Discovery of the Solar System

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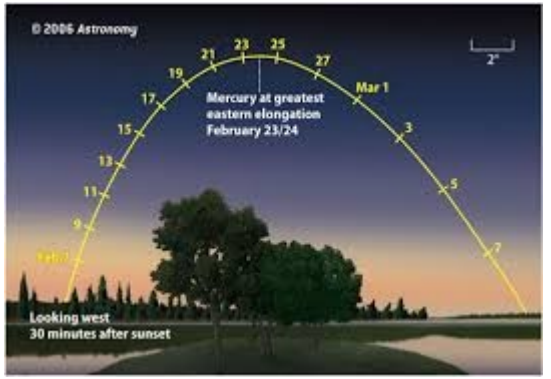
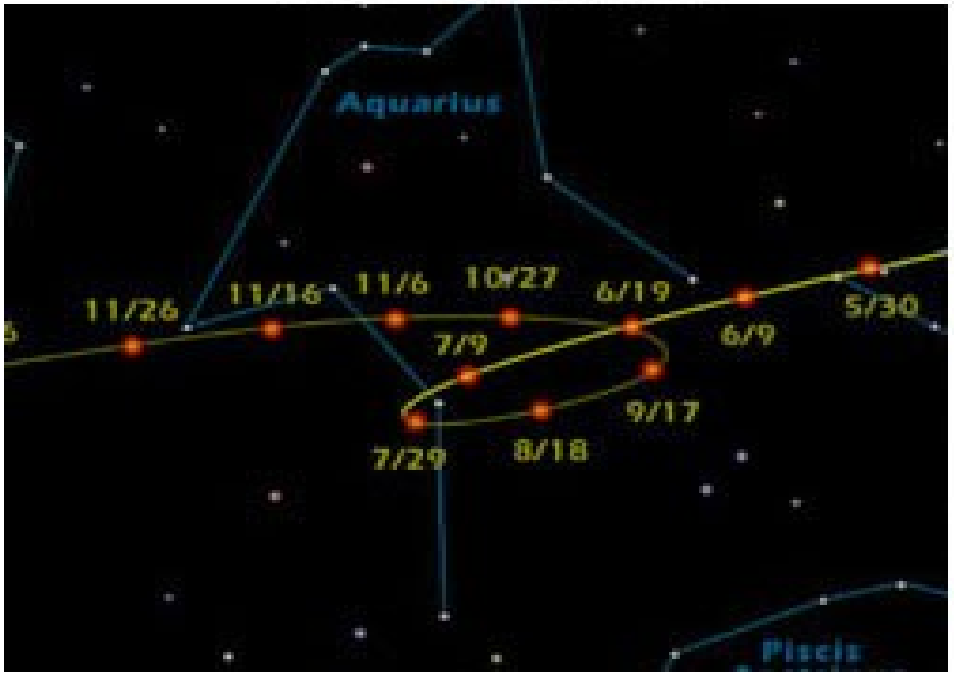
How did we discover the solar system?

Stellar tracks through the night

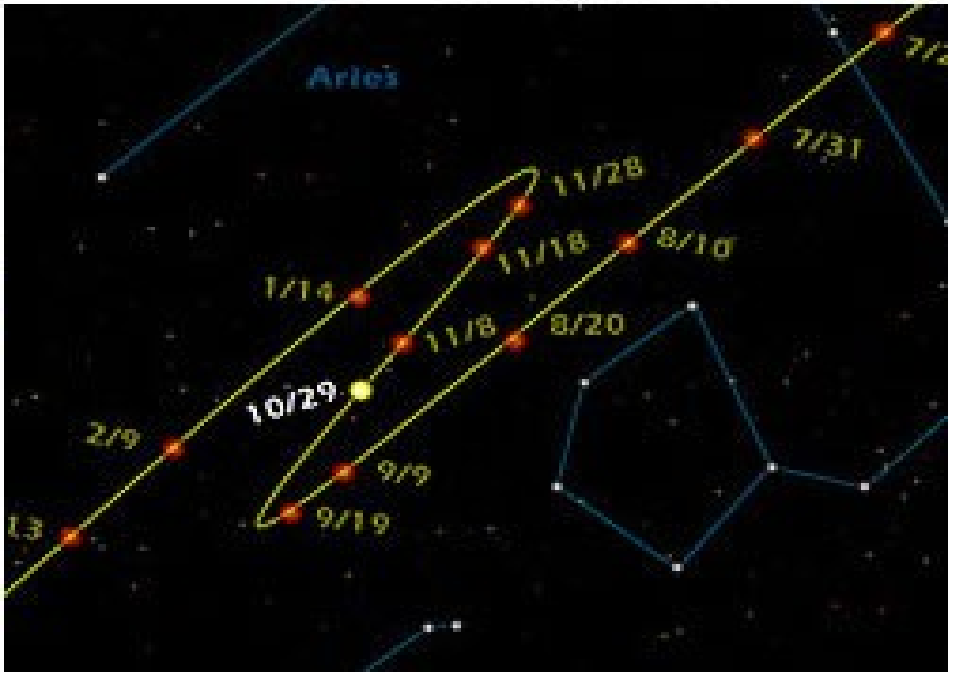
Planets were wanderers....

