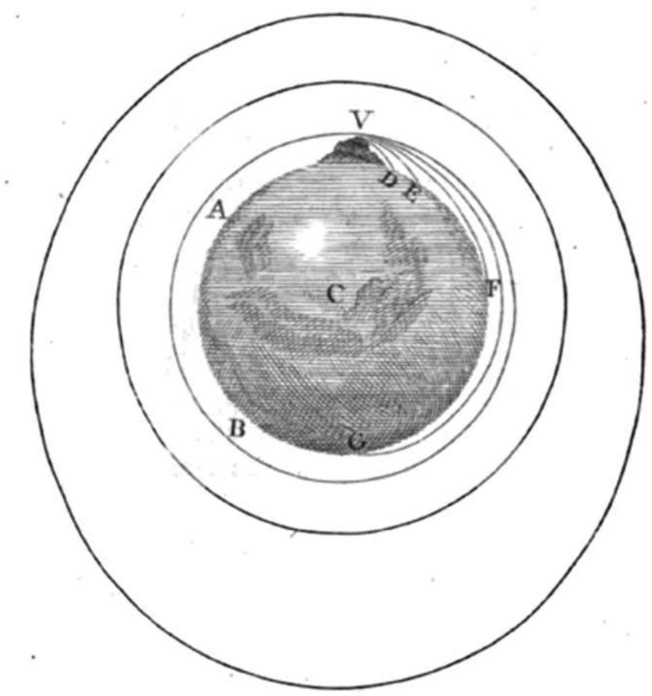
b. B: The force of gravity acts tangential to the orbital path.

c. **C: The force of gravity goes between the center of the planet and the object.**

Here is Newton's cannonball thought experiment concerning firing a projectile at higher and higher velocities. (The imaginary cannon is at "V" in the figure. The paths of the imaginary cannon ball are A - G.)



Pre-14.3: What is the correct interpretation of Newton's visualization?



a. A cannonball fired at progressively higher velocities will eventually go into orbit.

b. The orbit of the cannonball will become more elliptical as the firing velocities increase.

c. Given enough velocity, the cannonball could escape Earth's gravity.

d. All of these answers are correct

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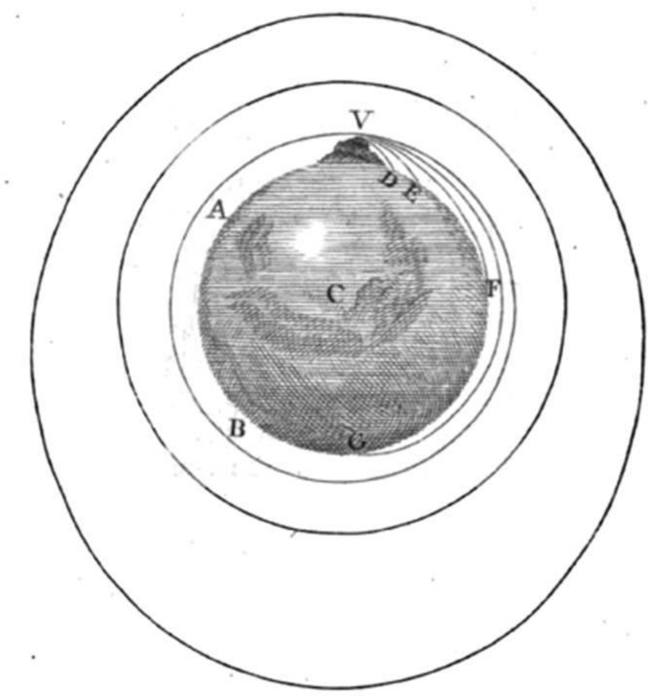

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Pre-14.4: True or False: Although it takes a much higher velocity to put the cannonball into a higher orbit, it will actually travel much slower there than it would in a lower orbit.

a. true
b. false

Pre-14.4: True or False: Although it takes a much higher velocity to put the cannonball into a higher orbit, it will actually travel much slower there than it would in a lower orbit.

a. **true**
b. false

Activity 14

Name ______________________________ Date __________ Section________

ACTIVITY 14

The Clearing and Herding of Saturn's Ring Particles

Learning Goals

In this activity you will use Kepler's and Newton's laws to analyze the behavior of ring patterns in the rings of Saturn. After completing this activity you will be able to:

1. Apply Kepler's third law to sections of the ring system of Saturn.
2. Summarize the process by which a single moon will clear a gap in a ring system like Saturn's.
3. Summarize how the two shepherd moons manage to keep the particles that orbit between their orbits tightly confined within a narrow ring.

