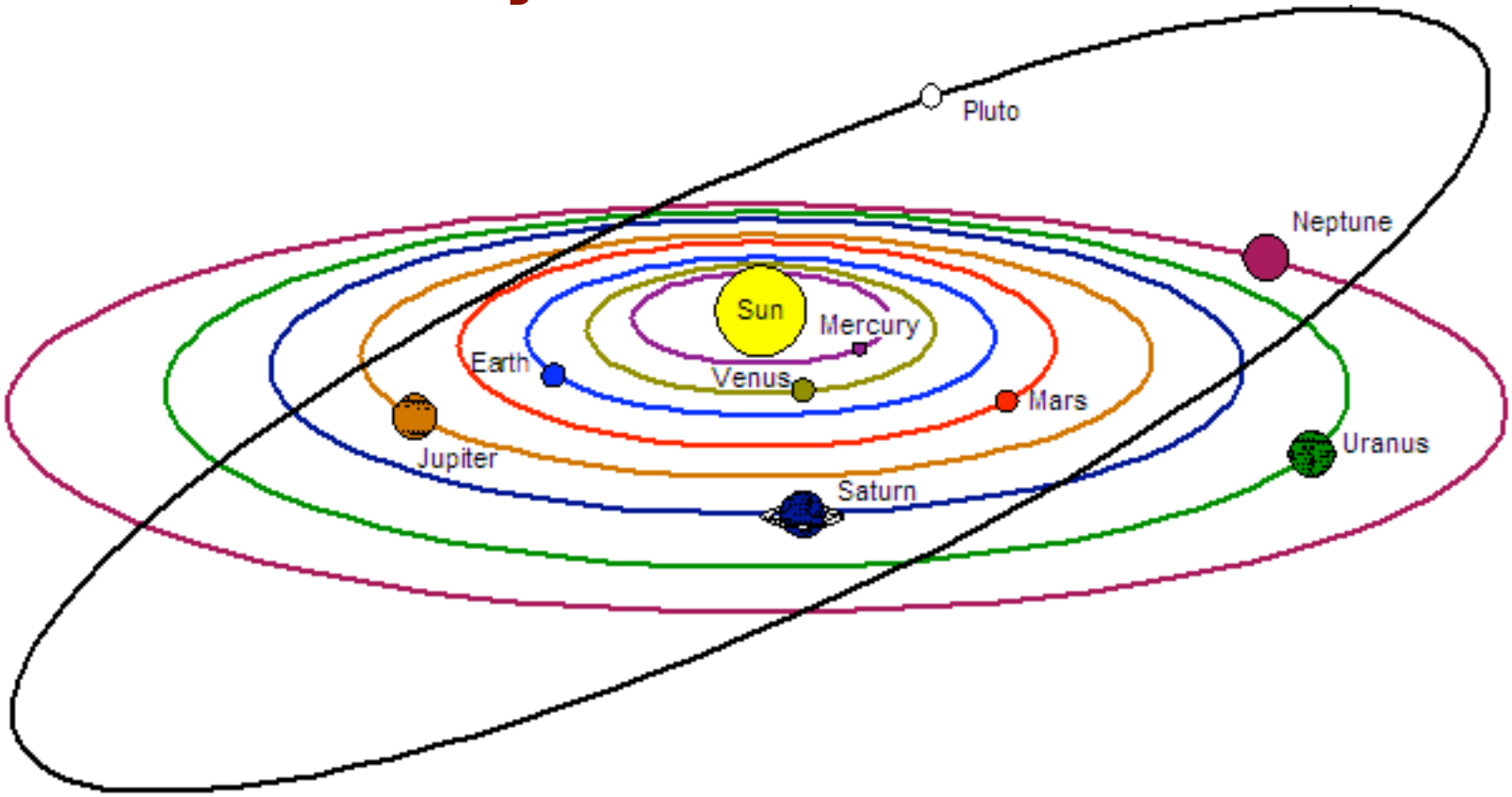
The Solar System: Some Questions

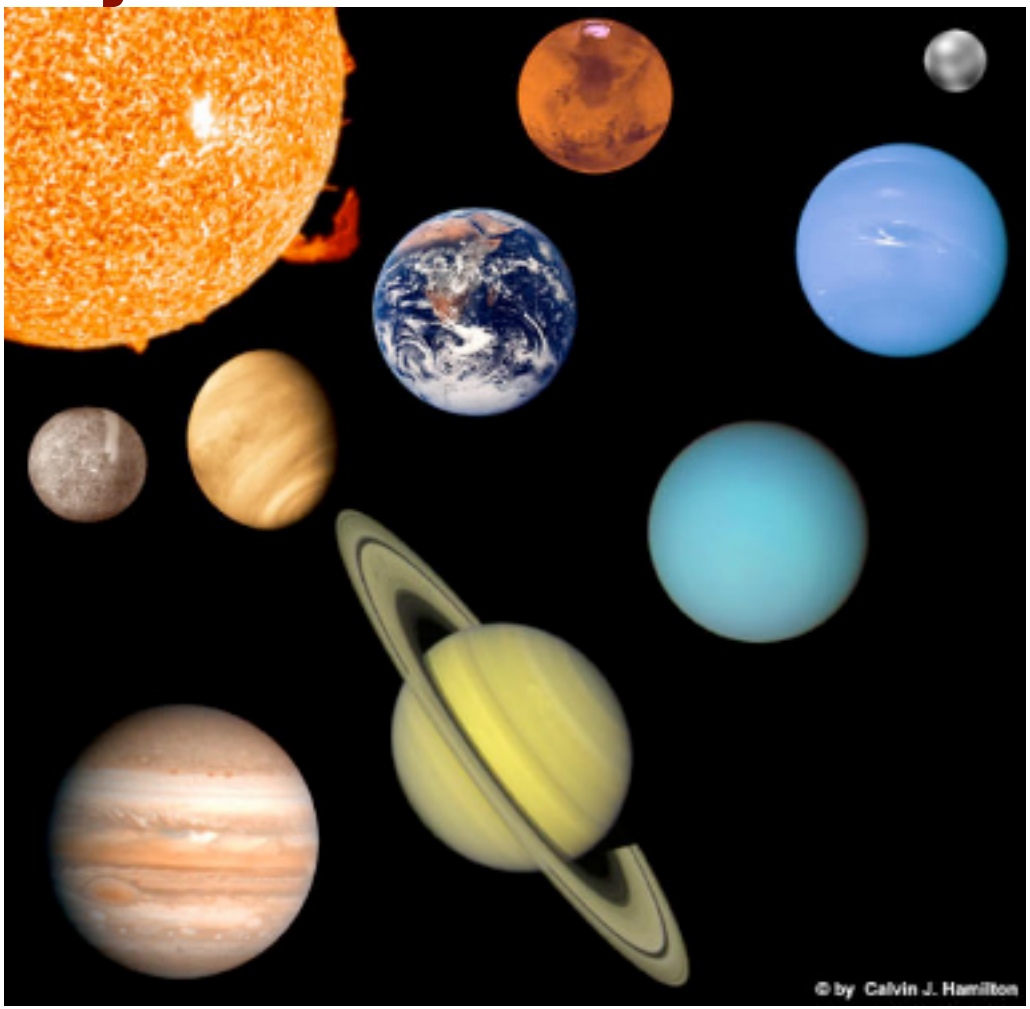
- What is meant by the Solar System?
- What are its constituents?
- What is its structure?
- What are its motions?
- What are the properties of its contents?
- How and when did it form?
- Are there other such systems?

The Solar System: Basic Structure



Planetary orbits are (1) nearly circular, (2) "centered" on the Sun, (3) lie nearly in the same plane, and (4) the orbital motions are <u>all</u> in the same direction.

Inventory: The Sun and its Planets



Not to scale: The Sun is about 100 times the size of the Earth.

The Solar System: Mass Inventory

Units

The mass of the Earth: $M_{Earth} = 5.98 \times 10^{24}$ kg