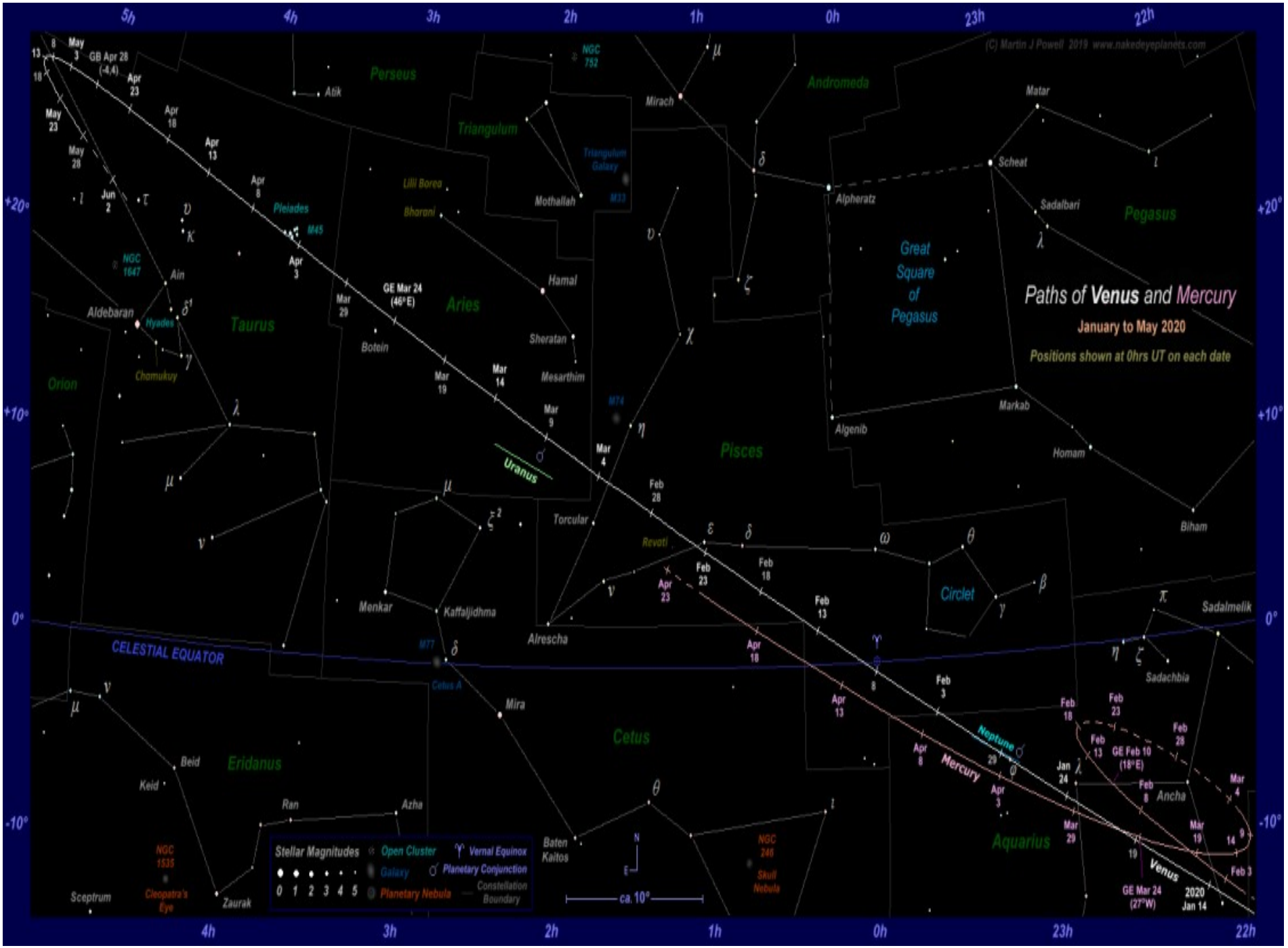


2003 Retrograde

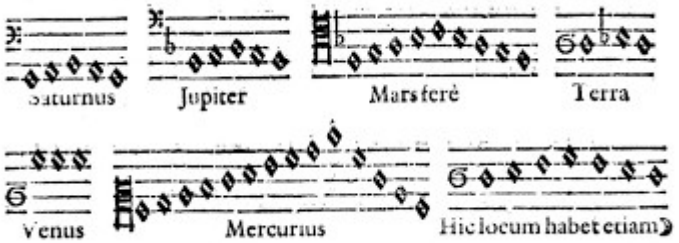


2005 Retrograde



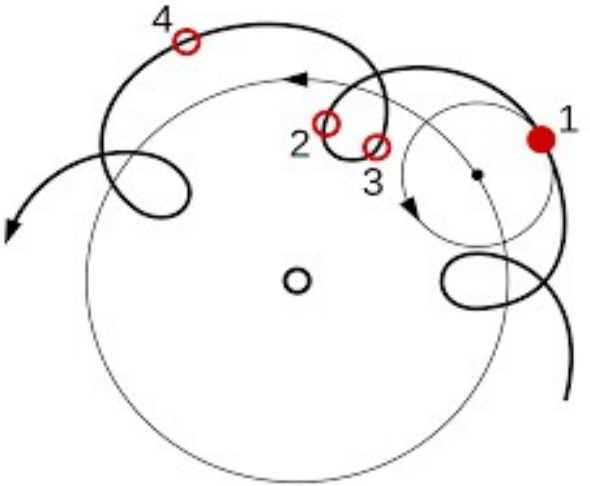

Paths of Venus and Mercury
January to May 2020
Positions shown at 0hrs UT on each date
(C) Martin J Powell 2019 www.nakedeyeplanets.com
Perseus
Andromeda
Triangulum
Pegasus
Great Square of Pegasus
Aries
Taurus
Pisces
Orion
Eridanus
Cetus
Aquarius
Circlet
CELESTIAL EQUATOR
Uranus
Neptune
Mercury
Venus
Pleiades
Hyades
Atik
Mirach
Matar
Scheat
Alpheratz
Sadalbari
Hamal
Sheratan
Mesarthim
Botein
Ain
Aldebaran
Chamukuy
Mothallah
Bharani
Lilli Borea
Algenib
Markab
Homam
Biham
Torcular
Revati
Alrescha
Menkar
Kaffaljidhma
Mira
Sadalmelik
Sadachbia
Ancha
Beid
Keid
Ran
Azha
Zaurak
Baten Kaltos
Sceptrum
NGC 752
NGC 1647
NGC 1535
Cleopatra's Eye
NGC 246
Skull Nebula
Triangulum Galaxy
M33
M45
M74
M77
Cetus A
GB Apr 28 (-4.4)
GE Mar 24 (46°E)
GE Feb 10 (18°E)
GE Mar 24 (27°W)
2020 Jan 14
Stellar Magnitudes
0 1 2 3 4 5
Open Cluster
Galaxy
Planetary Nebula
Vernal Equinox
Planetary Conjunction
Constellation Boundary
ca. 10°
5h
4h
3h
2h
1h
0h
23h
22h
+20°
+10°
0°
-10°

The Music of the Spheres

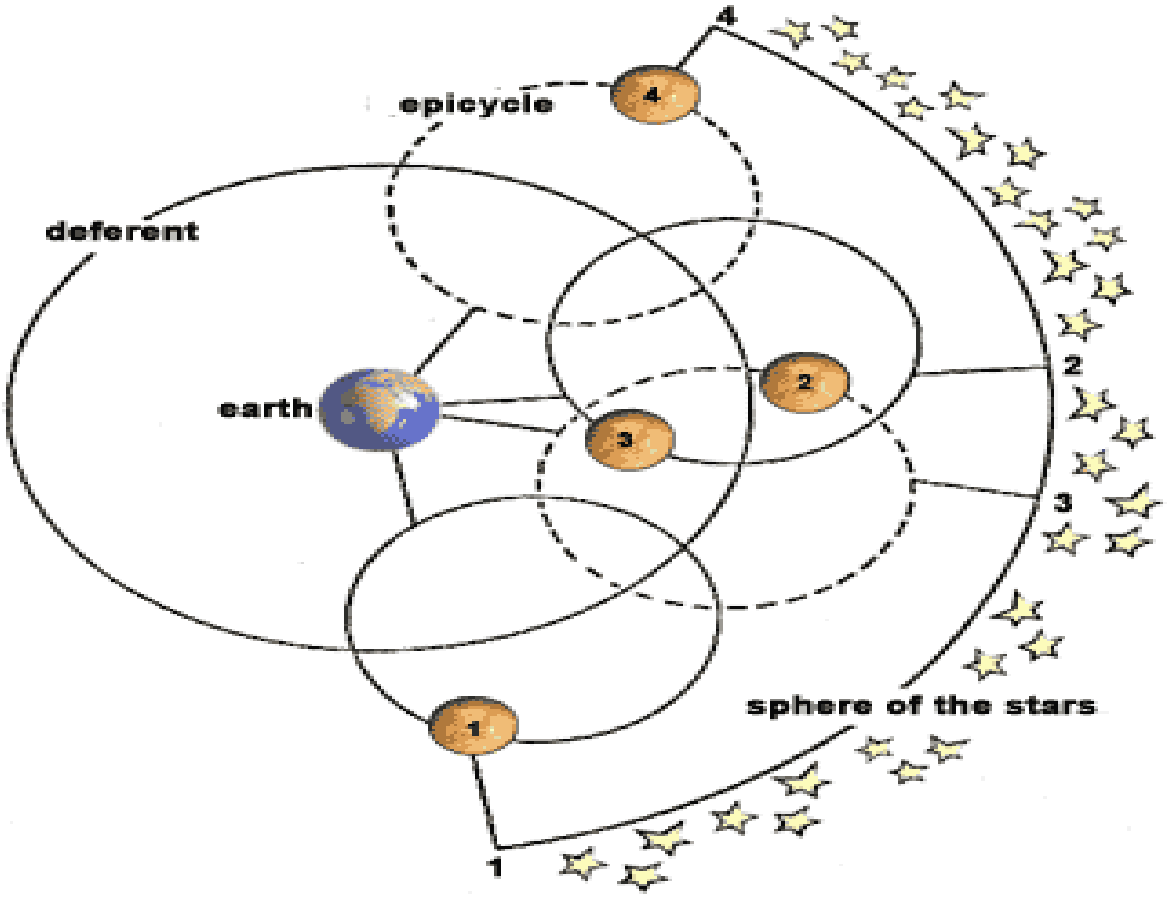


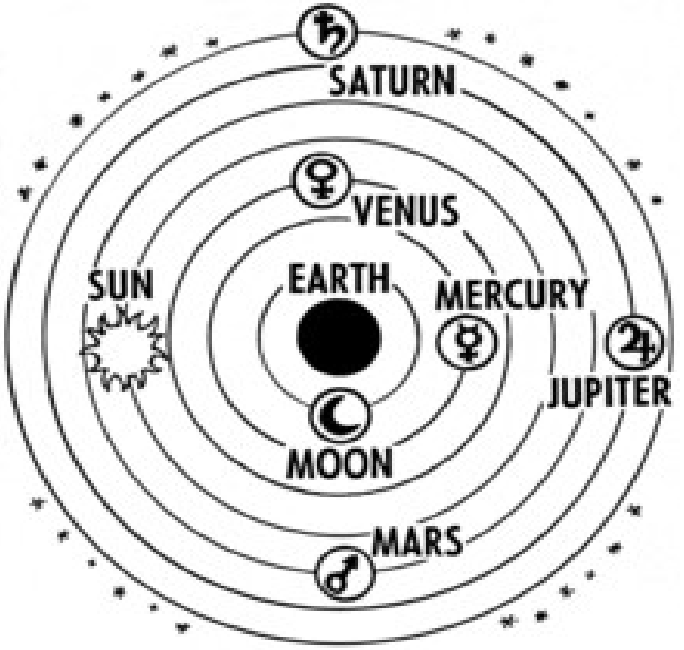
Pythogoras, Plato:

Sun, moon, and planets were thought to revolve around Earth in their proper spheres. The spheres were thought to be related by the whole-number ratios of pure musical intervals, creating musical harmony.