Step 1—Applying Kepler's Laws to Rings and Satellites

Figure 14.1 shows an image of part of Saturn's rings taken by the *Cassini*

- Work together in your groups
  - *Work with at least one other person*
- Complete:
  - Step 1, #1-4 (**skip 5-8**)
  - Step 2
  - Step 3
- Complete in your individual workbook
  - *I will post answers later for you to check against*
- Complete photocopy: **ONE per lettered group**
  - 5-6 students per copy
  - Make sure your name is on the copy
  - ***Discuss answers as a full group***
  - Hand in the copy for credit

Post-14.1: In general, the gravity of a moon will always move ring particles

a. toward the planet.
b. out to space.
c. toward the moon.
d. away from the moon.

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Post-14.2: Consider a moon and an outer ring particle. The outer ring particle is sent farther out. It stops going outward because

a. the moon pulls it back in.
b. other moons push it back in.
c. the planet's gravity acts on it.
d. it bumps into other particles.

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Post-14.3: The inner shepherd moon of the F Ring of Saturn, Prometheus, is about 16 percent more massive than the outer moon, Pandora. What would most likely happen to the F Ring if Prometheus were many times as massive as Pandora?

a. Nothing because the orbits of the shepherd moons would be the same.
b. The particles would gradually be absorbed by Pandora.
c. Prometheus would gravitationally “steal” all of the F Ring particles.
d. The particles would all spiral into Saturn

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Post-14.4: What would you predict will happen to Saturn's rings over time?

a. The rings will go away as ring particles are swept up into larger moons.
b. The rings will stabilize into an equilibrium configuration.
c. The rings probably stabilized a long time ago and will not change in the future.

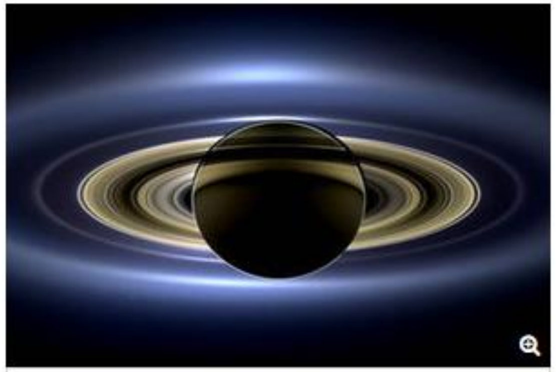
Post-14.4: What would you predict will happen to Saturn’s rings over time?

a. The rings will go away as ring particles are swept up into larger moons.
b. The rings will stabilize into an equilibrium configuration.
c. The rings probably stabilized a long time ago and will not change in the future.
d. **There is not a correct answer to this question.**

Space.com > Science & Astronomy

Age of Saturn's Rings Revealed

By Mike Wall, Senior Writer | December 13, 2013 07:01am ET



A new mosaic of Saturn and rings made by Cassini spacecraft, brightened version with contrast and color enhanced. Image released Nov. 12, 2013.

Credit: NASA/JPL-Caltech/SSI

SAN FRANCISCO — Saturn's iconic rings likely formed about 4.4 billion years ago, shortly after the planet itself took shape, a new study suggests.

The origin of Saturn's ring system has long been the subject of debate, with some researchers arguing that it's a relatively young structure and others holding that it coalesced long ago, at roughly the same time as the gas giant's many satellites.

