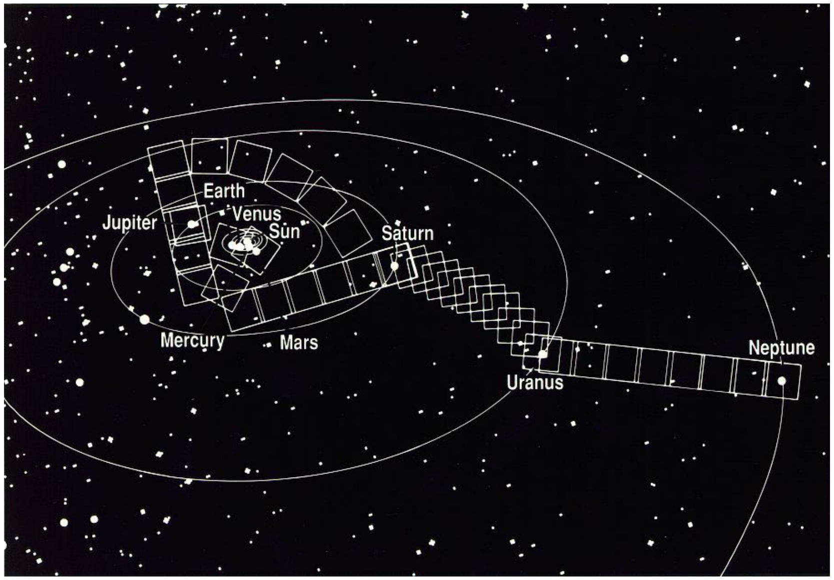
[12] Overview of the Solar System (10/5/17)

Upcoming Items

1. Read Ch. 8.1 & 8.2 by next class and do the self-study quizzes
2. Midterm #1 on Tuesday
   Good luck to all of you!

Voyager Family Portrait



LEARNING GOALS

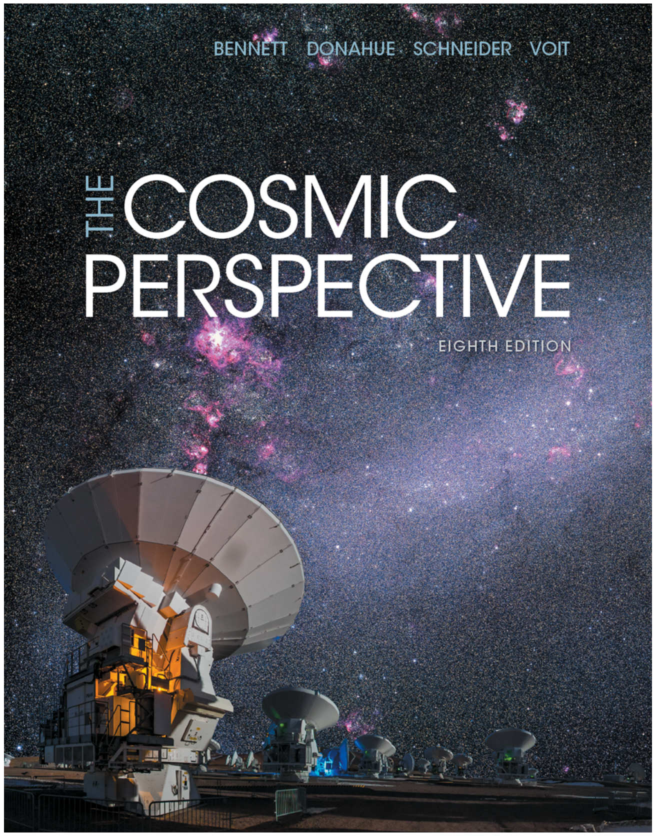
Chapter 7

For this class, you should be able to…

… *rank the planets of the solar system by average orbital distance from the Sun;*

… *classify each of the planets in the solar system as terrestrial or jovian, and relate this to differences in bulk density;*

… *describe the significant patterns and notable exceptions in the solar system for the following characteristics: orbital and spin direction, orbital inclination, and the typical locations where various solar system bodies are found.*