Ptolemaic System: Geocentric Theories





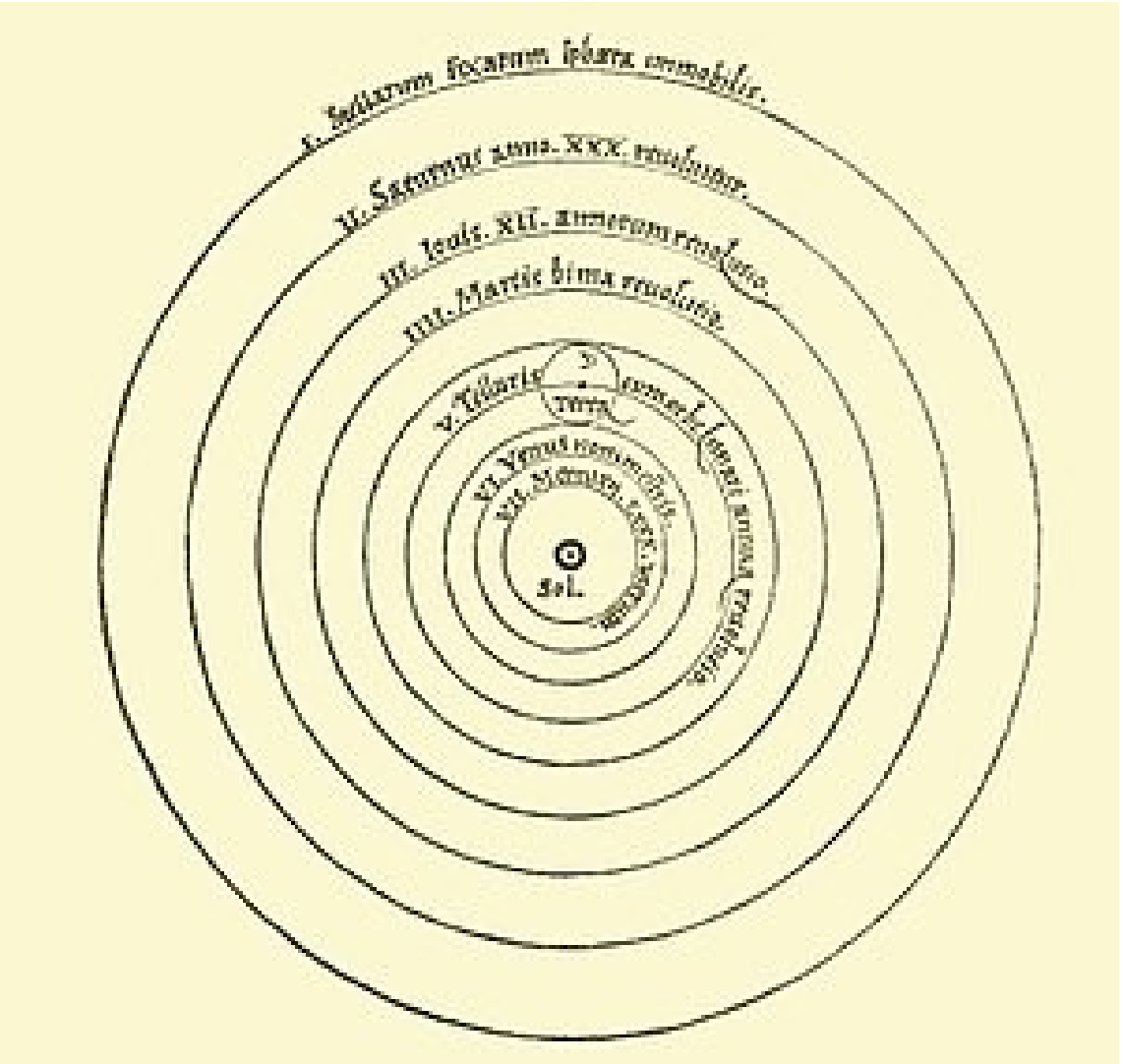
Copernican heliocentrism (1543)


NICOLAI
COPERNICI TO-
RINENSIS DE REVOLVTIONI-
bus orbium cœlestium,
Libri VI.

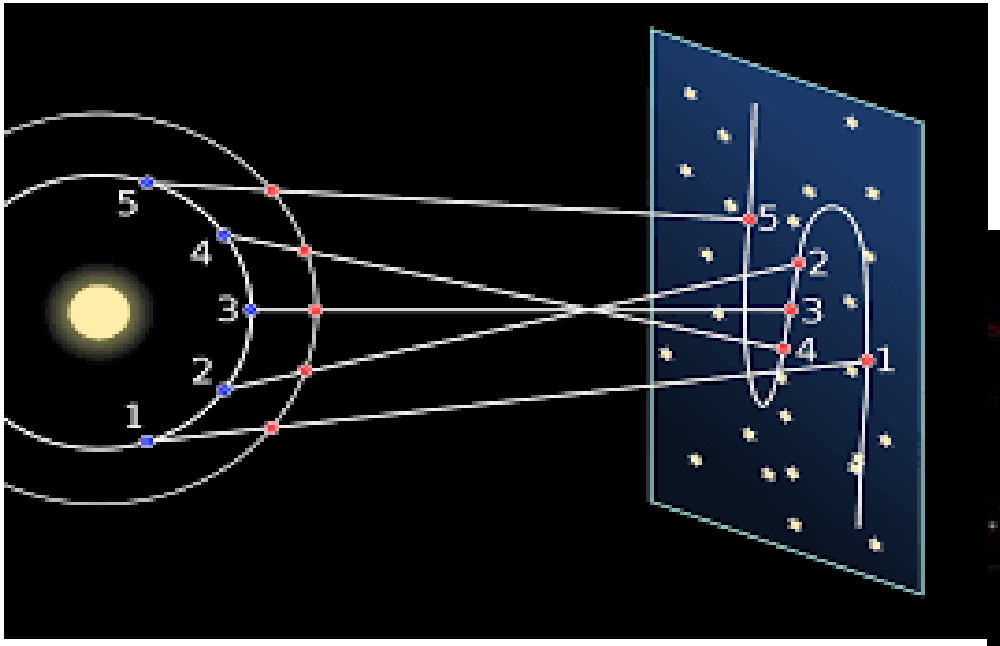
IN QVIBVS STELLARVM ET FI-
XARVM ET ERRATICARVM MOTVS, EX VETE-
ribus atq; recentibus observationibus, restituit hic autor.
Præterea tabulas expeditas luculentasq; addidit, ex quibus eosdem motus ad quoduis tempus Mathematum studiosus facillime calculare poterit.

ITEM, DE LIBRIS REVOLVTIONVM NICOLAI
Copernici Narratio prima, per M. Georgium Ioachimum Rheticum ad D. Ioan. Schonerum scripta.

Cum Gratia & Priuilegio Cæs. Maiest.
BASILEAE, EX OFFICINA
HENRICPETRINA



Retrograde-Prograde Motion



As Earth (blue) passes a superior planet, such as Mars (red), the superior planet will temporarily appear to reverse its motion across the sky.

Johannes Kepler

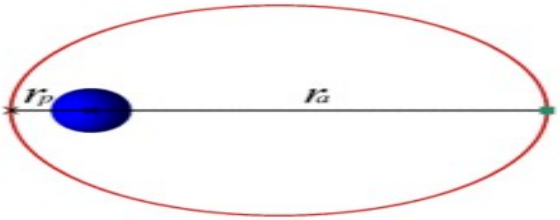
- Connection between geometry and music
- Spheres were regarded as the purely geometrical spatial regions containing each planetary orbit rather than physical bodies as rotating orbs

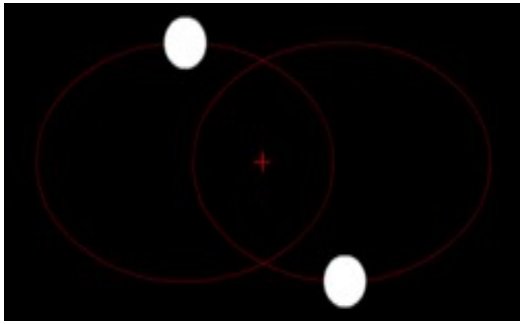
The beauty in the details....