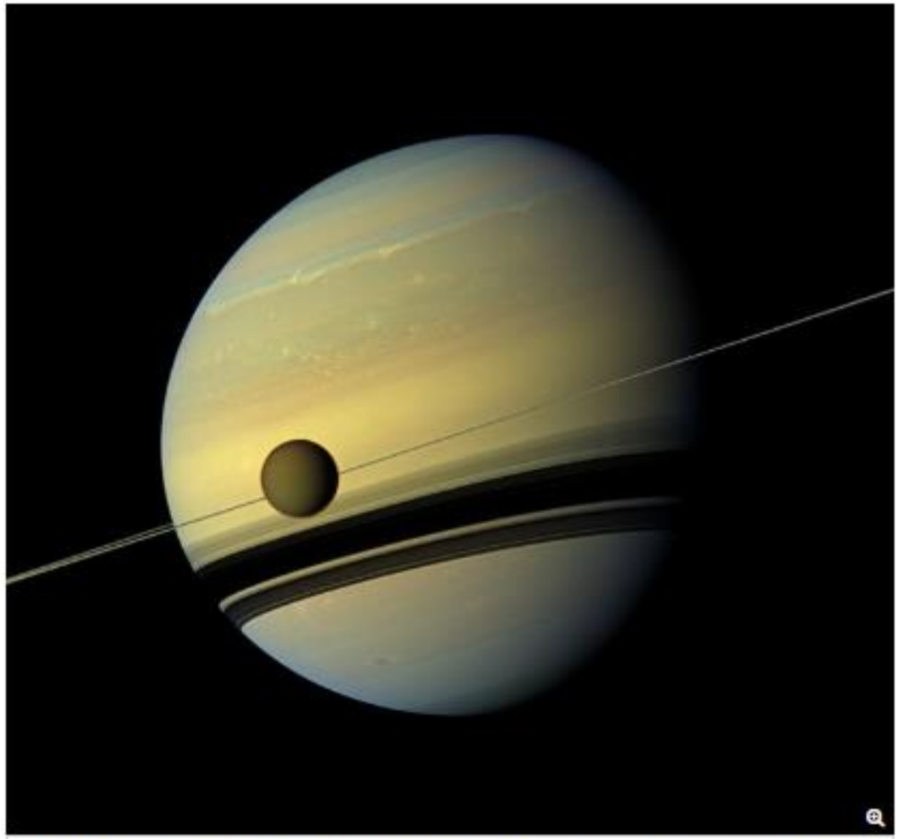
The new study, conducted using data gathered by NASA's Saturn-orbiting Cassini spacecraft, strongly supports the latter scenario, researchers said here Tuesday (Dec. 10) at the annual meeting of the American Geophysical Union. [Photos: Saturn's Glorious Rings Up Close]

Say what?!