The mass of the Sun: $M_{Sun} = 1.99 \times 10^{30}$ kg

The Sun: 99.87% of the Solar System's mass!

$M_{Sun} = 322{,}776\ M_{Earth}$

The Planets: Only 0.13% of the Solar System's mass!

$M_{Mercury} = 0.055\ M_{Earth}$ $M_{Jupiter} = 318\ M_{Earth}$

$M_{Venus} = 0.825\ M_{Earth}$ $M_{Saturn} = 95.1\ M_{Earth}$

$M_{Earth} = 1.000\ M_{Earth}$ $M_{Uranus} = 14.5\ M_{Earth}$

$M_{Mars} = 0.108\ M_{Earth}$ $M_{Neptune} = 17.2\ M_{Earth}$

also

$M_{Pluto} = 0.002\ M_{Earth}$ $M_{Eris} = 0.003\ M_{Earth}$

$M_{Total} = 448\ M_{Earth}$

Solar System Mass Inventory (continued)

Planetary Satellites

$M_{Moon} = 0.0123\ M_{Earth}$ $M_{Total} = 0.123\ M_{Earth}$

Asteroids or Planetoids

$M_{Total} = 0.00038\ M_{Earth}$

Trans-Neptunian Objects

$M_{Total} < 0.1\ M_{Earth}$??