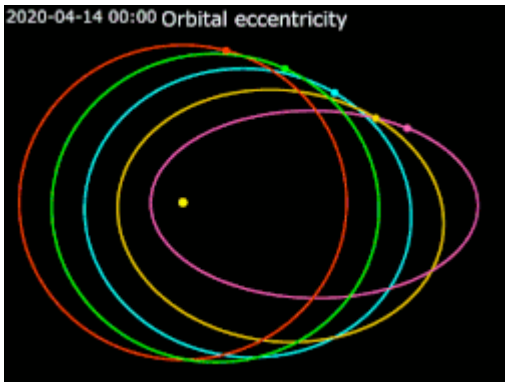
Eccentricities of Solar System bodies

Object	eccentricity
Triton	0.000 02
Venus	0.006 8
Neptune	0.008 6
Earth	0.016 7
Titan	0.028 8
Uranus	0.047 2
Jupiter	0.048 4
Saturn	0.054 1
Moon	0.054 9
1 Ceres	0.075 8
4 Vesta	0.088 7
Mars	0.093 4
10 Hygiea	0.114 6
Makemake	0.155 9
Haumea	0.188 7
Mercury	0.205 6
2 Pallas	0.231 3
Pluto	0.248 8

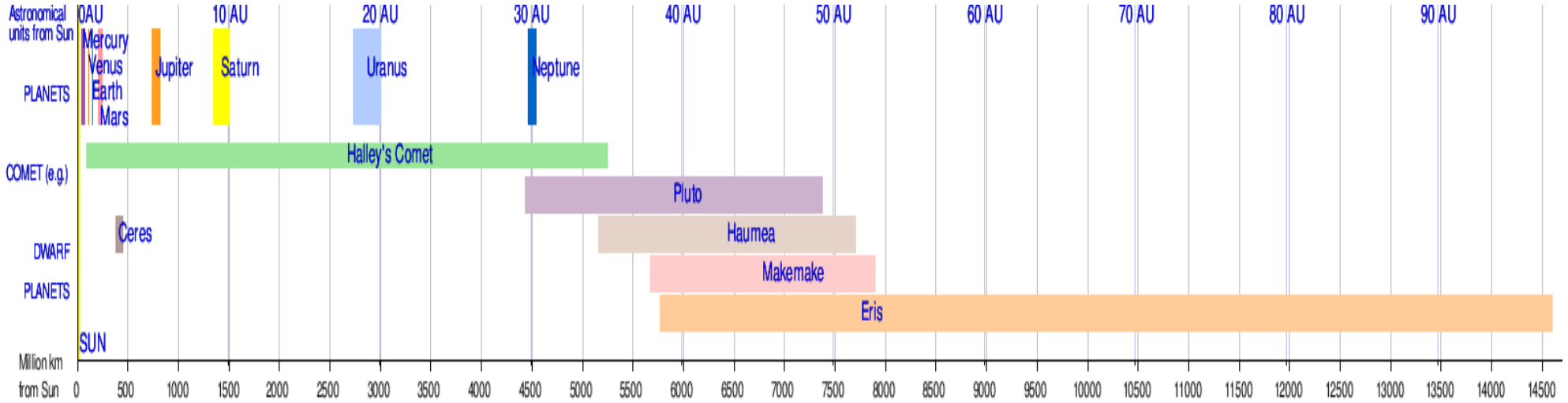
Comparison to observations of Tycho Brahe.....







In a gravitational two-body problem with negative energy, both bodies follow similar elliptic orbits with the same orbital period around their common barycenter. Also the relative position of one body with respect to the other follows an elliptic orbit.


Astronomical units from Sun
0AU
10 AU
20 AU
30 AU
40 AU
50 AU
60 AU
70 AU
80 AU
90 AU
PLANETS
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
COMET (e.g.)
Halley's Comet
DWARF PLANETS
Ceres
Pluto
Haumea
Makemake
Eris
SUN
Million km from Sun
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
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11000
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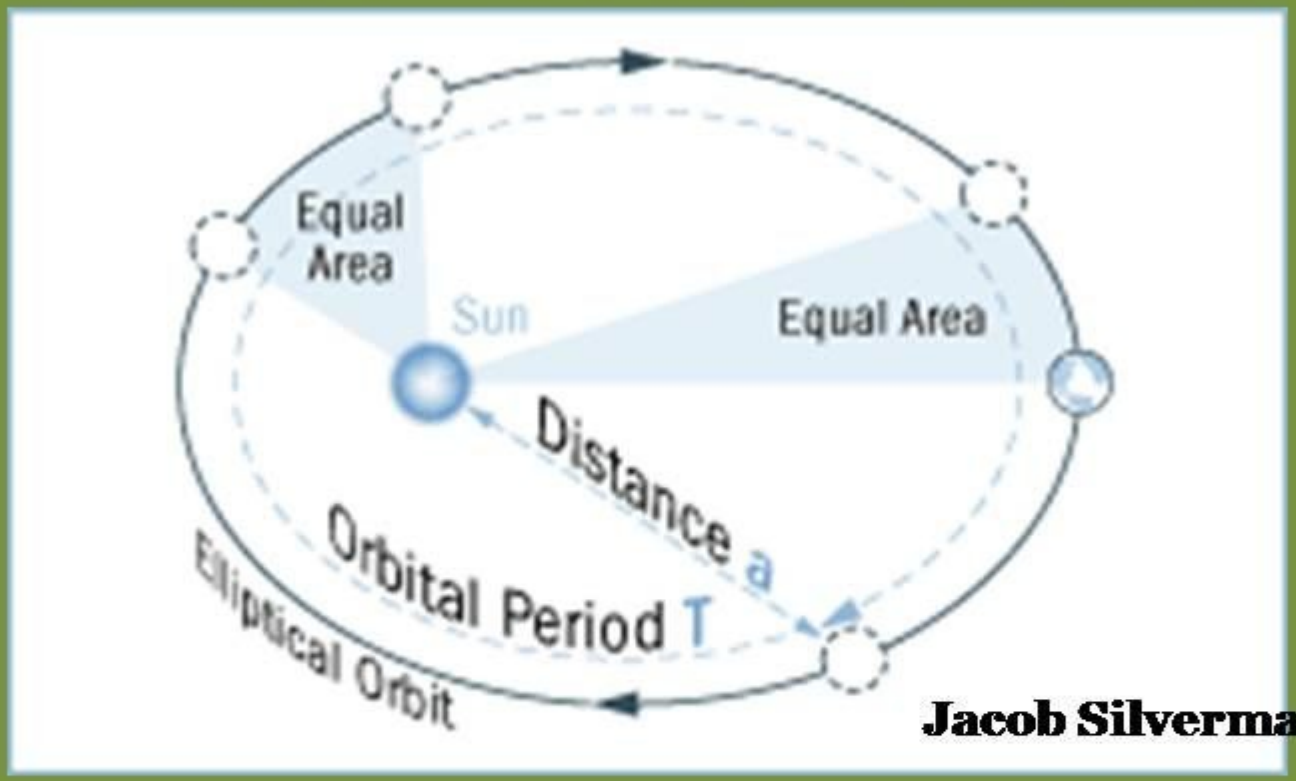
13000
13500
14000
14500

8. Kepler's Laws of Planetary Motion



Jacob Silverman

1. **law of orbits**, states that planets orbit the sun elliptically.
2. **law of areas**, states that a line connecting a planet to the sun covers an equal area over equal periods of time.
3. **law of periods**, allows us to establish a clear relationship between a planet's orbital period and its distance from the sun.

Mechanical Orrery:

were built to scale, then if the diameter of the smallest planet, Mercury, was 1mm, the Sun would be 30cm in diameter, and the distance from the Sun to Saturn would be 29 m! The orbits of the outer five planets occupy a radius of about 19 times that occupied by the four inner planets !!!

Planetary Orbits

All planets in almost circular (elliptical) orbits around the sun, in approx. the same plane (ecliptic).

