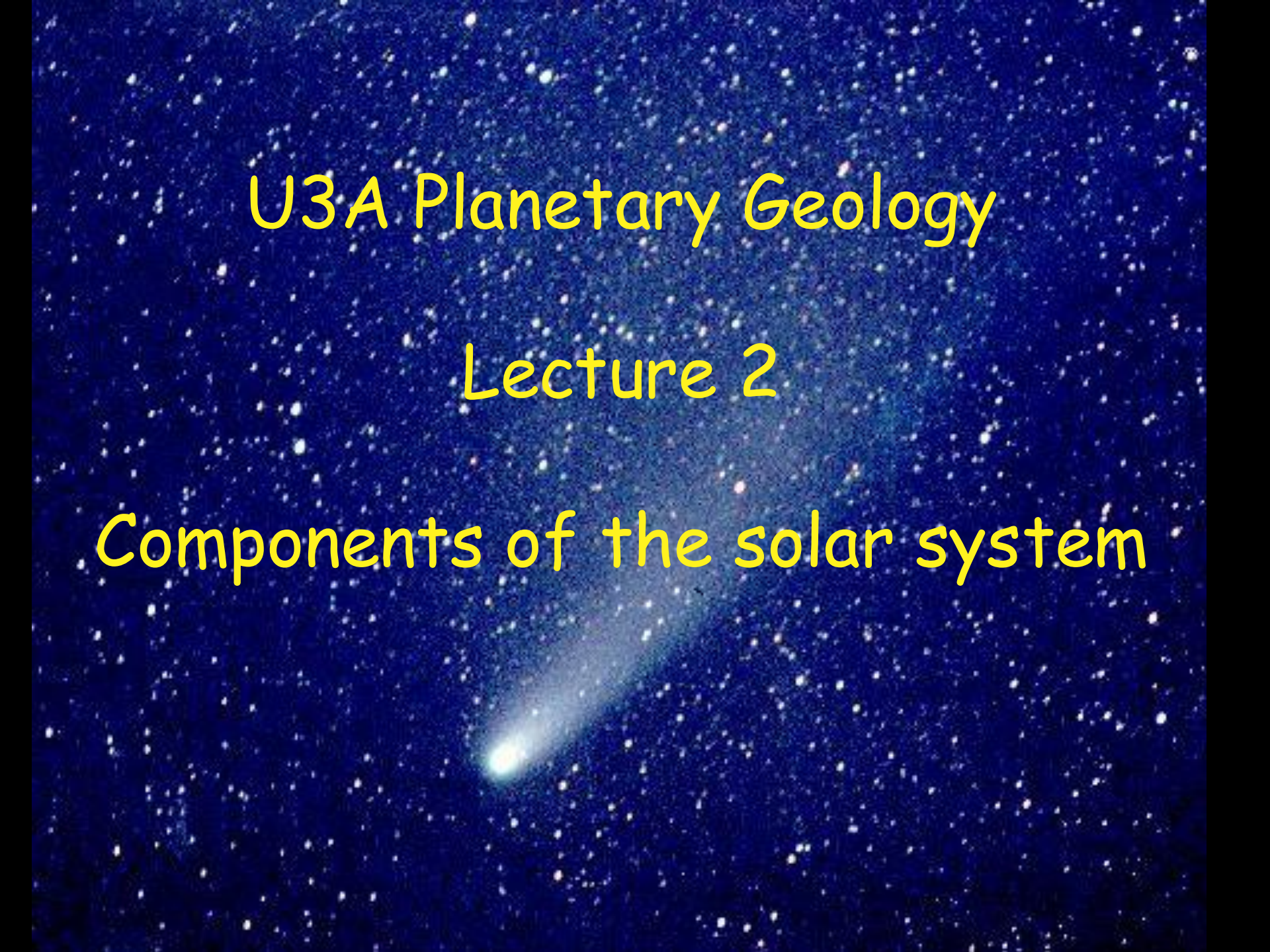
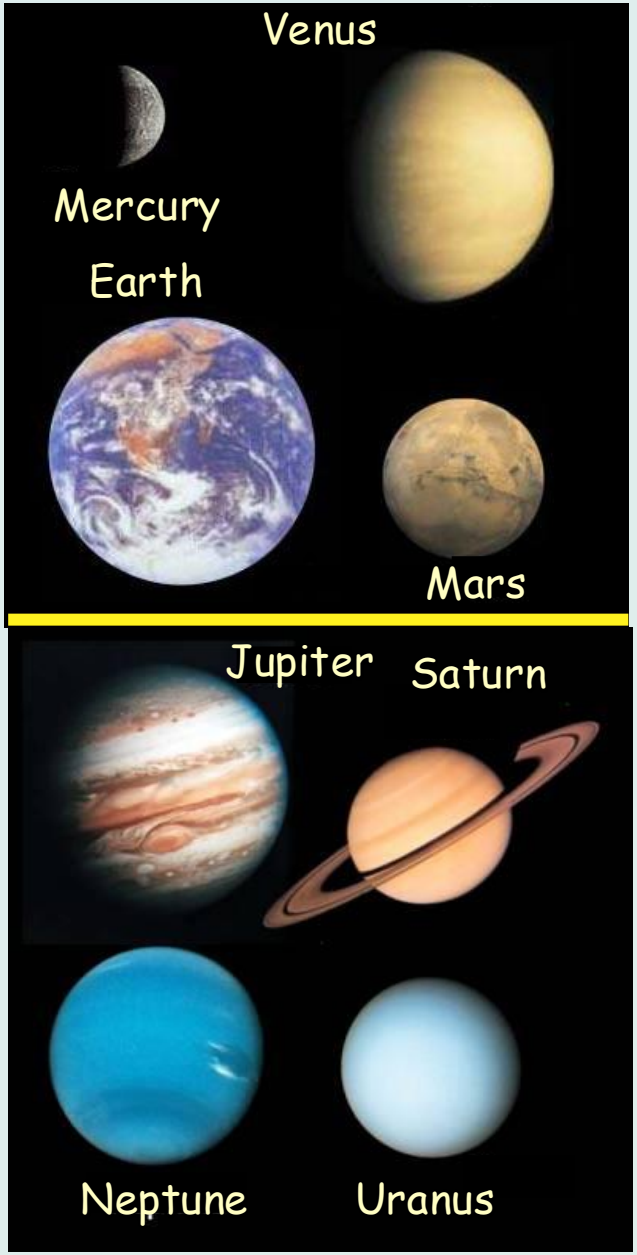