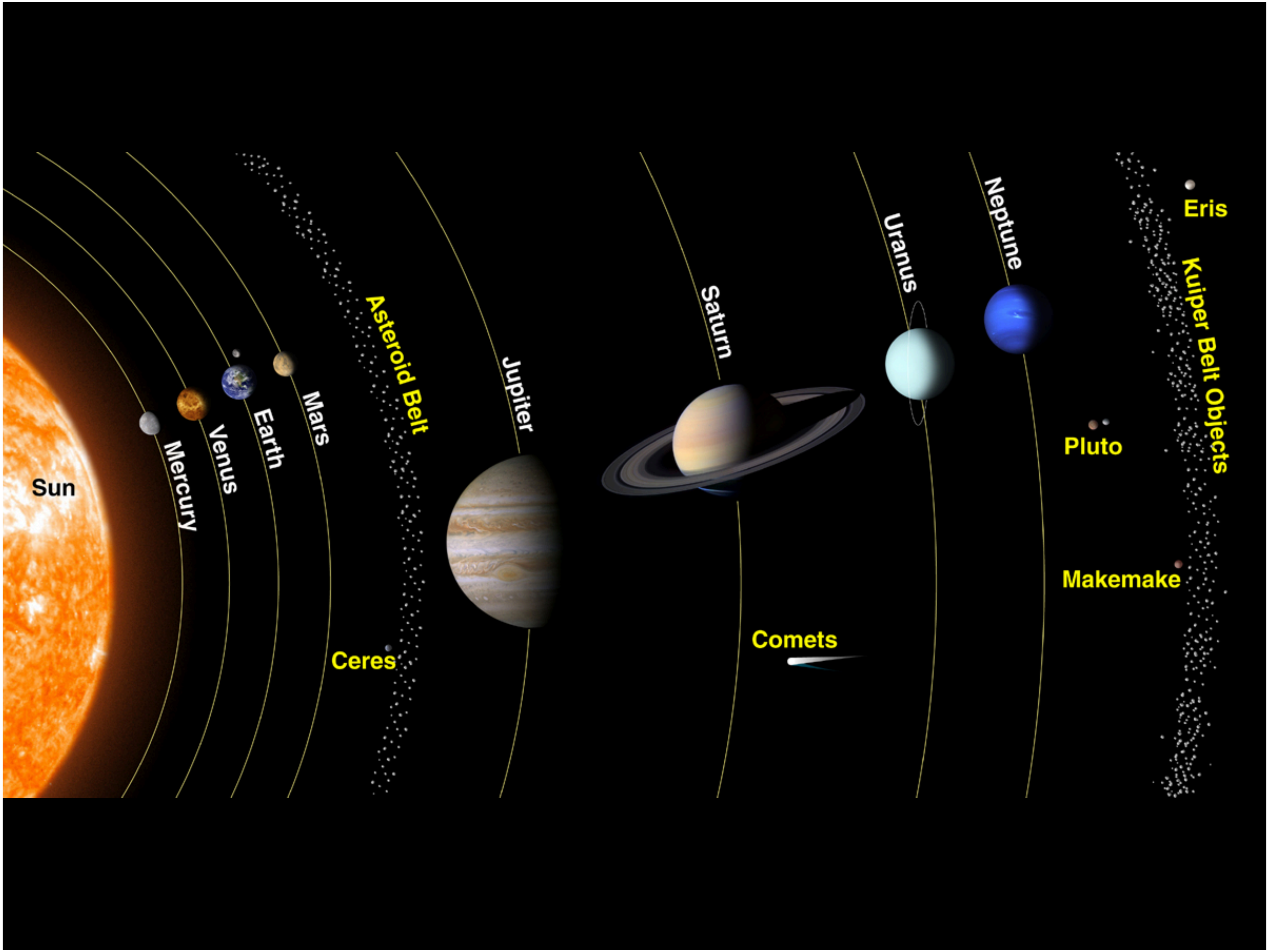
Exam Reminders

- Bring your own pens! (yes, pens, please; pencil is tougher to read)
  Also bring calculators; all phones should be off and away
- We will seat you
  Left-handers first
  Seating makes it easier to keep a row clear, so we can come by and answer questions
- Early leave time: 11:45
  Less distracting than constant movement
- After 12:00, turn in exams when you're done
- Good luck!

Any astro questions?

Second Debate

- Should Pluto be considered a planet?


Sun
Mercury
Venus
Earth
Mars
Asteroid Belt
Ceres
Jupiter
Saturn
Comets
Uranus
Neptune
Pluto
Makemake
Eris
Kuiper Belt Objects

Overview of the Solar System

- There is a lot of variety in the solar system: no two planets are alike, and smaller bodies show even more diversity.
- But there are patterns that suggest a common origin: orderly motions, two categories of planet, swarms of smaller bodies in distinct regions, and notable exceptions.
- Important planetary properties include: size & mass (density & composition), moons, atmospheres, surfaces.
  - Terrestrial planets are high density, close to the Sun.
  - Jovian planets are low density, far from the Sun.
- Smaller bodies include comets (icy) and asteroids (rocky).
- Pattern exceptions include Venus' backward spin, Earth's large moon, and Uranus' extreme tilt.