Orbits generally inclined by no more than 3.4°

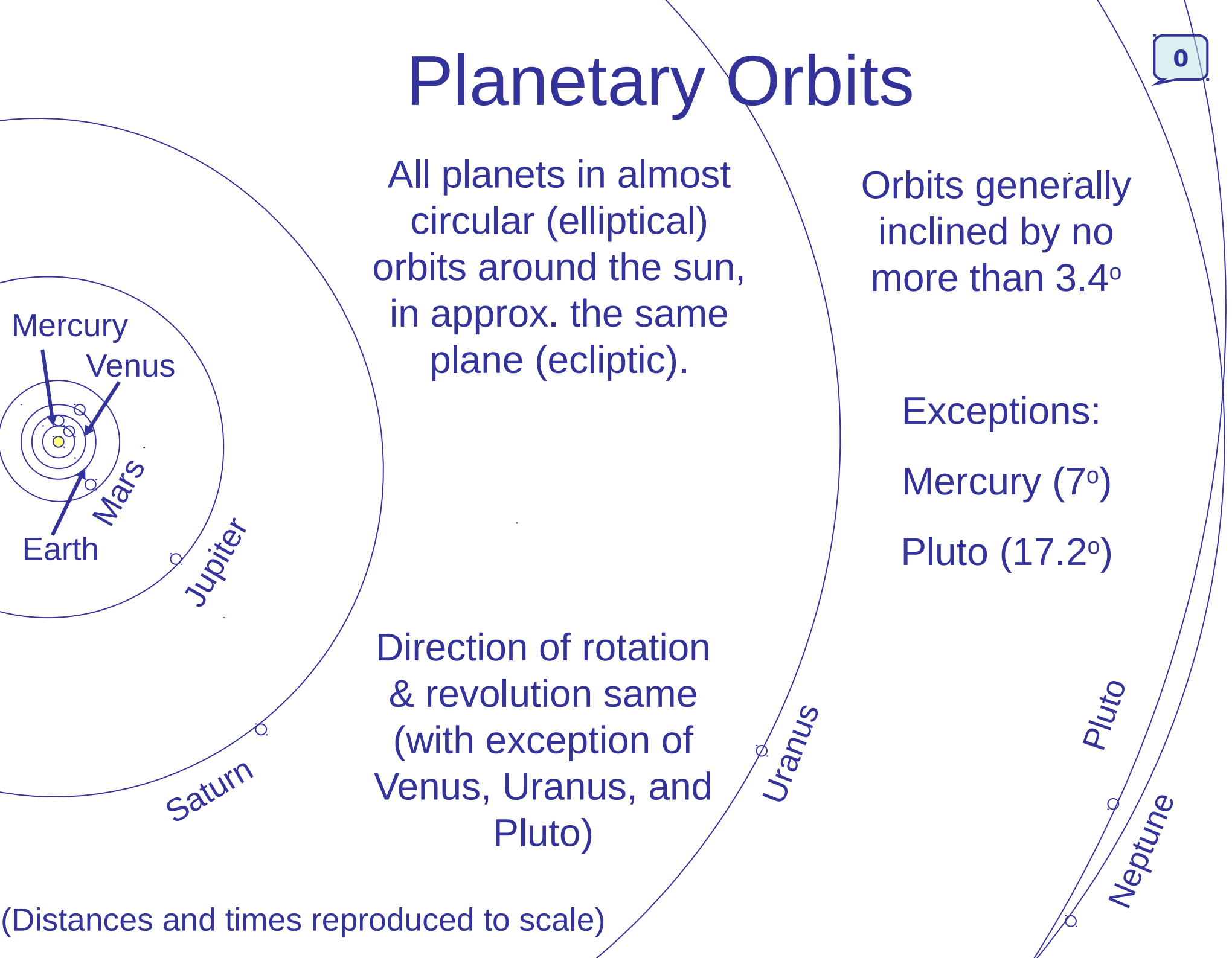
Exceptions:

Mercury (7°)

Pluto (17.2°)

Direction of rotation & revolution same (with exception of Venus, Uranus, and Pluto)

(Distances and times reproduced to scale)

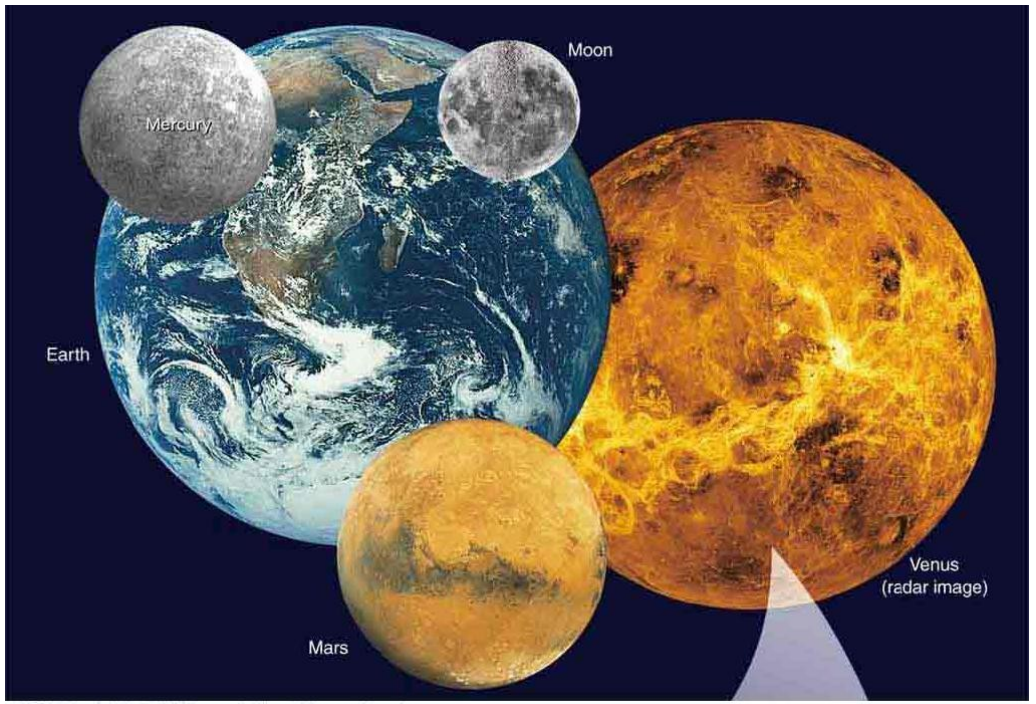


Scale of Solar System

https://www.youtube.com/watch?v=zR3Igc3Rhfg

Two Kinds of Planets

Planets of our solar system can be divided into two very different kinds:



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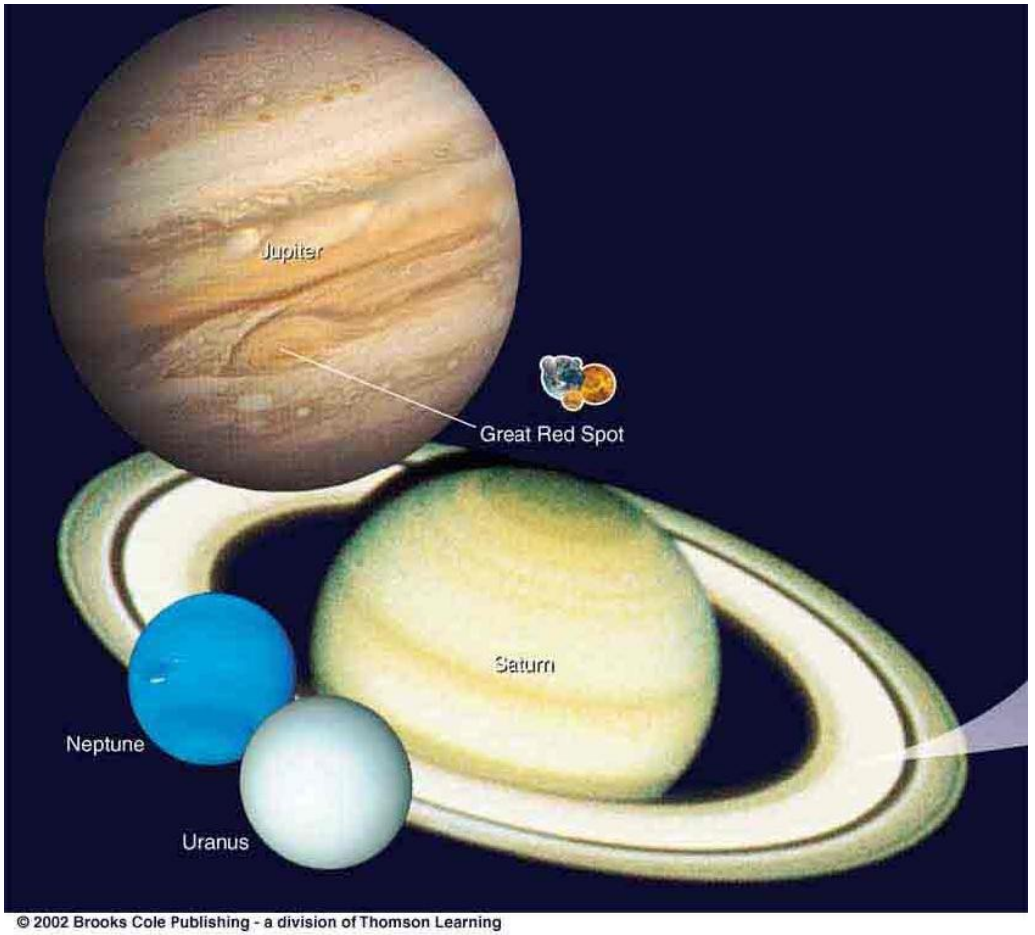
Terrestrial (earthlike) planets: Mercury, Venus, Earth, Mars