U3A Planetary Geology
Lecture 2
Components of the solar system

The planets

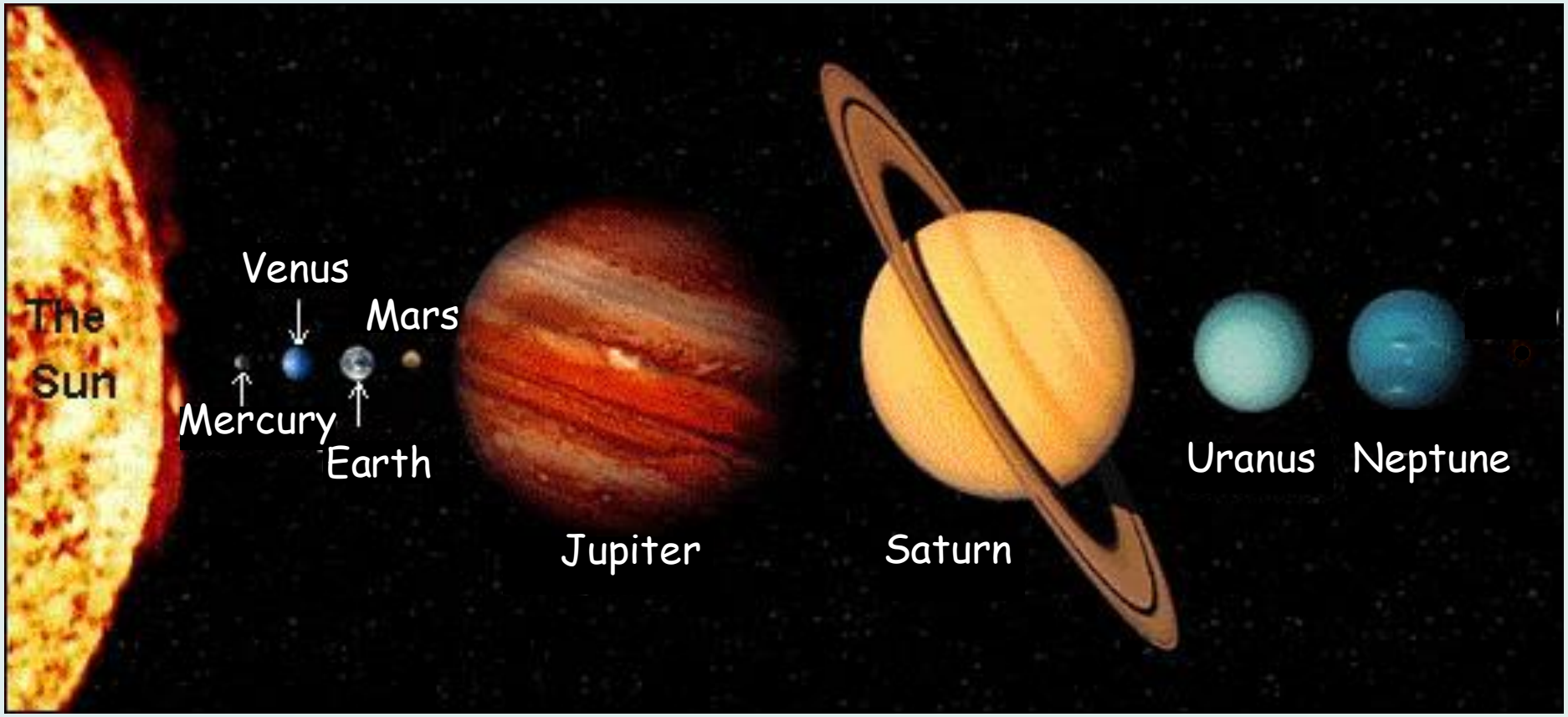
- Two major groups*

1. The inner or Terrestrial planets