Comets

$M_{Total} \sim 6 \times 10^{-5}\ M_{Earth}$?

Interplanetary Dust & Interplanetary Gas

$M_{Total} \sim 6 \times 10^{-9}\ M_{Earth}$

The Solar System: A Size Inventory

Units

The radius of the Earth: $R_{Earth} = 6{,}371$ km

The radius of the Sun: $R_{Sun} = 695, 777$ km

The Sun

$R_{Sun} = 109\ R_{Earth}$

The Planets

$R_{Mercury} = 0.38\ R_{Earth}$

$R_{Venus} = 0.95\ R_{Earth}$

$R_{Earth} = 1.00\ R_{Earth}$

$R_{Mars} = 0.53\ R_{Earth}$

$R_{Jupiter} = 11.1\ R_{Earth}$ $(0.10\ R_{Sun})$

$R_{Saturn} = 9.42\ R_{Earth}$

$R_{Uranus} = 3.84\ R_{Earth}$

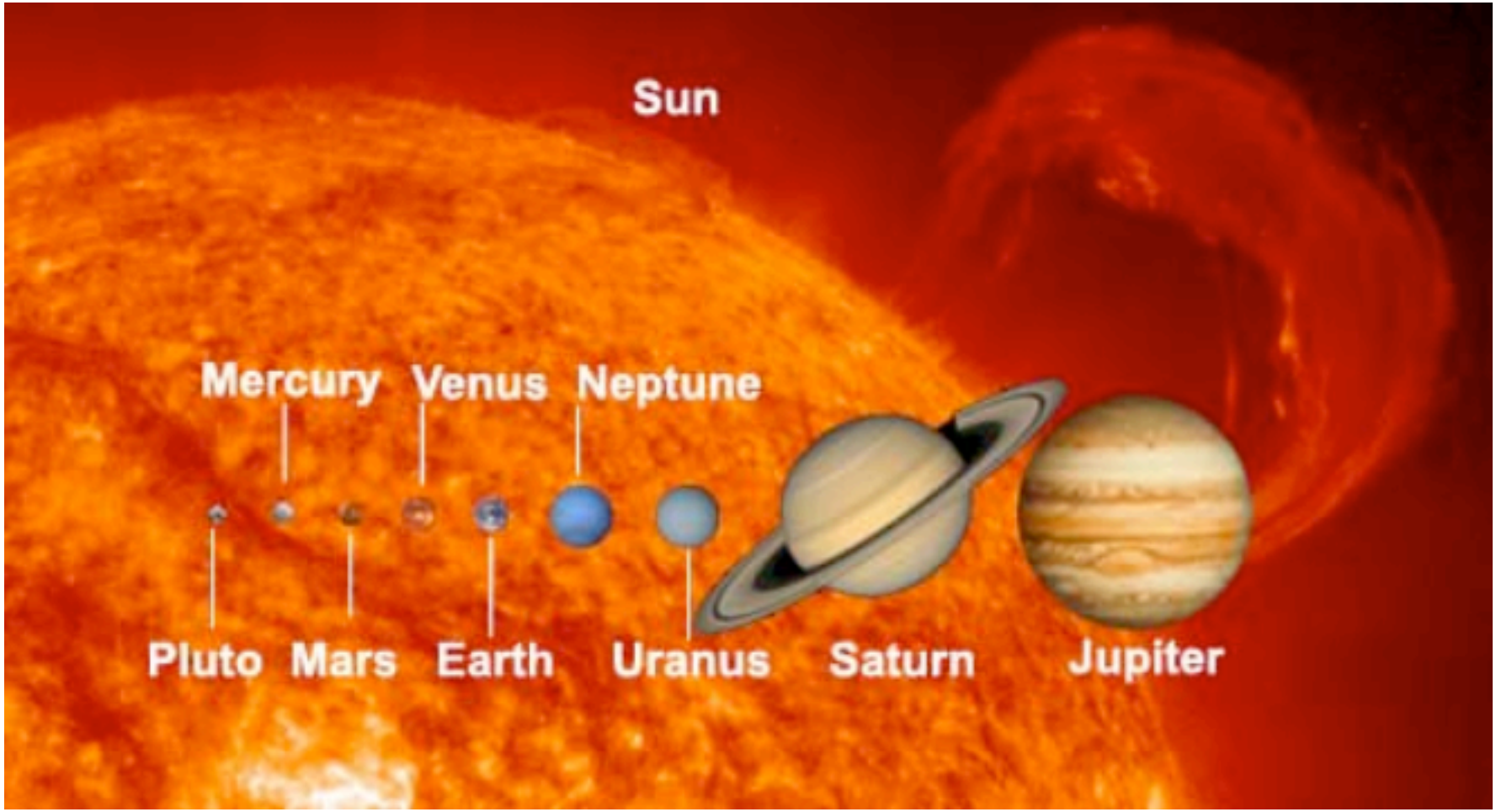
$R_{Neptune} = 3.93\ R_{Earth}$

also

$R_{Pluto} = 0.18\ M_{Earth}$

$R_{Eris} = 0.38\ R_{Earth}$

Relative Sizes of the Sun and the Planets



Some Planetary Satellites

Earth: $R_{Moon} = 0.27\ R_{Earth}$

Mars: $R_{Phobos} = 0.0011\ R_{Earth}$ $R_{Deimos} = 0.0006\ R_{Earth}$

Jupiter: $R_{Ganymede} = 0.41\ R_{Earth}$ $R_{Callisto} = 0.37\ R_{Earth}$

Saturn: $R_{Titan} = 0.38\ R_{Earth}$ $(R_{Mercury} = 0.38\ R_{Earth})$

Asteroids or Planetoids (a.k.a. Monor Planets)