Space.com > Science & Astronomy

Saturn's Moons and Rings May Be Younger Than the Dinosaurs

By Elizabeth Howell, Space.com Contributor | March 25, 2016 12:00pm ET

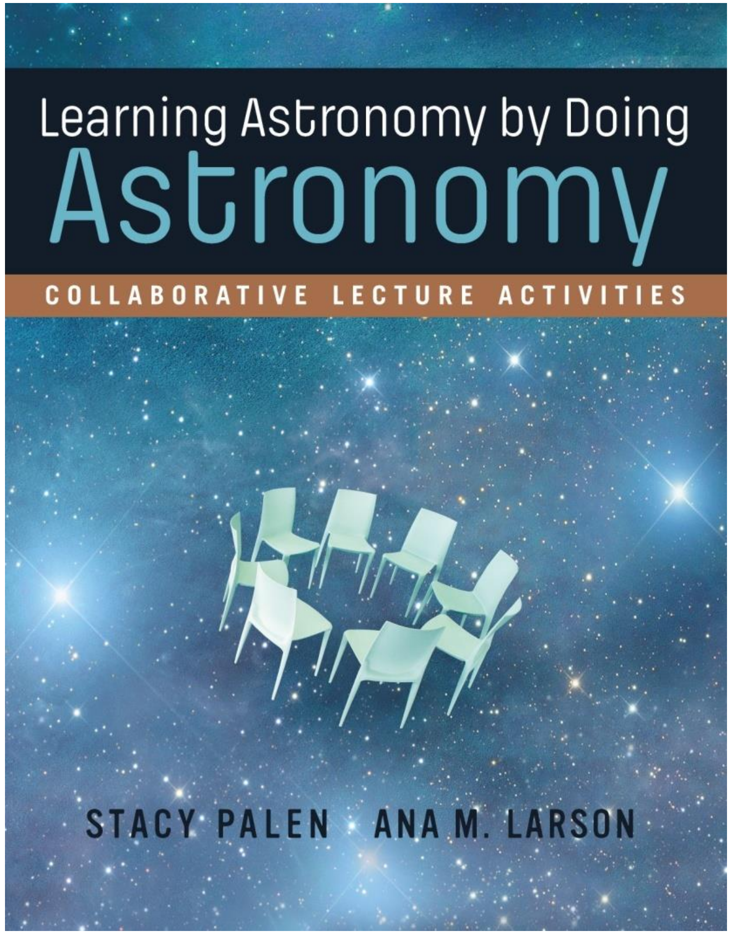


Saturn and its moon Titan appearin this image taken by the Cassini probe. The planet's rings and many of its moons may be only about 100 million years old.

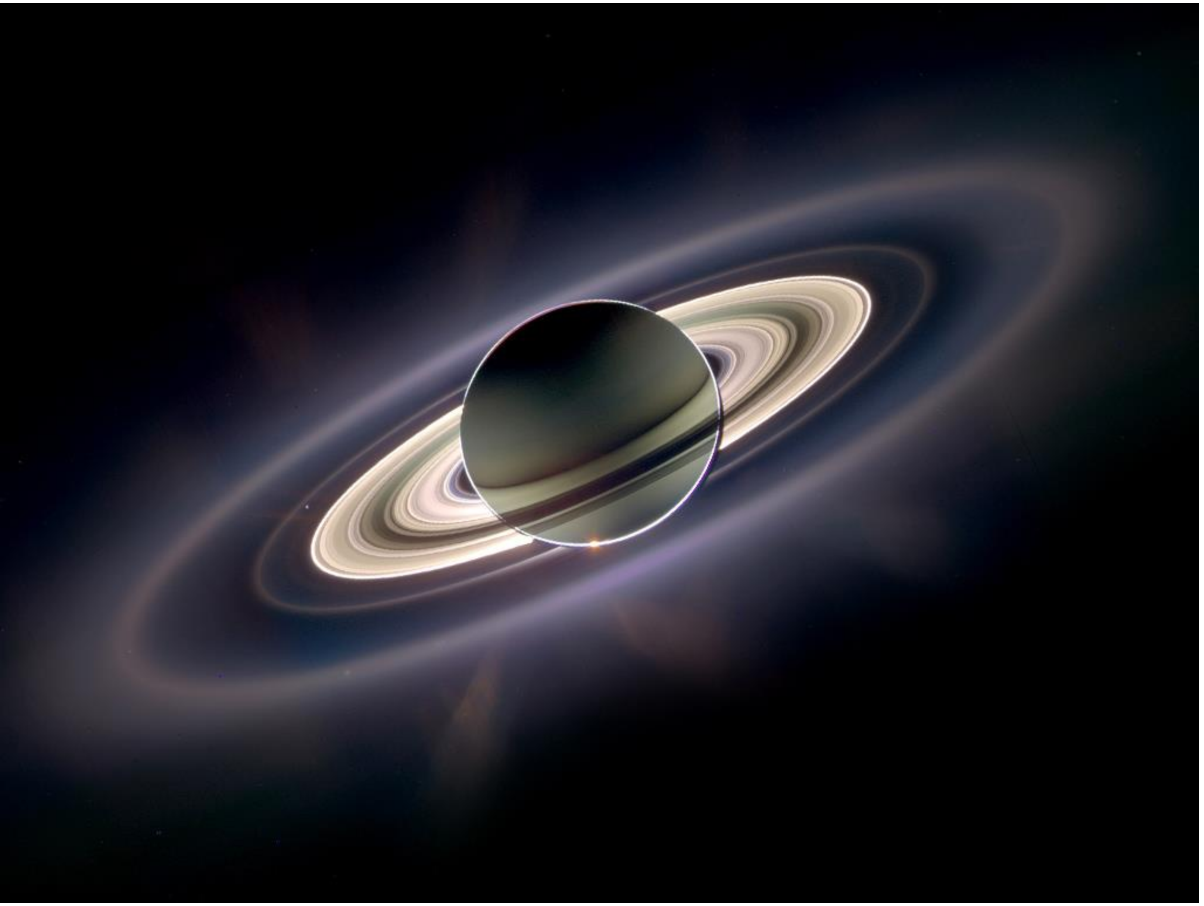
Credit: NASA/JPL-Caltech/Space Science Institute