2. the outer planets or Gas Giants

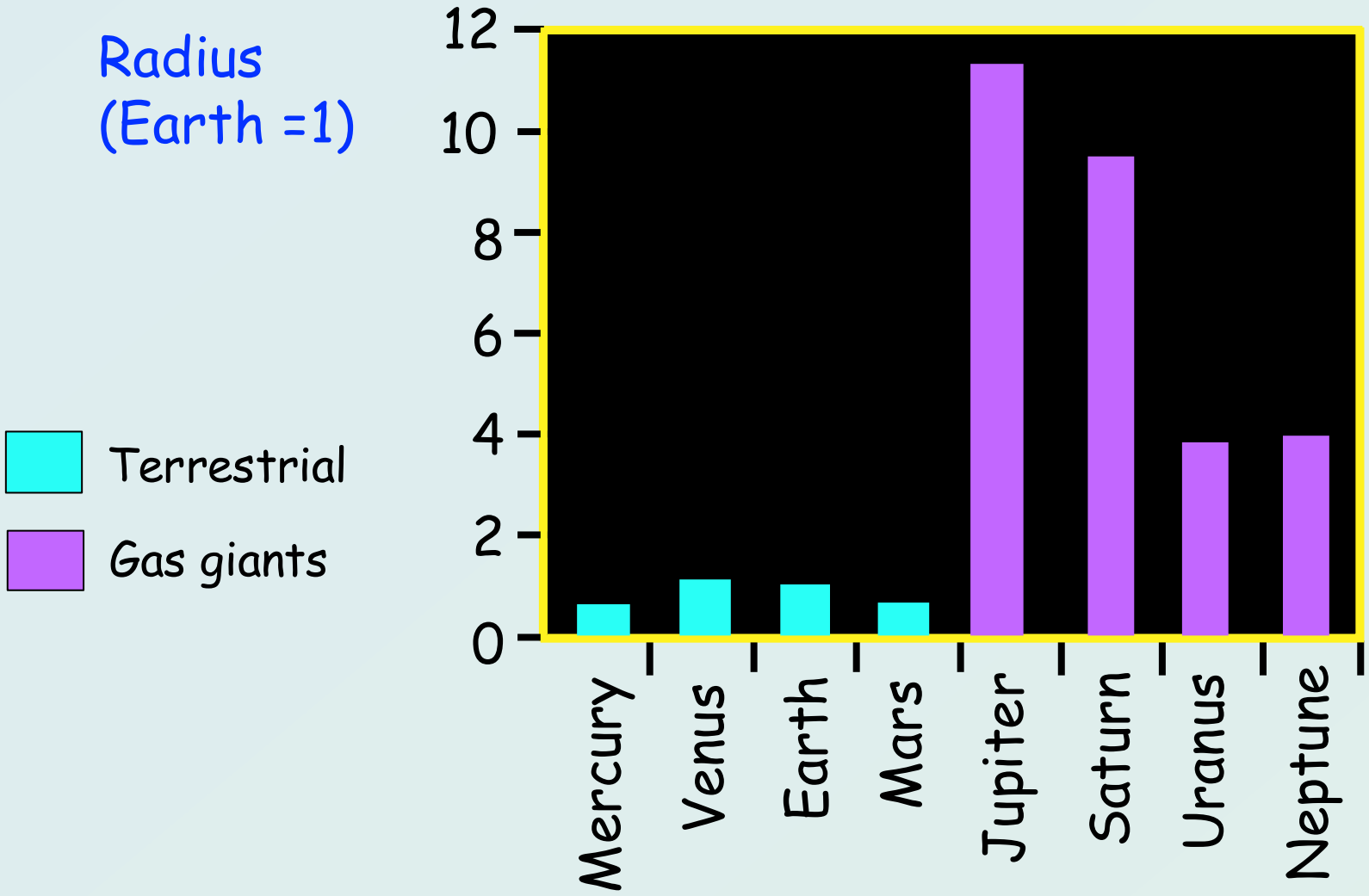
- in addition to the major planets, there are a number of smaller orbiting bodies referred to as dwarf planets