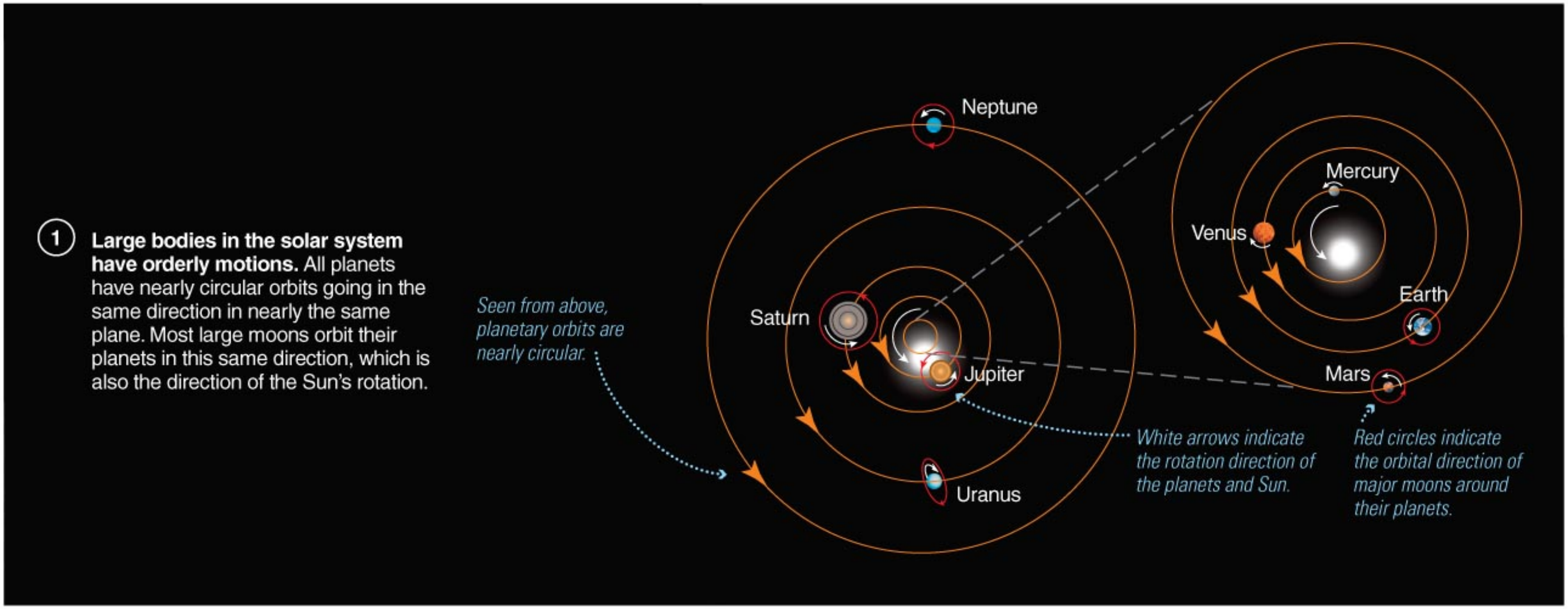
Kinematics of the Solar System

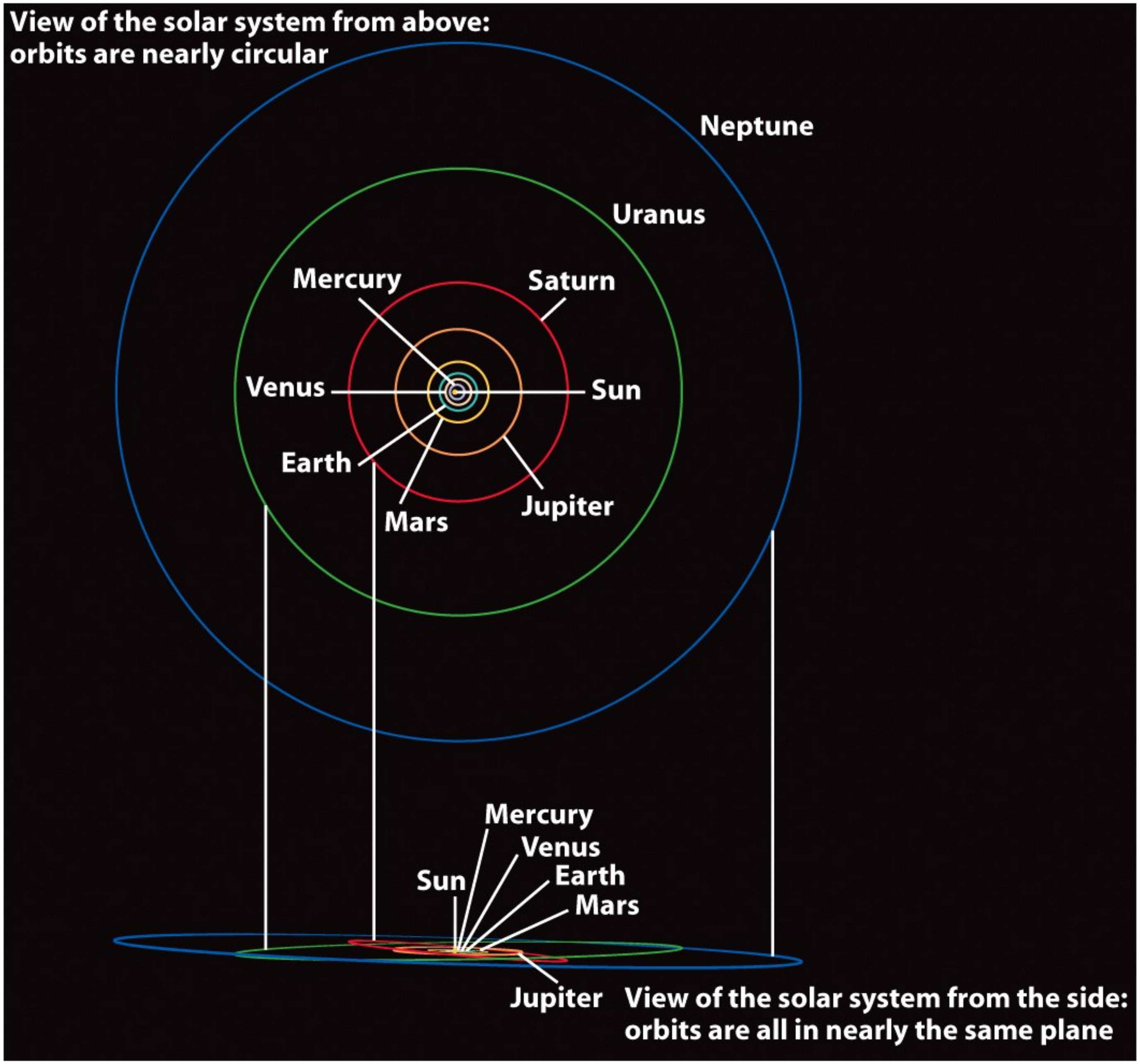
- Laws of physics (motion and gravity) explain…
  - Why planets move in elliptical orbits (with the Sun at one focus);
  - How the velocity of a planet changes as it orbits the Sun;
  - How the orbital period depends on the semimajor axis.
- But there are other patterns we need to explain…
  - All planetary orbits are almost circular.
  - All planetary orbits lie in nearly the same plane.
  - All planets orbit the Sun in the same sense.
  - Most of the planets (apart from Venus & Uranus) rotate in the same sense as they orbit.
- These patterns must be imprints of the way the solar system formed…

But Wait!

- We must not fall into the trap of assuming that all planetary systems are like our own
- In fact, they're not!
  Many exoplanets have highly elliptical orbits
  There are "hot Jupiters" very close to their stars
  There are exoplanets with strongly inclined orbits
- In a majors class, like this one, we need to look at the whole picture
- Question for discussion: is there anything special about our system (indeed, unique as far as we know now) that might favor nearly circular and nearly coplanar orbits?
- So let's proceed to think about ***our*** system, and at each step ask whether ***all*** systems must have those properties!

1. Large bodies in the solar system have orderly motions.





Must this be true for ***all*** planetary systems?

Why are the planets so far apart?

- Distance from Mercury to Venus is ~20,000 times Mercury's radius
- Distance from Jupiter to Saturn is ~10,000 times Jupiter's radius
  and so on...
- But why? Seems like there's a lot of empty space. Should this be typical? Is there a reason for the spacing?

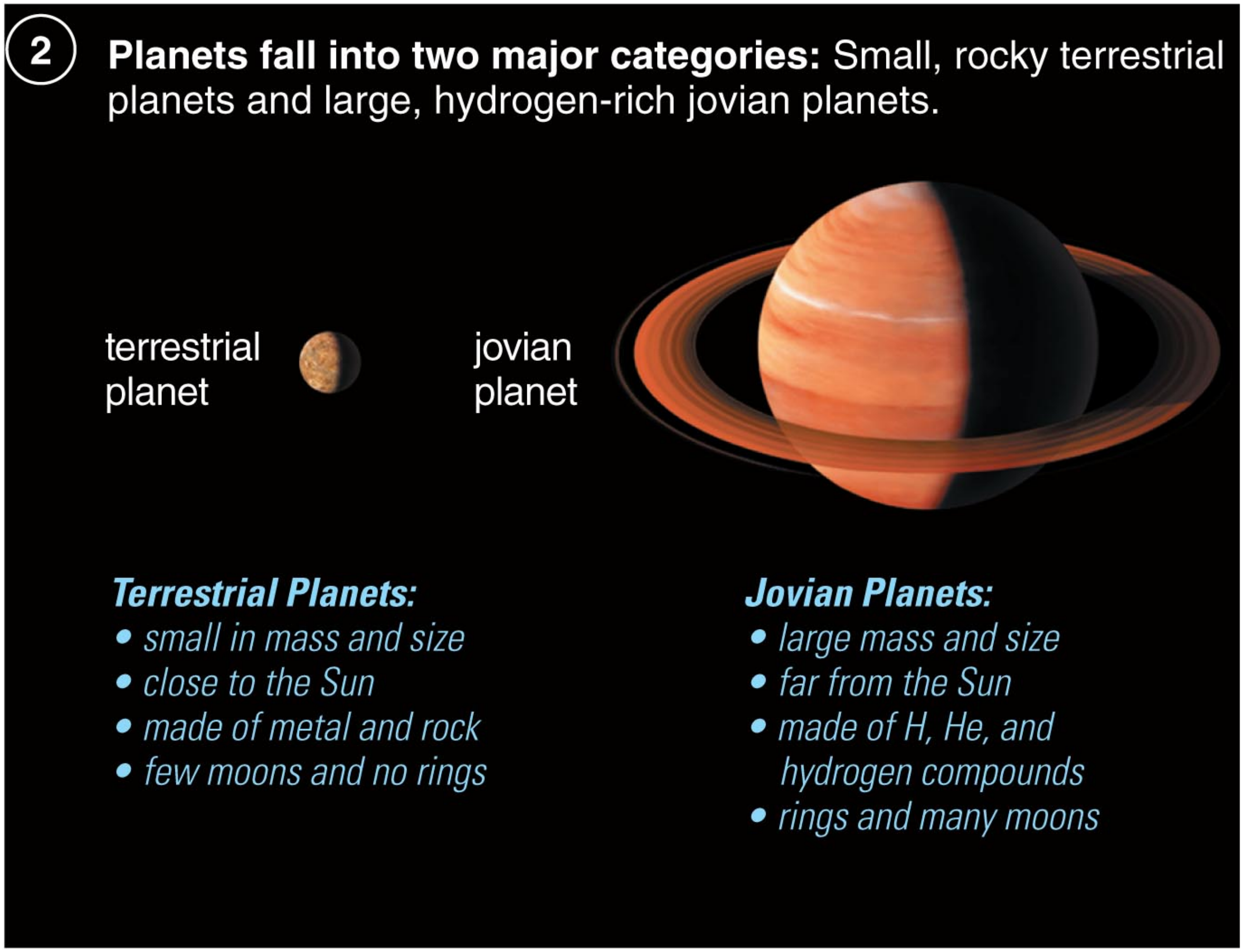
Why don't we have a more distant moon?