$R_{Ceres} = 0.07\ R_{Earth}$

$R_{Pallas} = 0.04\ R_{Earth}$

$R_{Vesgta} = 0.04\ R_{Earth}$

$R_{Others} < 0.025\ R_{Earth}$

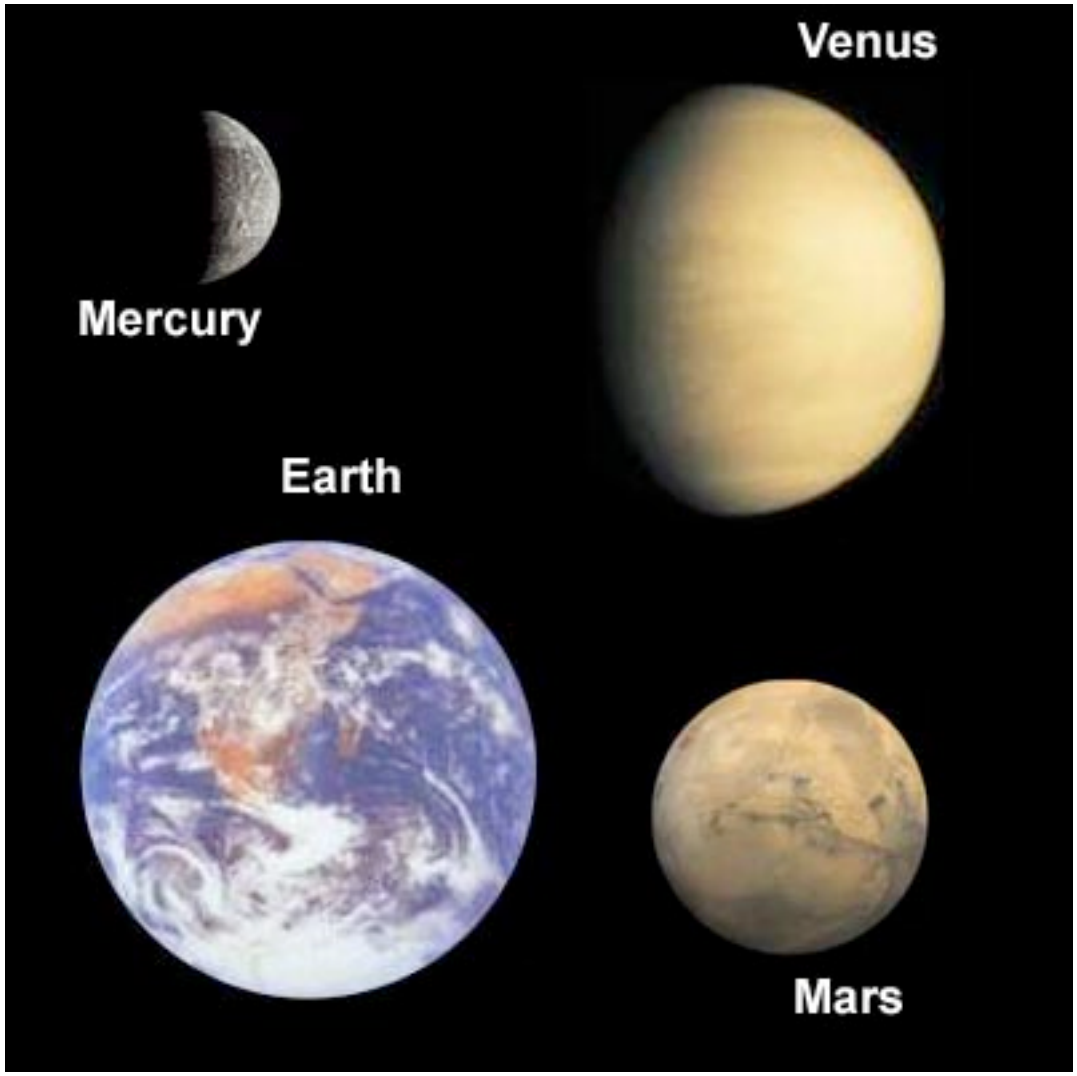
Trans-Neptunian Objects

$R_{Pluto} = 0.18\ M_{Earth}$ $R_{Eris} = 0.38\ R_{Earth}$

Comets

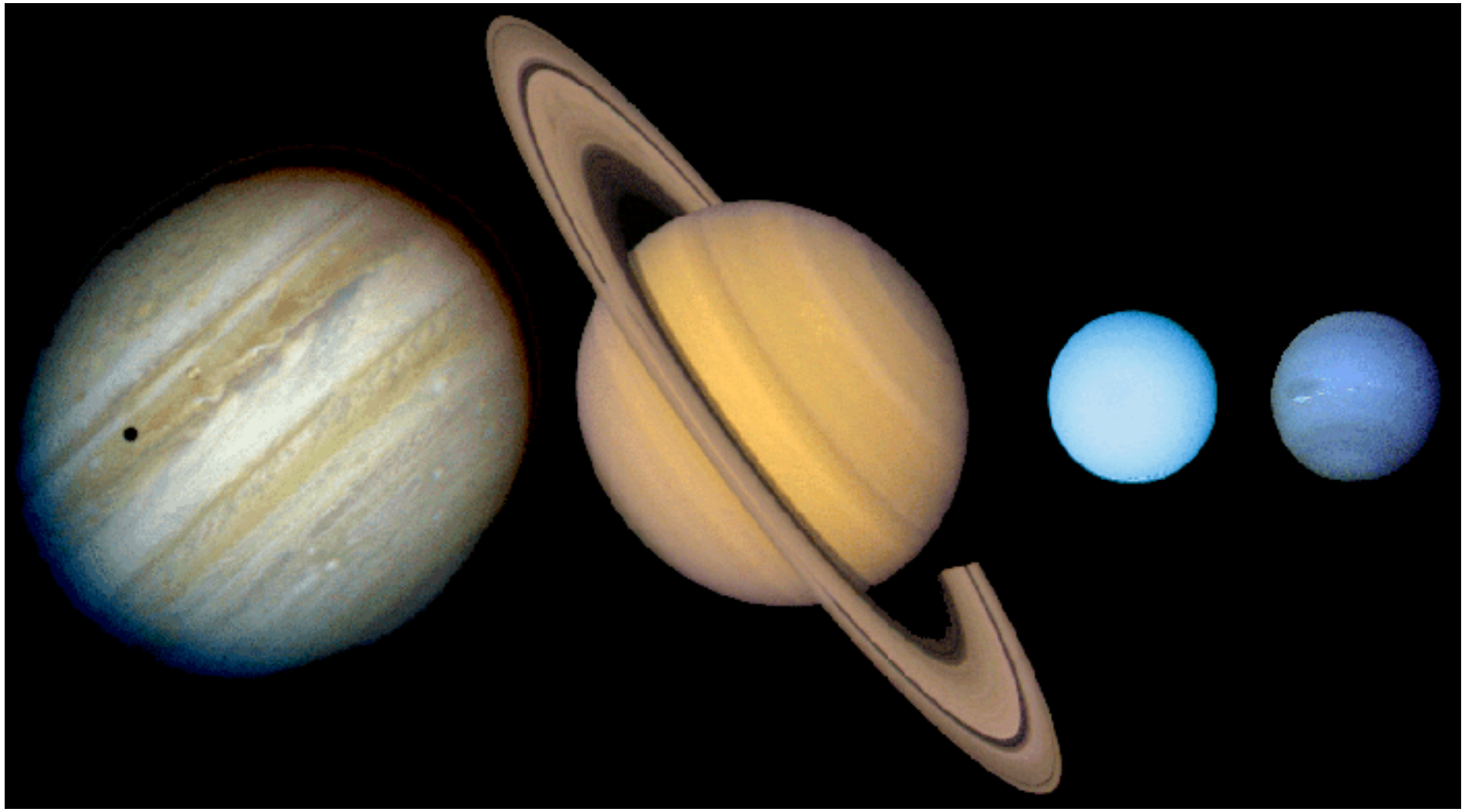
$R_{Nucleus} \sim 0.001\ R_{Earth}$

The Terrestrial Planets



(Perspective: The Sun is about 109 times the size of the Earth)

The Jovian Planets



(Jupiter is about 1/10 the size of the Sun and 11 times the size of the Earth.)

Orbits in the Solar System

Recollect Kepler's Laws:

- **Orbital Geometry: The orbits of the planets are ellipses - with the Sun at a focus of the ellipse**

- **Law of Areas: The Sun-planet line sweeps out equal areas in equal intervals of time**

- **Harmonic Law: Orbital periods and sizes are related by:**

$a^3 = KP^2$ where **K** is a constant

*** The "orbital elements" can be determined by triangulation ***

BUT ALSO

These apply to all objects in orbit about the Sun!