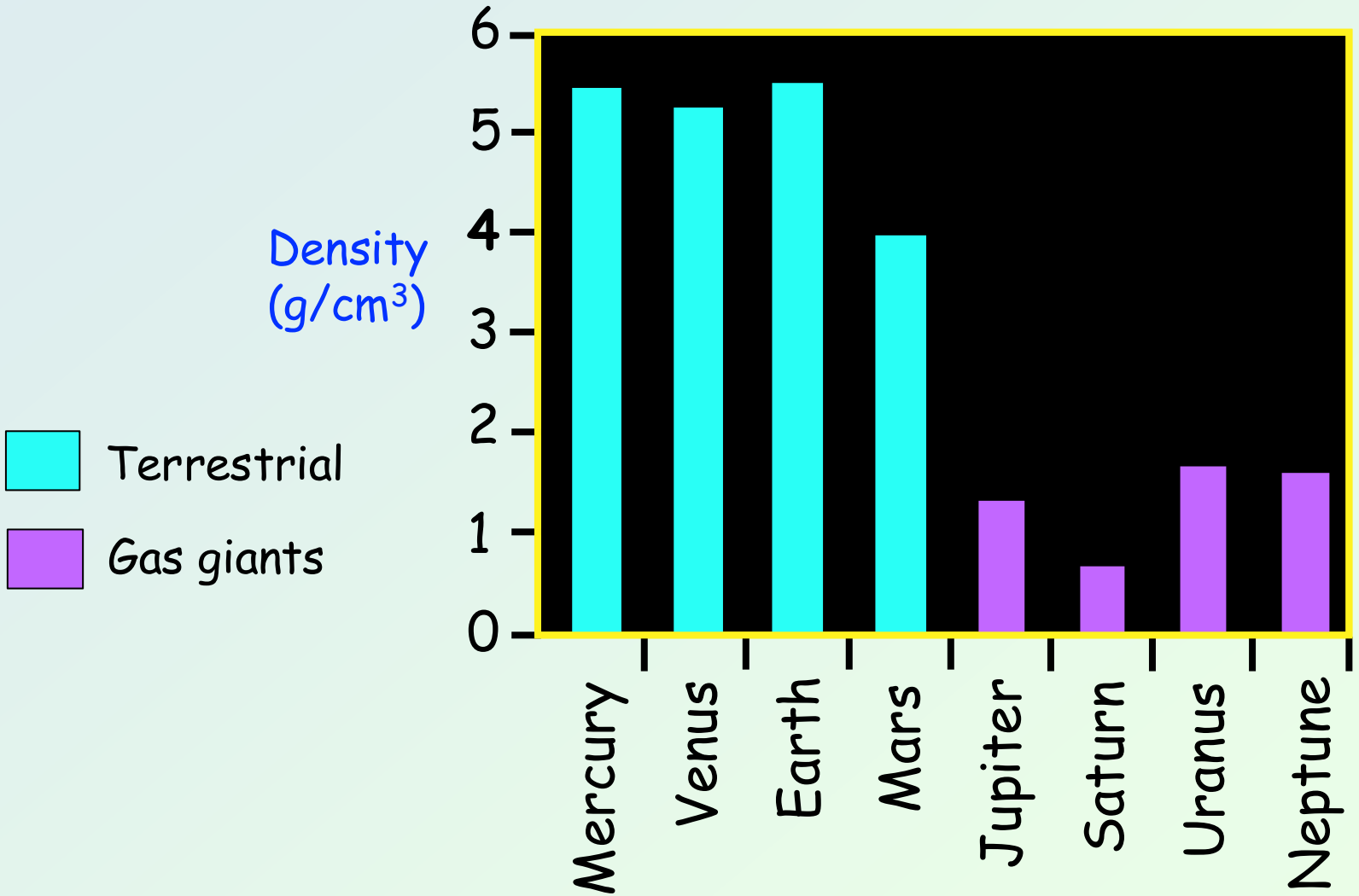
Relative sizes of the planets and Sun



Relative sizes of the planets



Relative densities of the planets



Planetary characteristics