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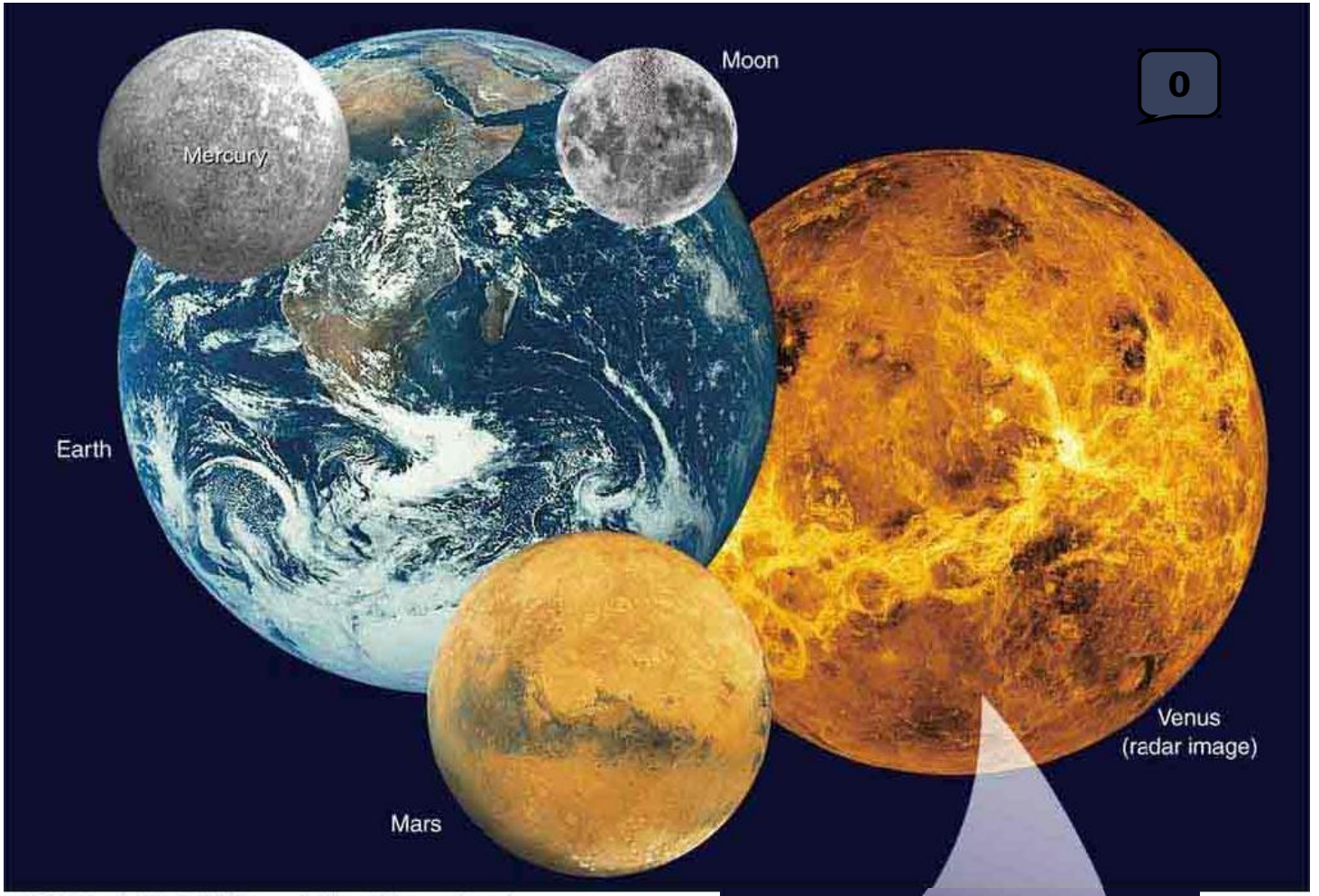
Jovian (Jupiter-like) planets: Jupiter, Saturn, Uranus, Neptune

Terrestrial Planets

Four inner planets of the solar system

Relatively small in size and mass (Earth is the largest and most massive)

Rocky surface



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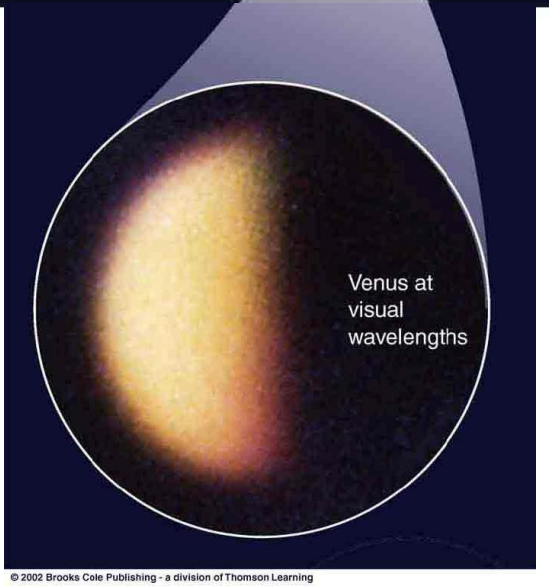
Surface of Venus can not be seen directly from Earth because of its dense cloud cover.



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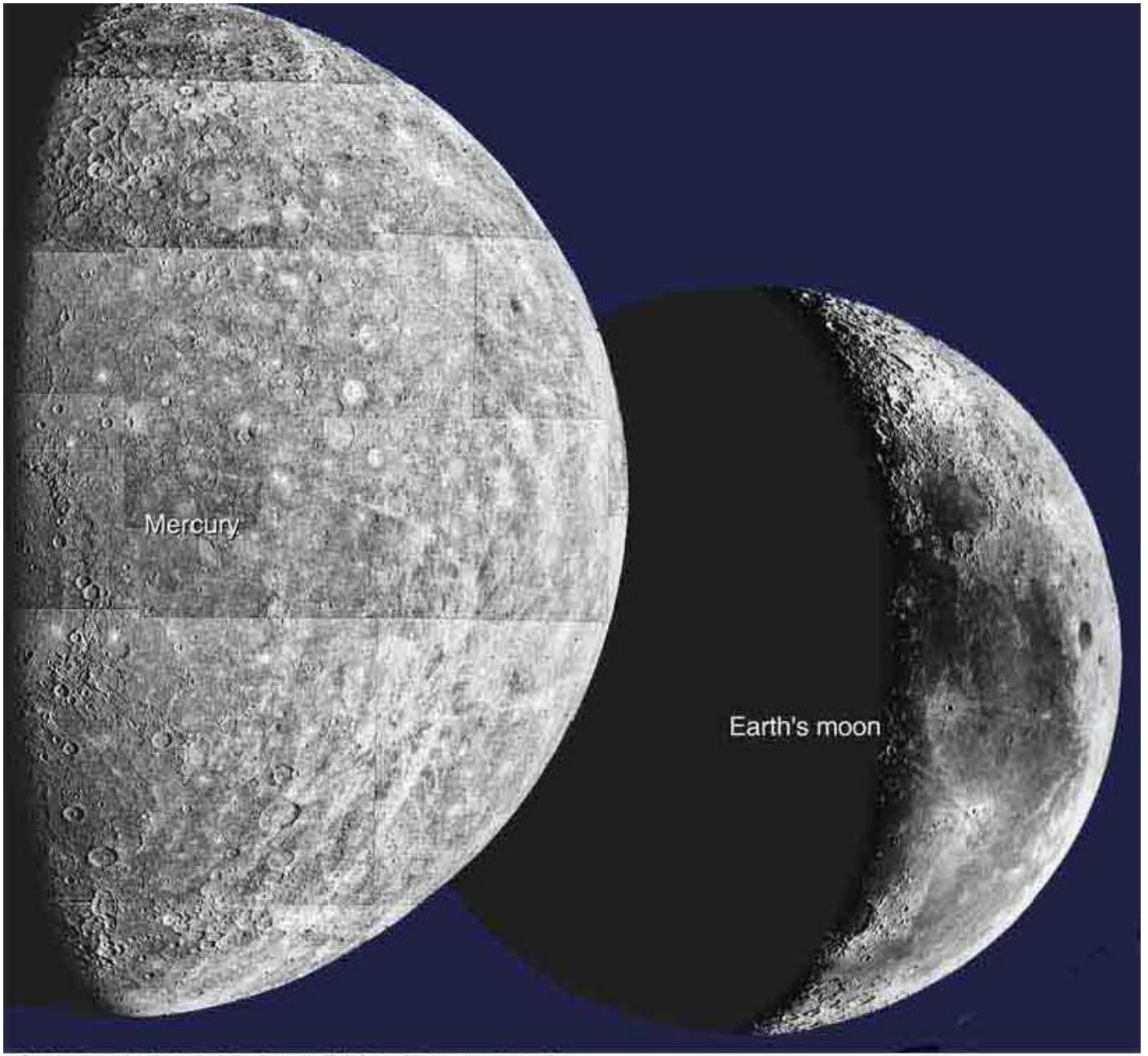
Craters on Planets' Surfaces