- Average Earth-Moon distance is ~3.8×10^5 km
  Average Earth-Sun distance is ~1.5×10^8 km
- Big difference!
- Why couldn't we have a moon 10x farther away?

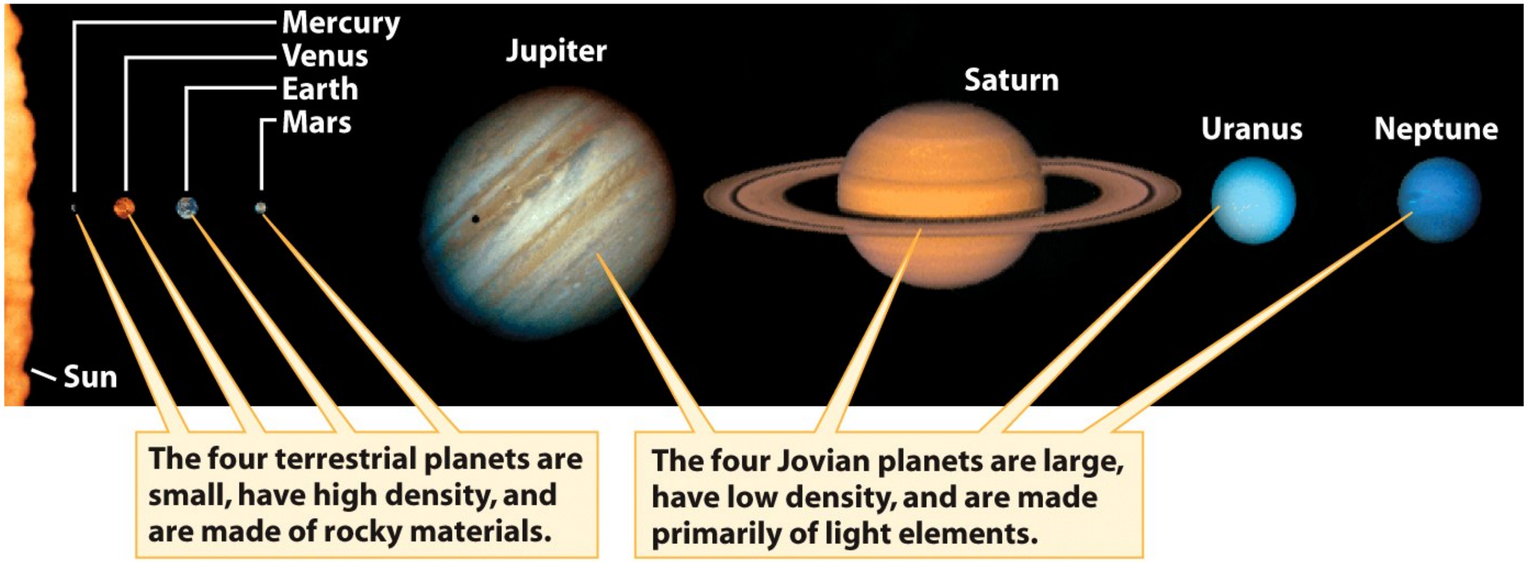
Group Question

- Calculate the ***ratio*** of the Sun's gravitational force on the Moon, to the Earth's gravitational force on the Moon
- Before you calculate, please make a guess in each of your groups; if you're right, you can reinforce your intuition, but if you're wrong, you'll learn more that way
- Information:
  Mass of Sun = 1.989×10^{30} kg
  Mass of Earth = 5.972×10^{24} kg
  Mass of Moon = 7.348×10^{22} kg
  Moon-Earth distance: 3.84×10^{5} km; Moon-Sun 1.5×10^{8} km
  Newton's constant $G = 6.67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}
- Hint: to calculate the ratio, not all the info is needed!

2. Planets fall into two major categories.



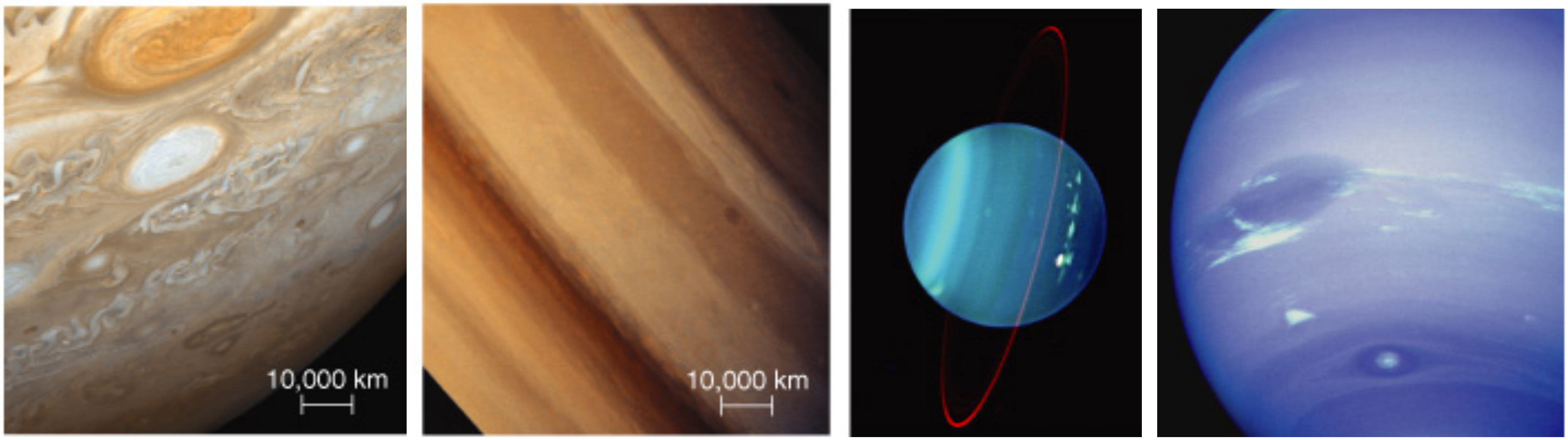
Comparative Planetology



- What kinds of comparisons can we make?
  - Size and mass ➔ density.
  - Presence/properties of any satellites.
  - Properties of the atmosphere.
  - Properties of the surface.
  - Magnetic fields.

What might cause the differences? Is this dichotomy inevitable?

Weather on Gas & Ice Giants



- All the jovian planets have strong winds and storms.

Are there any properties of the gas giants that might be related to the storms?