Terrestrial planets

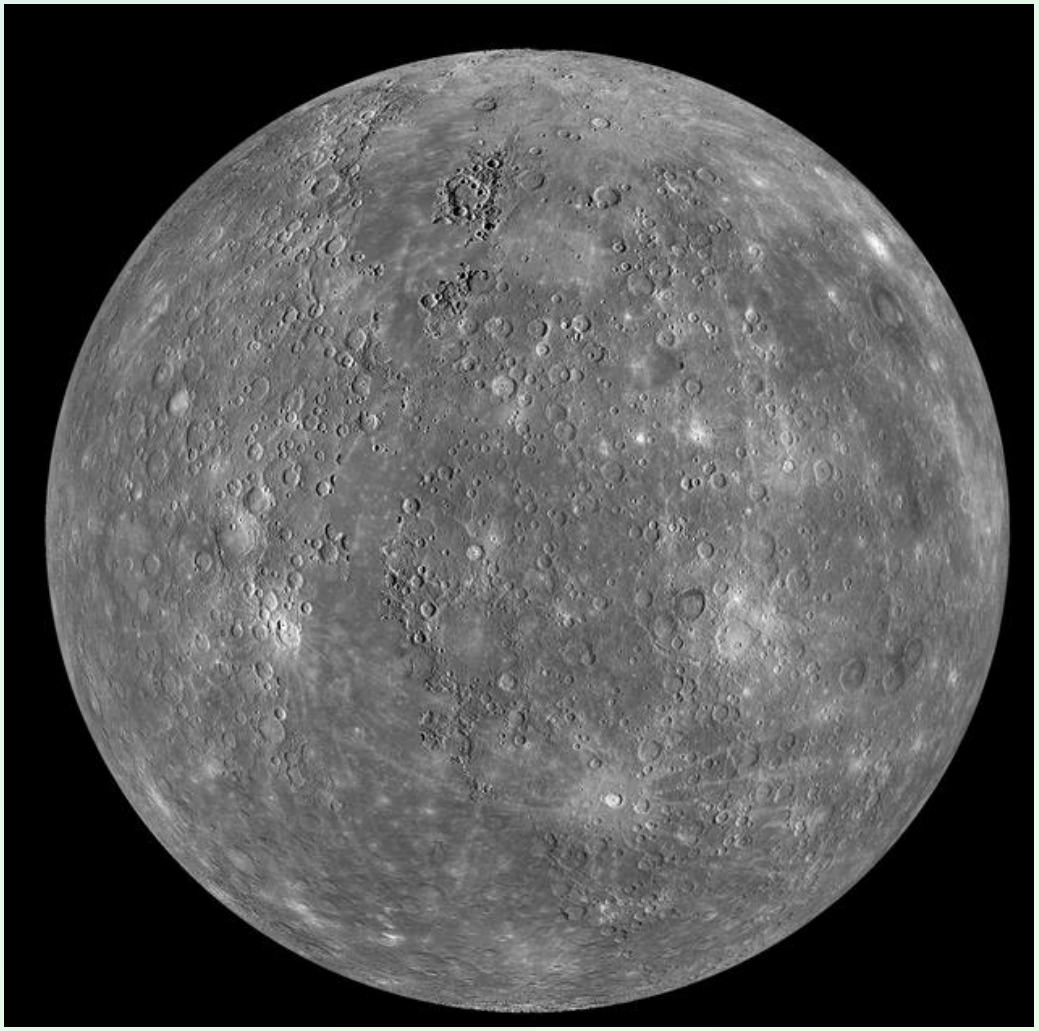
- low mass
- high density
- rocky materials
- high abundance of heavy elements
- thin atmospheres
- few moons*
- no rings