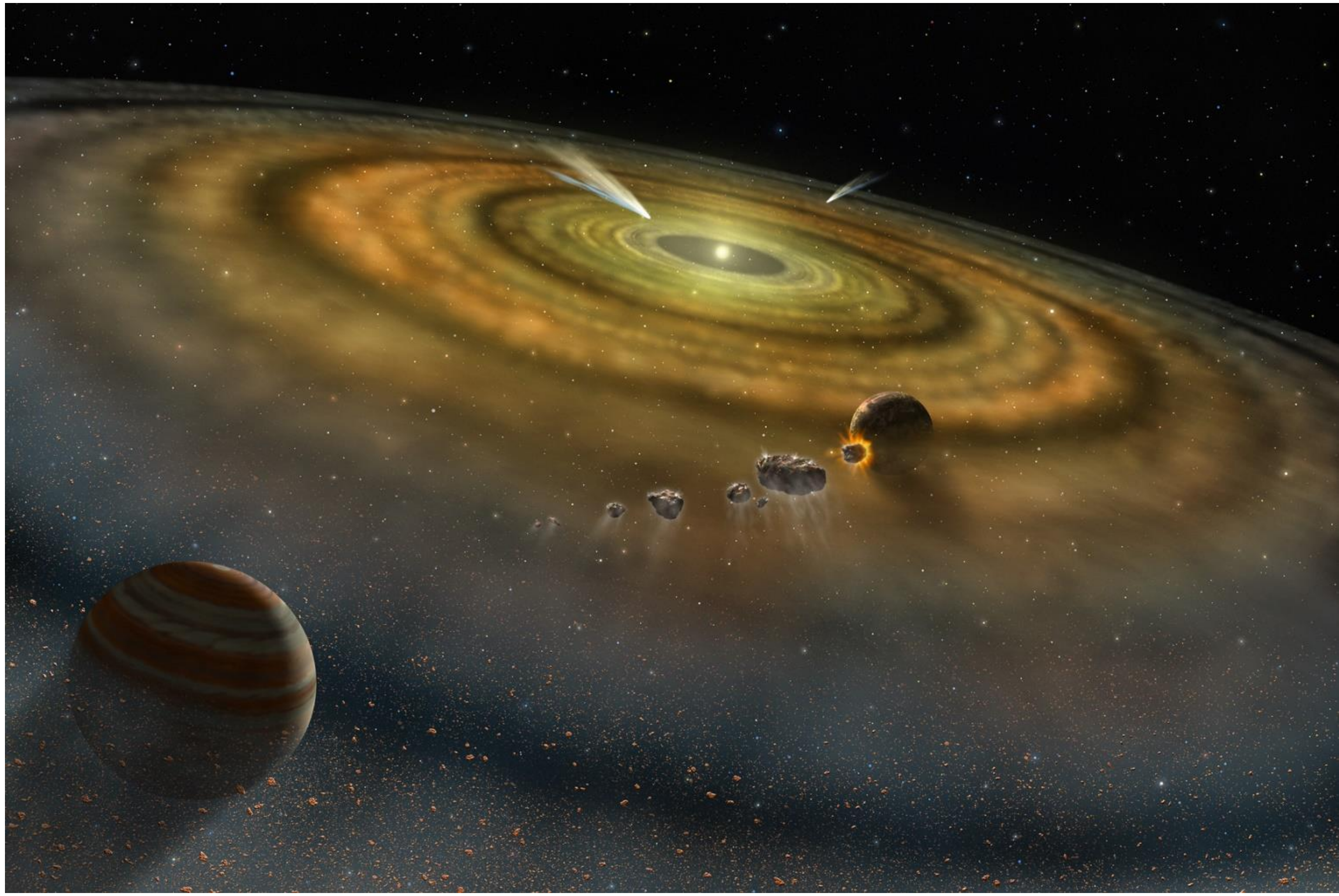
Some of Saturn's icy moons may have been formed after many dinosaurs roamed the Earth. New computer modeling of the Saturnian system suggests the rings and moons may be no more than 100 million years old.