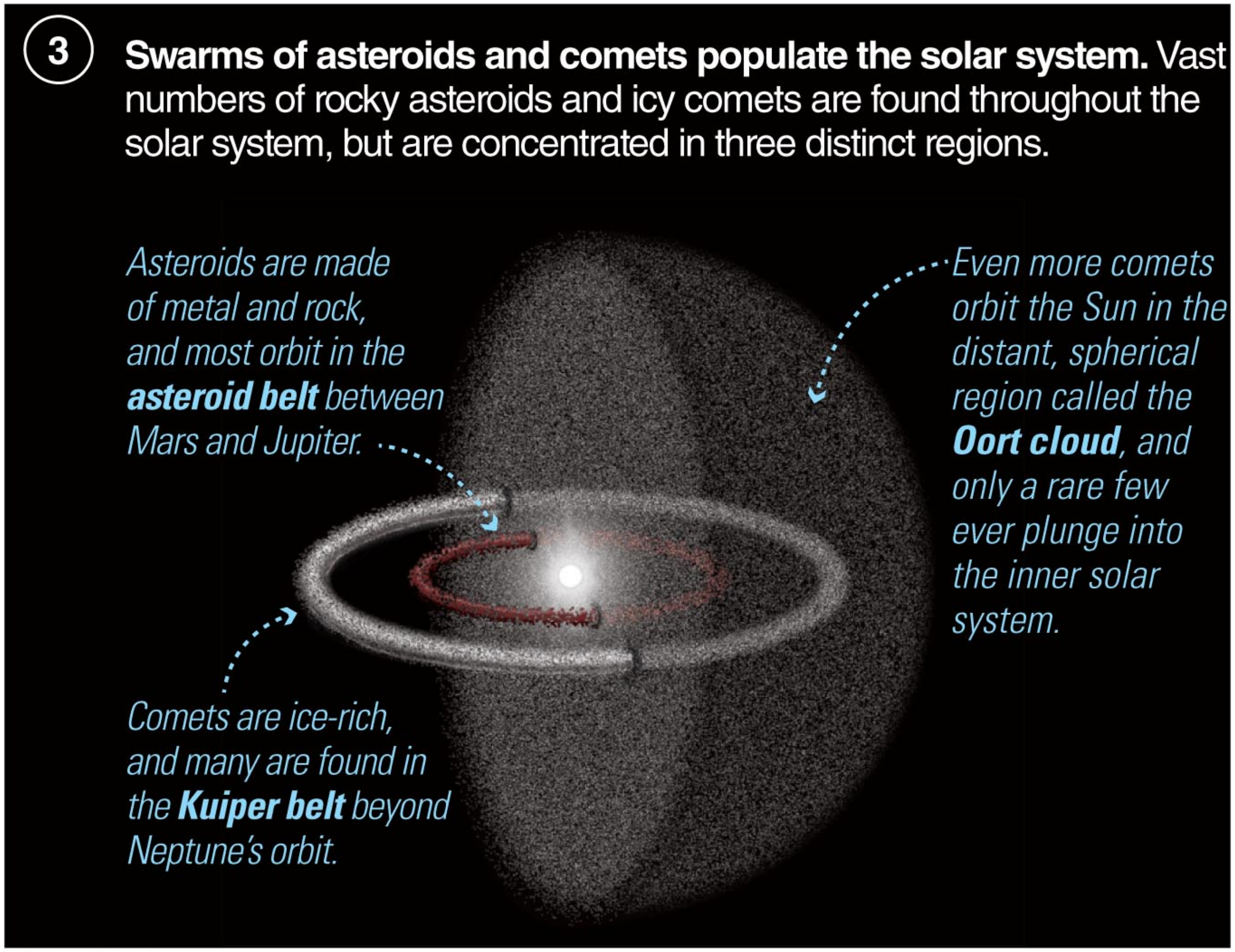
Big Moons in the Solar System

Which planets host each of these?
What do you notice about their surfaces?

Hm, that's odd...

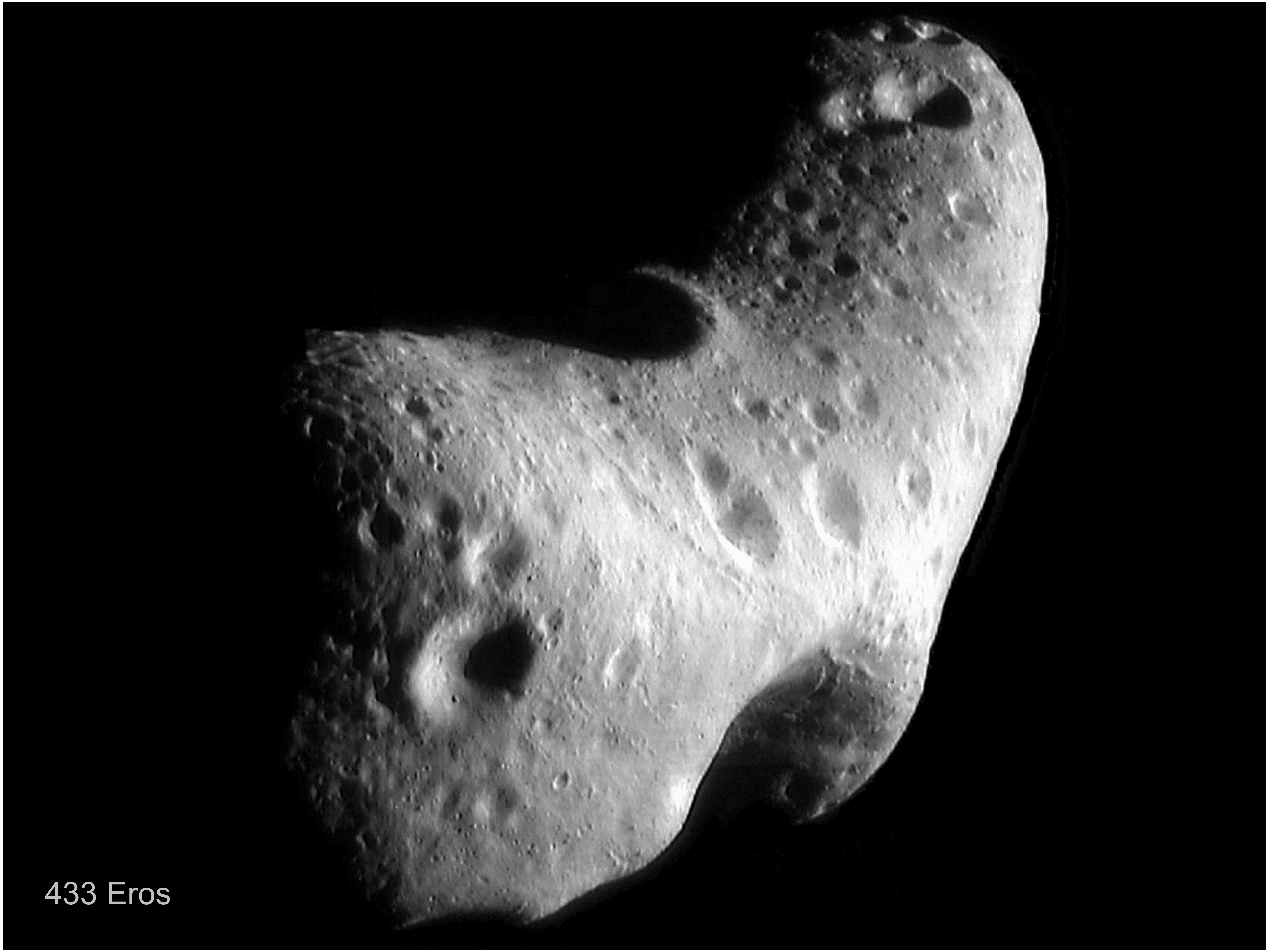
- Group question!
- Do you notice anything about the following numbers? Feel free to use your calculators!
- Mercury "day" 58.65 days; "year" 87.97 days
- Jupiter "year" 11.87 years; Saturn "year" 29.46 years
- Neptune "year" 164.8 years; Pluto "year" 248.5 years
- Io, Europa, Ganymede orbital periods around Jupiter: 1.77 days, 3.55 days, 7.15 days
- Do you see any patterns?
- Are those patterns accidental? There are many numbers we could play with, related to the Solar System...