Gas Giant planets

- high mass
- low density
- mostly gases
- low abundance of heavy elements
- massive atmospheres
- many moons
- all have ring systems

Mercury

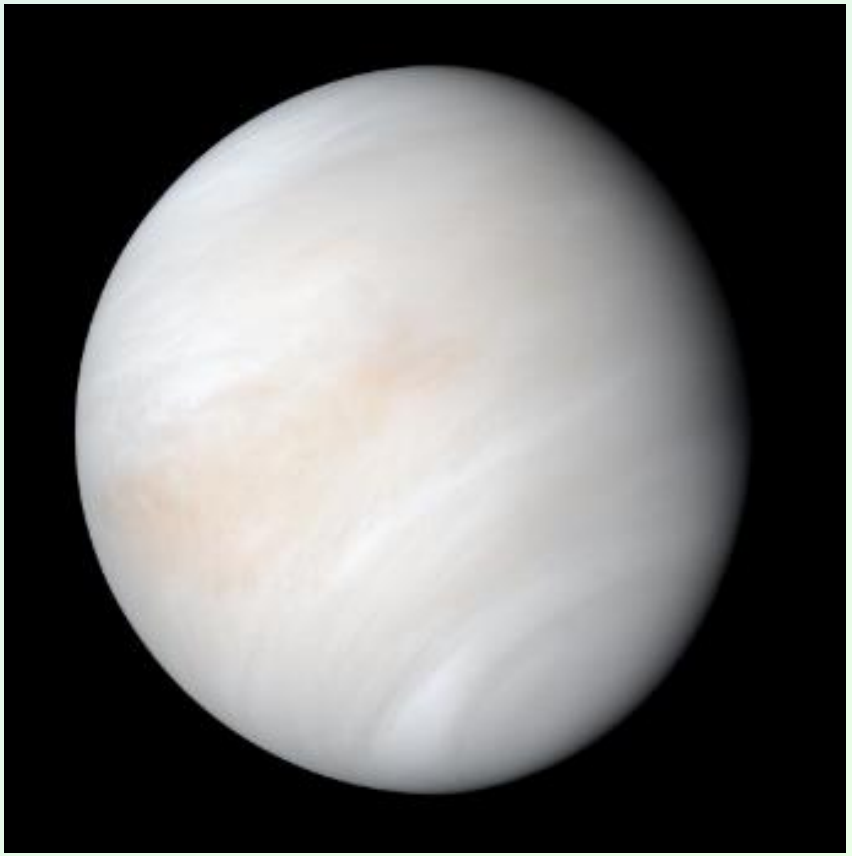
- Smallest of terrestrial planets
- has heavily cratered surface
- insignificant atmosphere
- dense rocky body
- similar appearance to our moon