This concludes Activity 14: The Clearing and Herding of Saturn’s Ring Particles



Are there similarities between Saturn’s moons and rings and planetary accretionary disk?



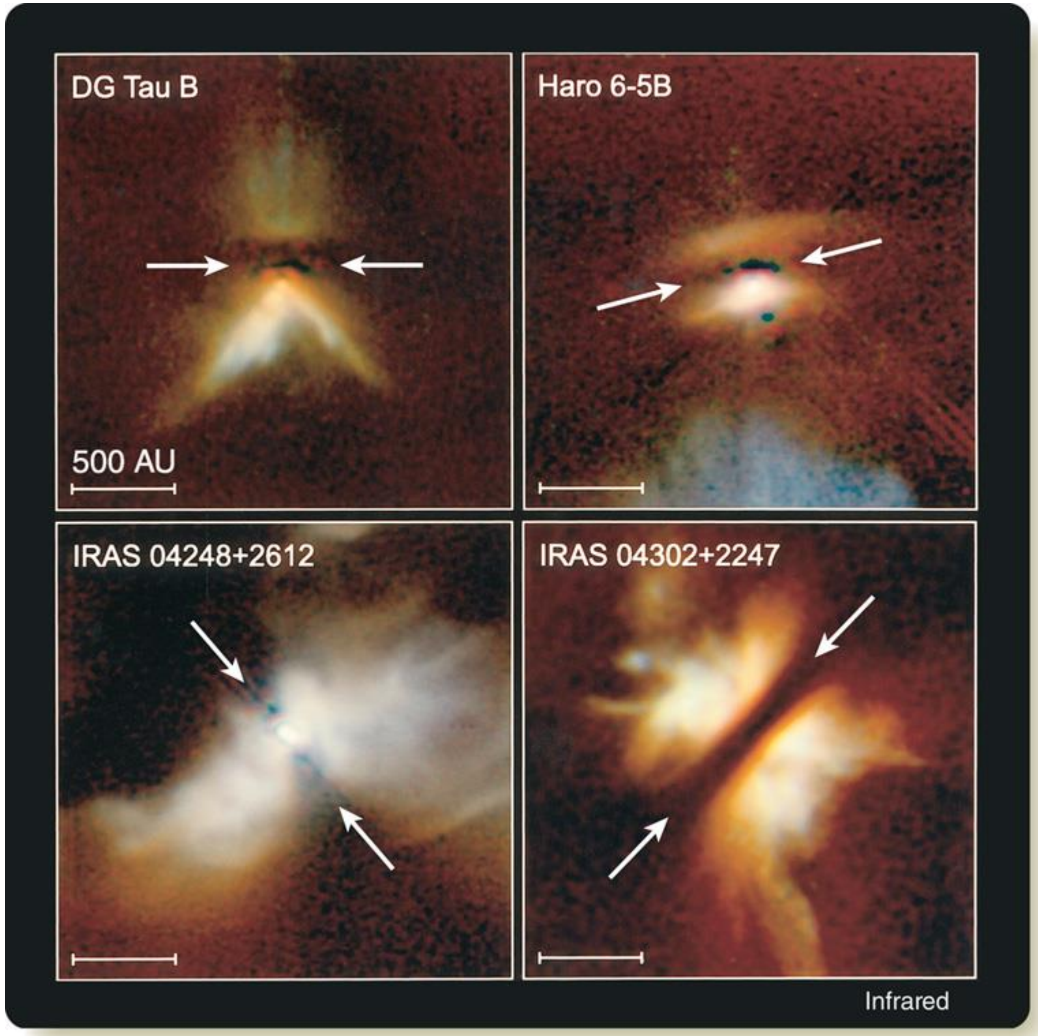


- How are they similar?
- How are they different?

A common process

We observe accretionary disks in other parts of our galaxy

- ‘New’ planetary systems
- Analogous to our own solar system formation



NASA/JPL-Caltech/D. Padgett, W. Brandner, K. Stapelfeldt