These apply to all satellites in orbit about a planet as well!
(but the "constant" **K** will be different for every planet system.)

Planetary Rotation

The planets (and other objects) orbit the Sun with periods P

P_{Earth} = 1 (sidereal) year

They also spin about their axes with rotational periods P_{rot}

$P_{rot,\ Earth}$ = 1 (sidereal) day

Axes of rotation are inclined with respect to the orbital axis

$i_{rot,\ Earth}$ = 23.5°

Determining axial rotation periods and inclinations:

- **Observe "surface" features**
  (Differential Rotation)
- **Observe Brightness variations.**
  (Pluto, Asteroids, ...)
- **Doppler measurements of rotation speed.**
  (Sunlight & Radar)

Orbits and Rotation in the Solar System

Planet	a(au)	P(yr)	i	ε	P_{rot}	i_{rot}
Mercury	0.387	0.241	7.00°	0.206	58.7 d	7.0°
Venus	0.723	0.615	3.39°	0.007	-243.0 d	-2.6°
Earth	1.000	1.000	0.00°	0.017	23.9 h	23.5°
Mars	1.524	1.881	1.85°	0.093	24.6 h	24.0°
Ceres	2.766	4.602	10.6°	0.079	9.1 h	
Jupiter	5.202	11.86	1.31°	0.048	9.83± h	3.1°
Saturn	9.539	29.46	2.49°	0.056	10.7± h	26.7°
Uranus	19.19	84.01	0.77°	0.046	17.4 h	-82.1°
Neptune	30.06	164.8	1.77°	0.010	16.1 h	28.8°
Pluto	39.53	248.5	17.2°	0.248	-6.39 d	-32.5°
Sun	-	-	-	-	25.38d	7.25°

Recollect Orbital Elements:

a = Semimajor axis
ε = Eccentricity

i = Inclination Angle
ω = Perhelion Angle
Ω = Nodal Angle

P = Orbital Period
T = Time of Perihelion Passage

Planetary Locations and Motions

Orbits

The planets orbit the Sun in elliptical orbits.
Orbital motions are all in the same direction.
These orbits are near-circular.
These orbits are nearly coplanar.
(..also usually true for satellite orbits about planets)

Axial Rotation

Planets also rotate about their polar axes.
(.. but not all rotate in the same sense)
Jovian Planets rotate more rapidly thanTerrestrial Planets

Exceptions

The above statements seem to be at least approximately true for the asteroids and other bodies except for the comets.
All observed comets have very eccentric orbits.
Long period comets also have orbits of all inclinations.