Composite image of Mercury taken by the Messenger spacecraft

Venus

- Planet shrouded by clouds of sulphuric acid
- dense atmosphere
- surface is almost entirely volcanic
- hottest planet in solar system (surface temperature ~470°C)
- similar in size to Earth



Earth

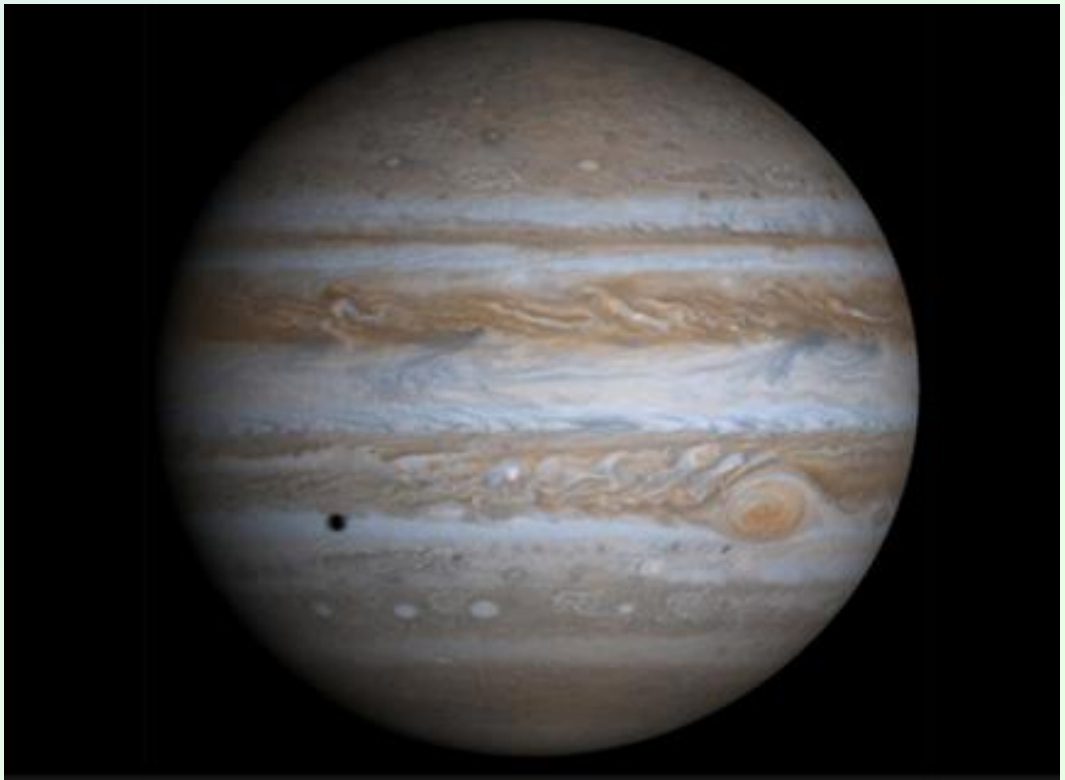
- Significant atmosphere and atmospheric circulation
- well-defined ice caps
- only planet to contain liquid water
- a two-fold classification of continents and oceans
- complex geological processes → interaction between atmosphere, hydrosphere and lithosphere

Mars

- Composed of dense rocky material
- thin atmosphere extending to 30km above surface
- atmosphere primarily CO_2
- polar ice caps are present