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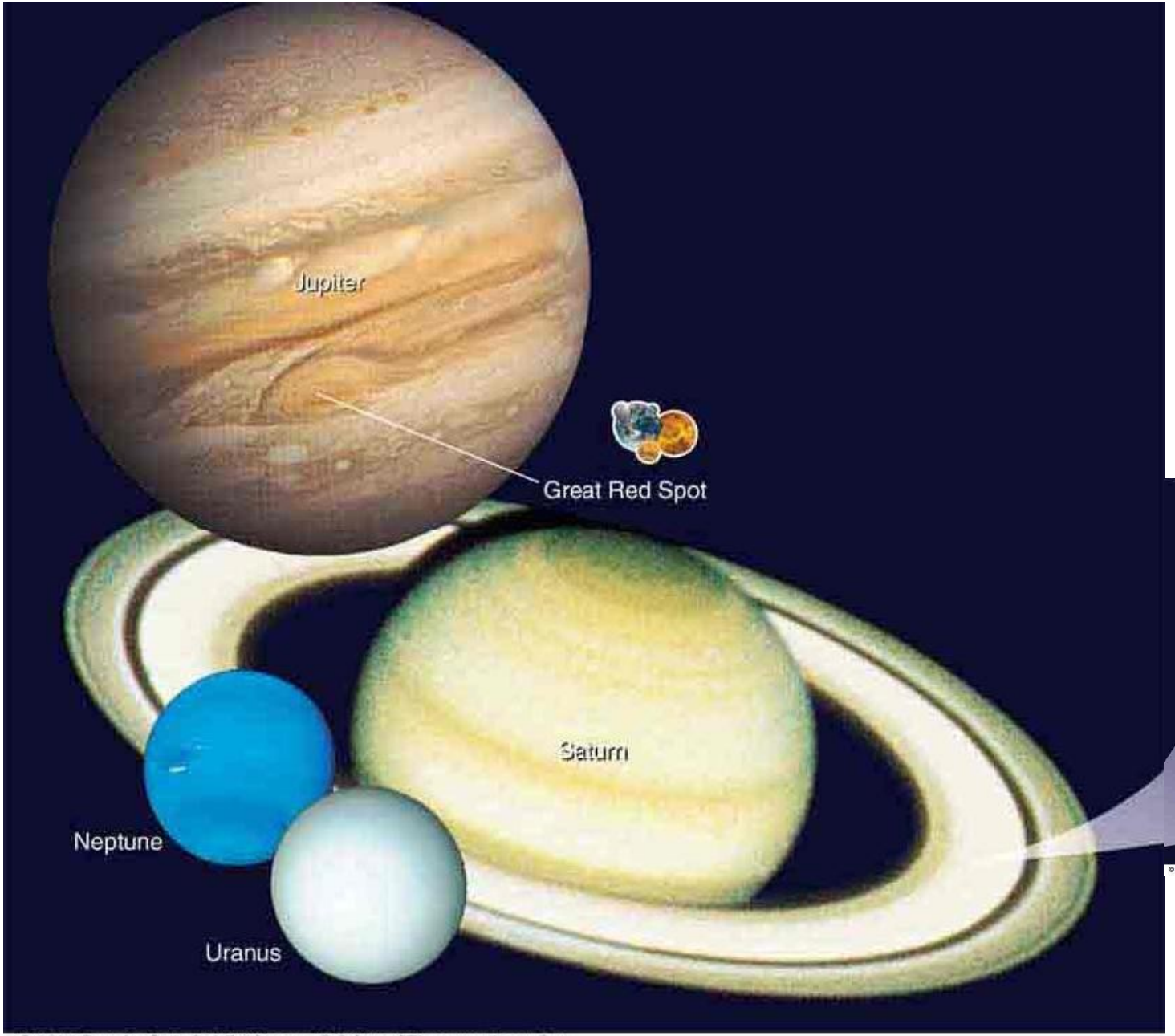
Craters (like on our moon's surface) are common throughout the solar system.

Not seen on Jovian planets because they don't have a solid surface.

The Jovian Planets



Much larger in mass and size than terrestrial planets

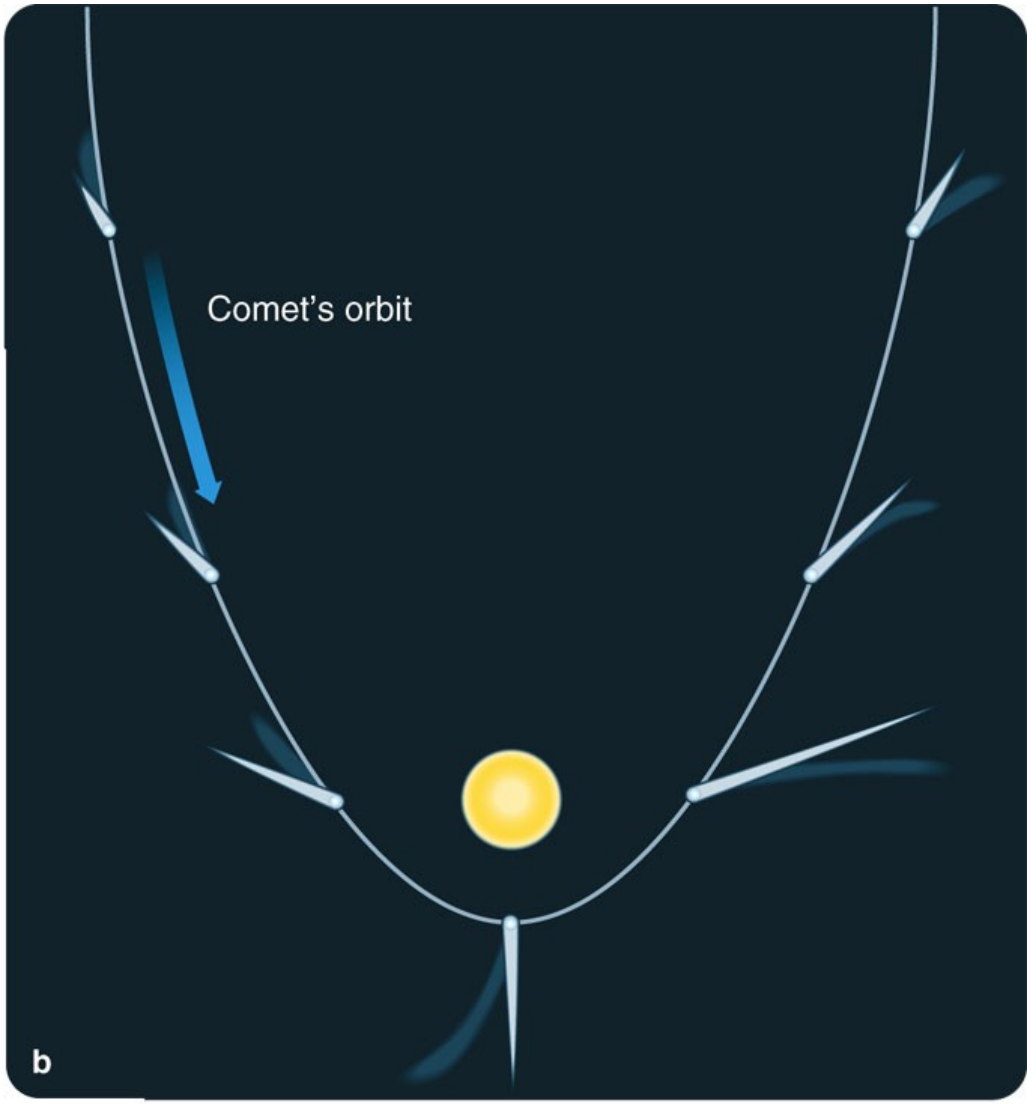
Much lower average density

All have rings (not only Saturn!)

Mostly gas; no solid surface

Comets

Icy nucleus, which evaporates and gets blown into space by solar wind pressure.