3. Swarms of asteroids and comets populate the solar system.

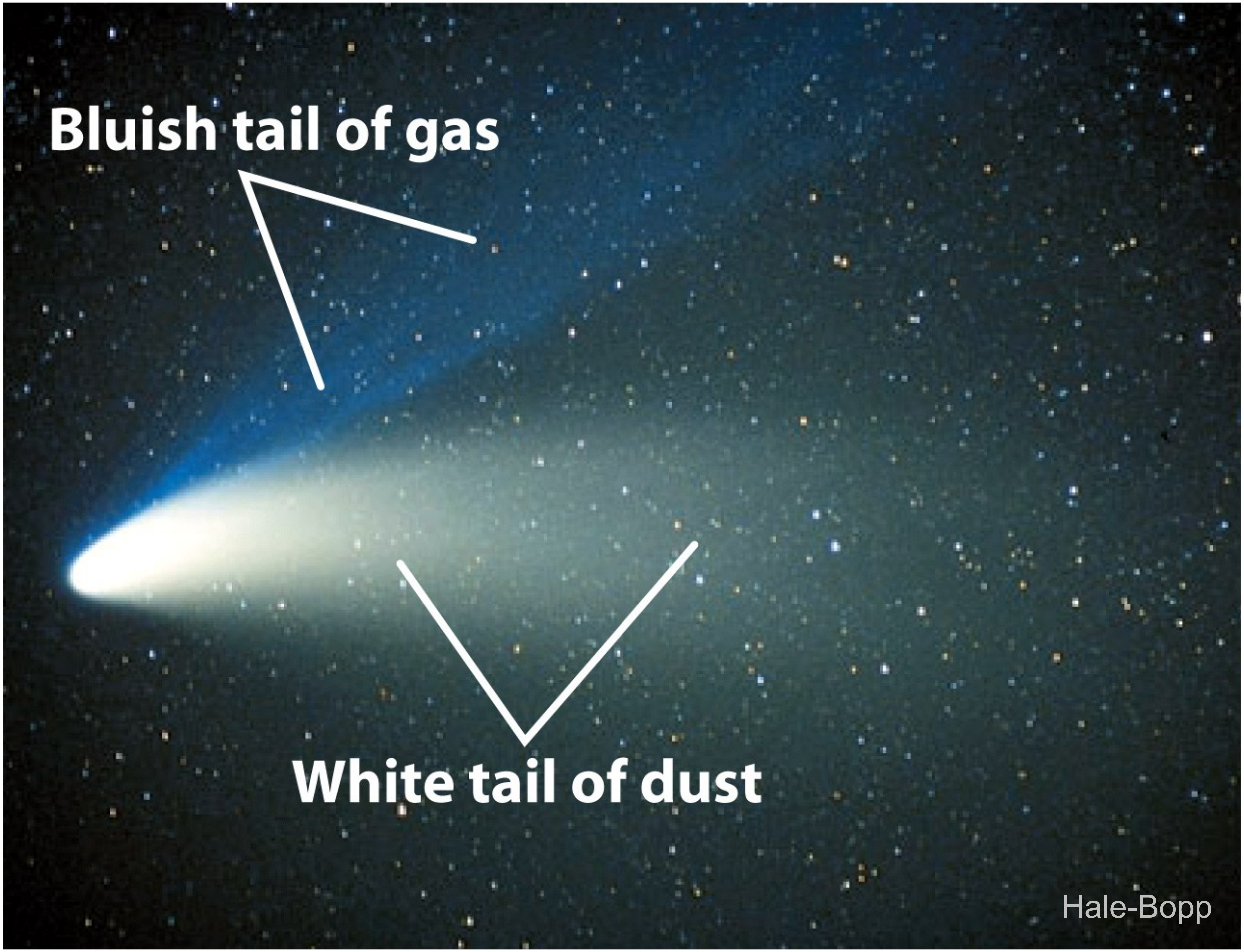


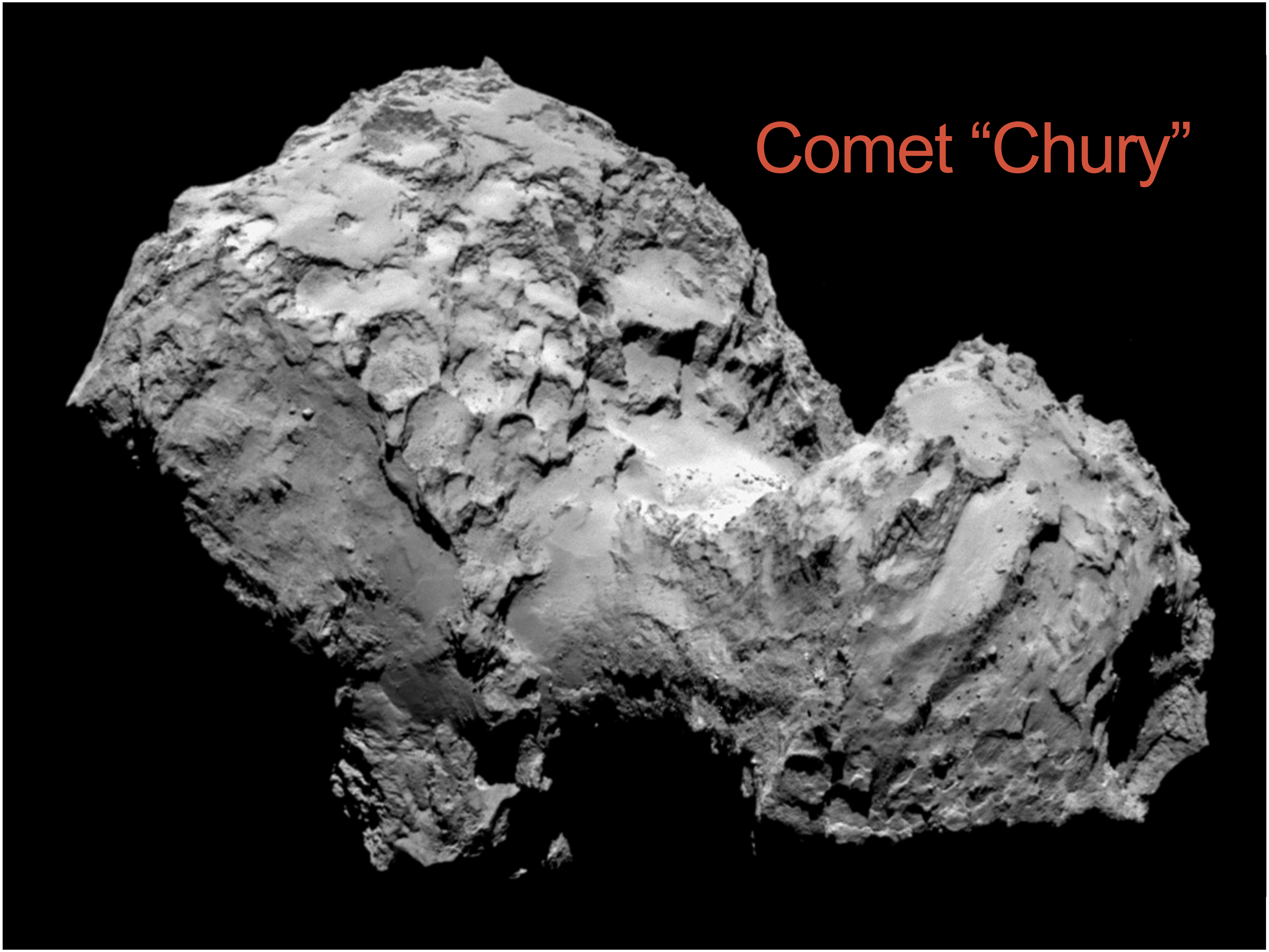
Asteroids & Comets (& Dust!)