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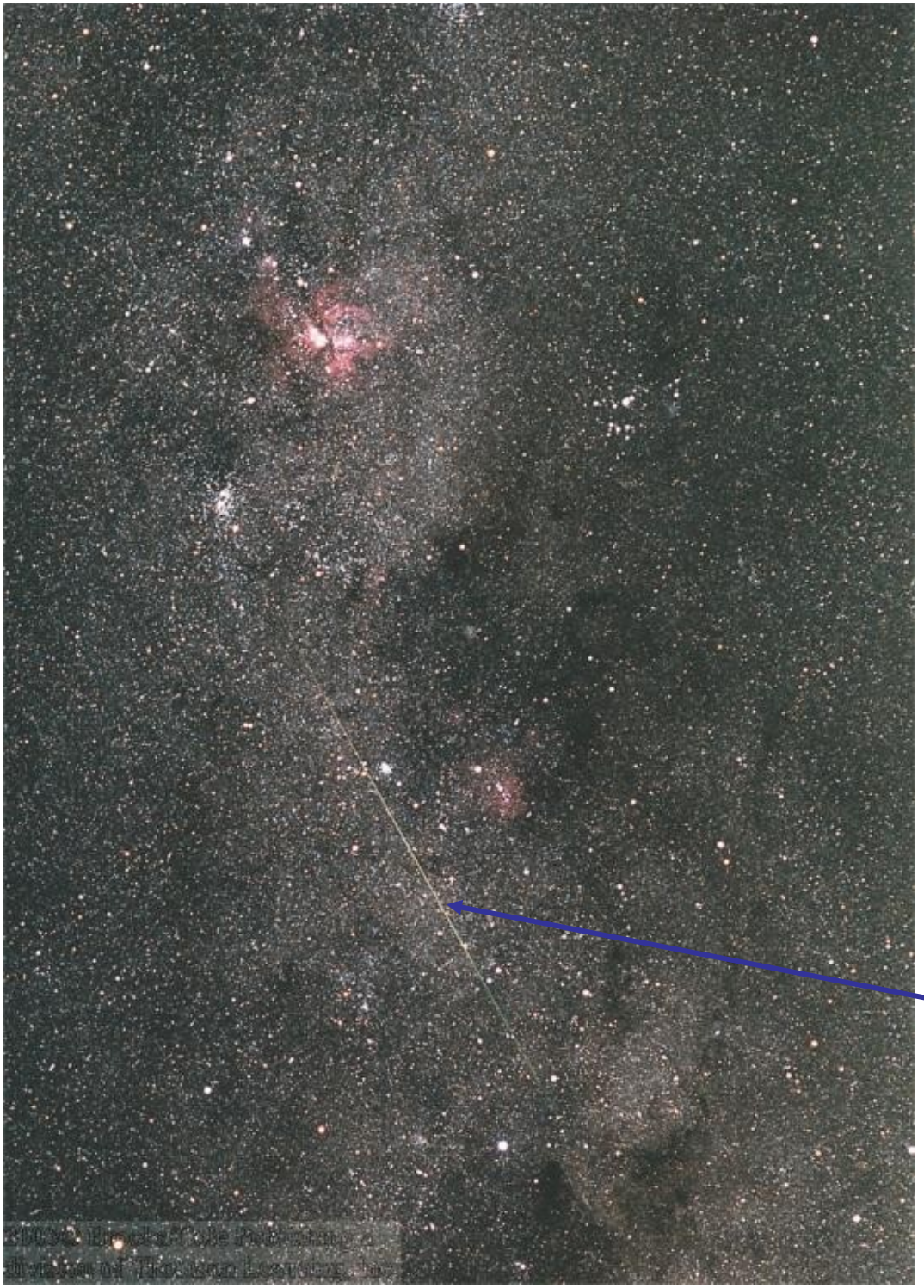
Mostly objects in highly elliptical orbits, occasionally coming close to the sun.



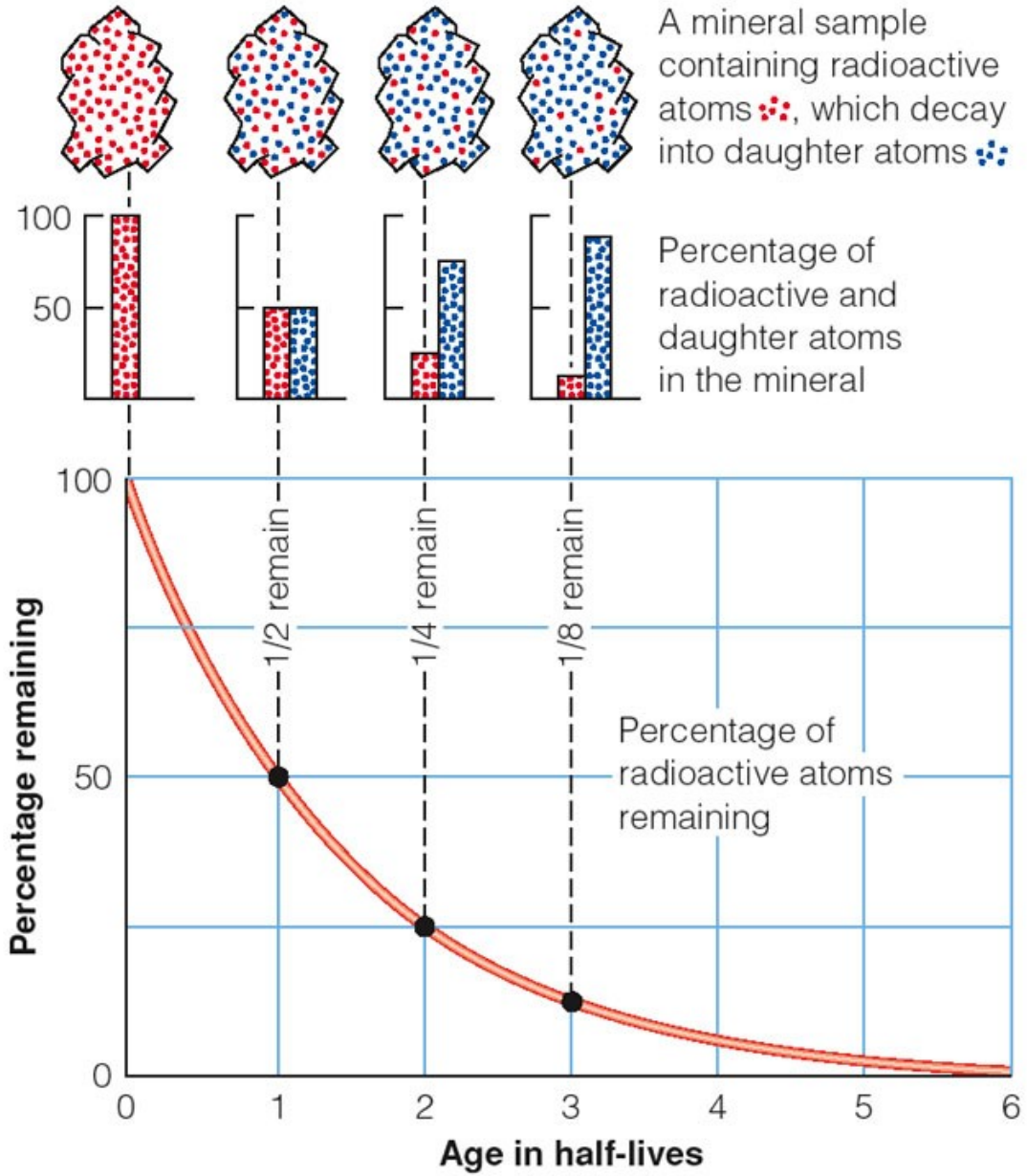
Meteoroids

Small (μm – mm sized) dust grains throughout the solar system

If they collide with Earth, they evaporate in the atmosphere.

→ Visible as streaks of light: meteors.

The Age of the Solar System



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Sun and planets should have about the same age.

Ages of rocks can be measured through radioactive dating:

Measure abundance of a radioactively decaying element to find the time since formation of the rock.

Dating of rocks on Earth, on the moon, and meteorites all give ages of ~ 4.6 billion years.

Properties of the Solar System

- Disk shape of the solar systemnearly five billion years old
- Regular panetary orbits: coplanar orbits, same direction of rotation and revolution
- Two planetary types;Inner planets are metal rich, small, outer planets gas-rich, large
- Planetary rings, large satellite systems
- Debris: Comets, asteroids....
- Common age of 4.6 billion yr

Exception to the Rules

- Mercury and Pluto have larger orbital eccentricities
- Uranus and Pluto have tilted rotational axes
- Venus rotates backwards (clockwise)
- Earth has a large moon
- Pluto has a moon almost as big as itself

Allow for these exceptions