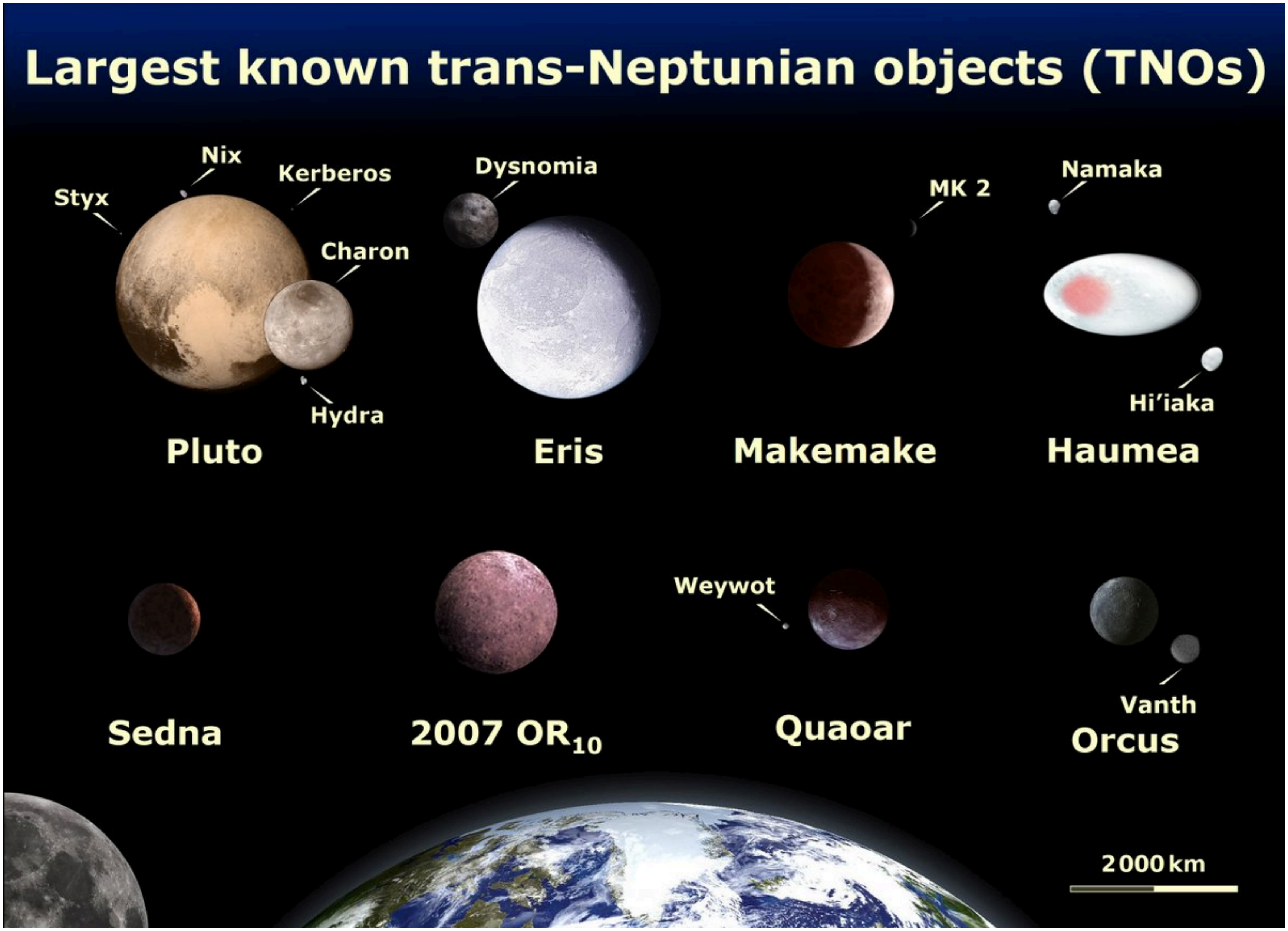
- Asteroids
  - Rocky objects orbiting Sun…most are between orbits of Mars and Jupiter (asteroid belt).
  - Largest diameter ~1,000 km (Ceres); most much smaller.
  - Some have orbits that cross planetary orbits (e.g., Earth's…).
  - Some have tiny satellites!
  - Could the asteroids have been an Earth-sized planet, broken up?
- Comets
  - Icy objects orbiting Sun…most originate beyond the orbit of Neptune (trans-Neptunian objects or TNOs) in the Kuiper belt (30–50 AU) or in the Oort cloud (1,000–50,000 AU).
  - These objects become comets when their orbits are disturbed, sending them plunging inward toward the Sun.
  - Ices start to vaporize when they are close to the Sun.
  - Largest TNOs are Pluto and Eris.



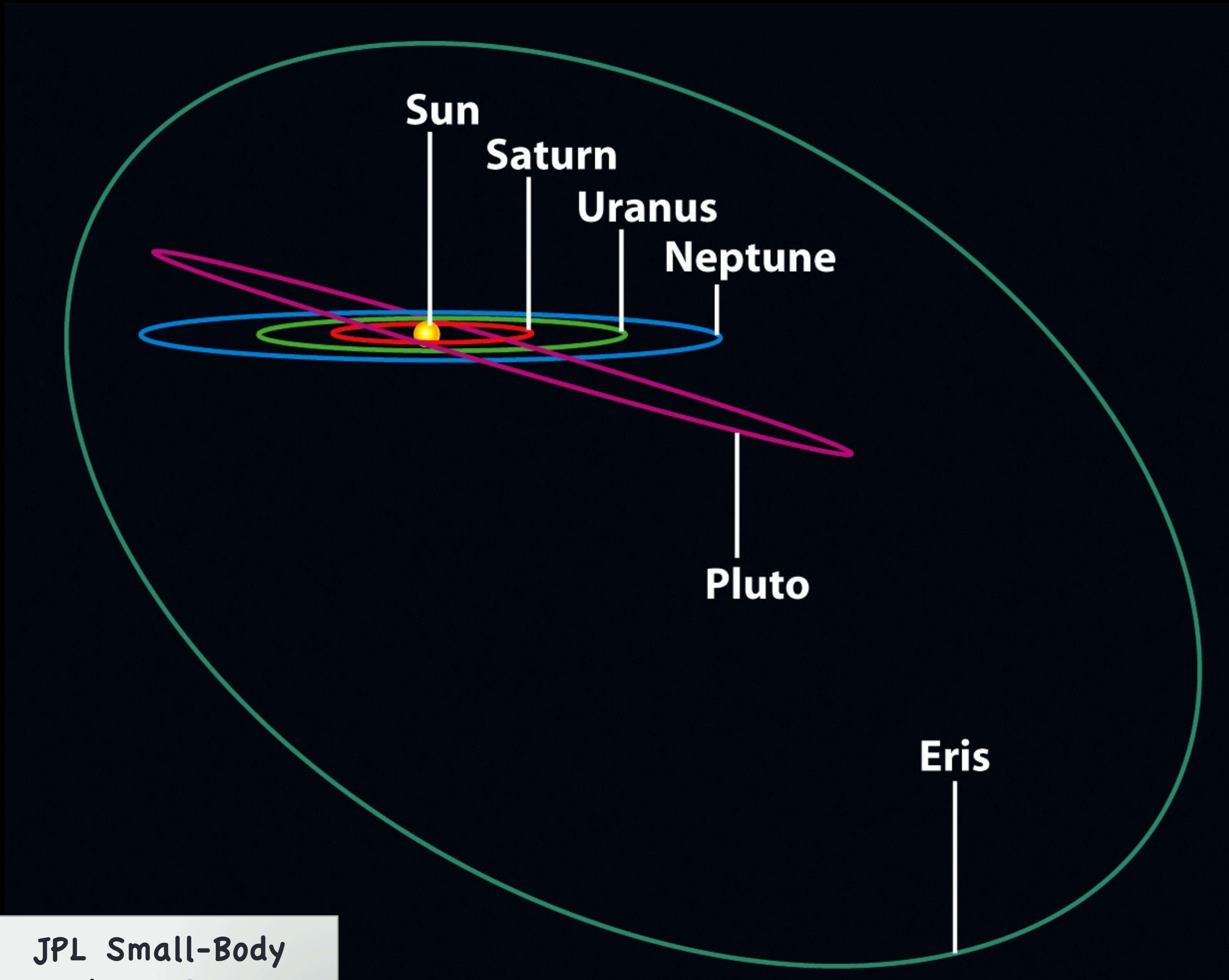
433 Eros


Bluish tail of gas
White tail of dust
Hale-Bopp


Comet "Chury"

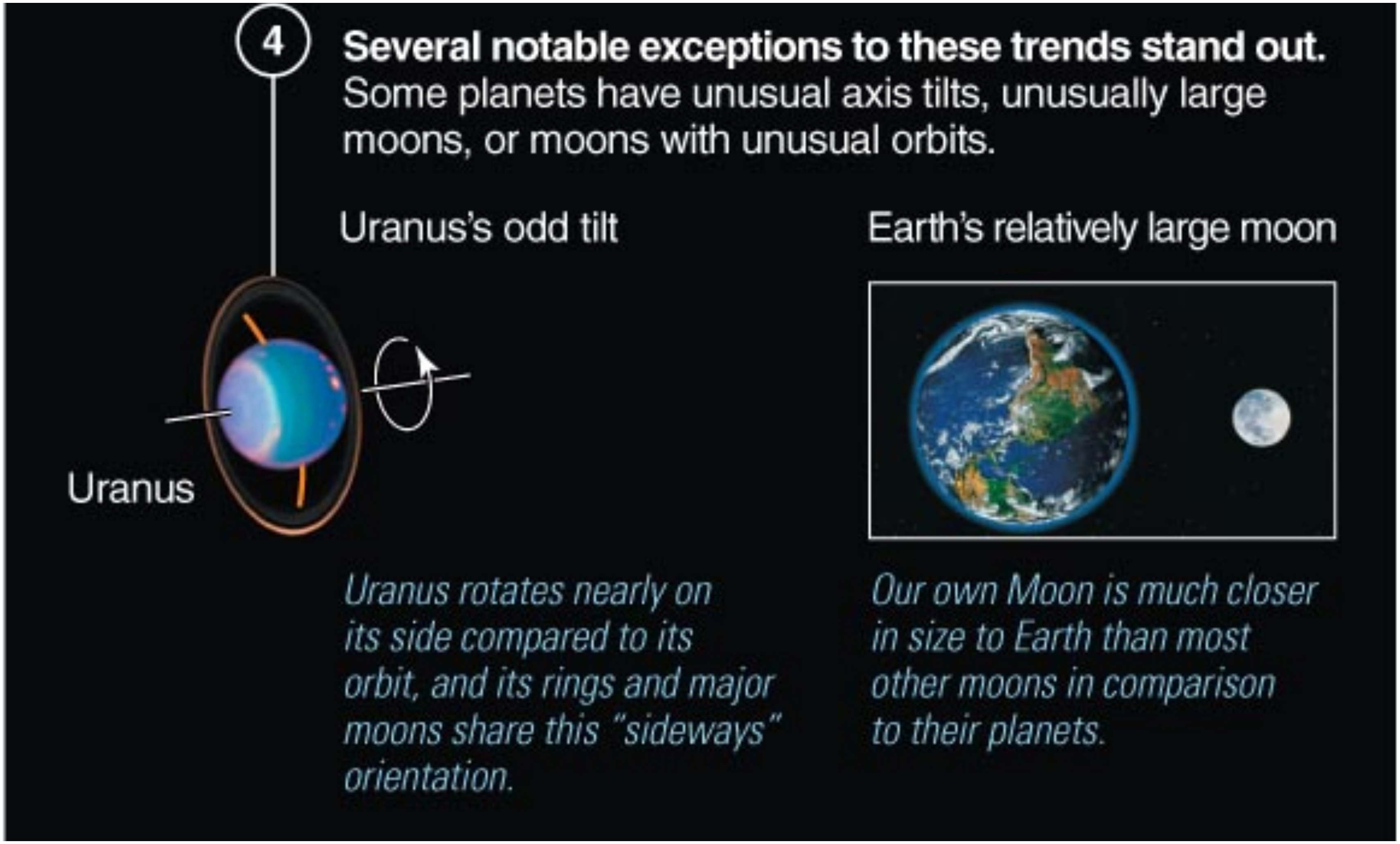


Largest known trans-Neptunian objects (TNOs)
Nix
Kerberos
Styx
Charon
Hydra
Pluto
Dysnomia
Eris
MK 2
Makemake
Namaka
Hi’iaka
Haumea
Sedna
2007 OR10
Weywot
Quaoar
Vanth
Orcus
2000 km



JPL Small-Body Database Browser

4. Several notable exceptions to these trends stand out.



Which Trends Must Be Explained?

- As astronomers, we are often confronted with a mass of data
- Some aspects of the data are happenstance; it had to be something, and it is this thing in this case
  License plate fallacy!
- Some are indications of trends; sometimes those trends reflect deep physics, sometimes they are incidental
- You therefore need a sense of the most important aspects of the data to explain
- What aspects strike you as most important for the Solar System?