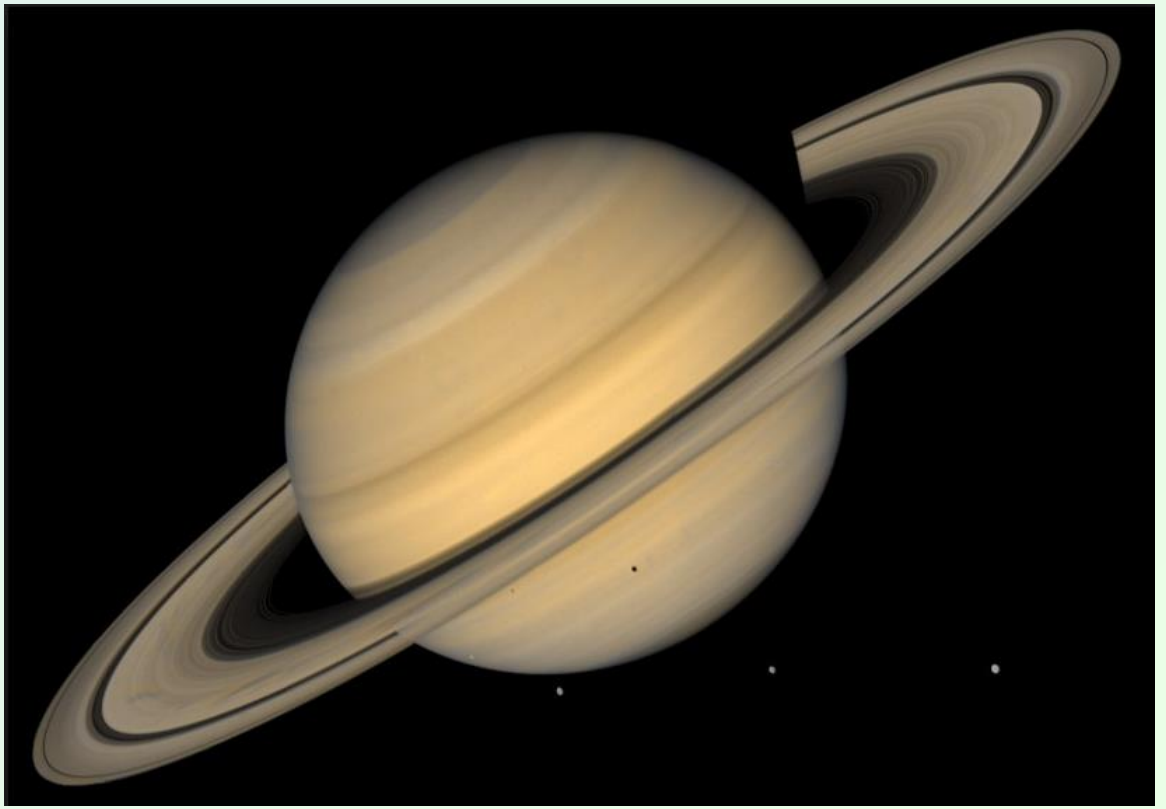
Jupiter

- Largest planet in the solar system
- mainly composed of H with lesser He (similar composition to Sun)
- essentially all atmosphere
- outer atmosphere contains turbulent storms
- if it was larger → it could actually become a star (if it reached critical mass)
- has at least 67 moons



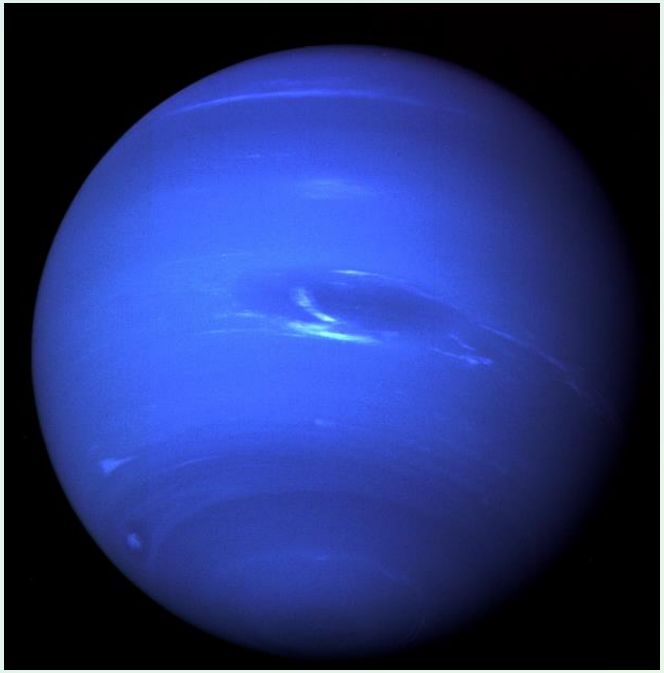
Saturn

- Second largest planet in the solar system*
- has prominent ring system composed of vast numbers of ice particles
- rotates quickly about its axis (10 hour rotation) → streaky surface
- core probably composed of Ni-Fe and rock, surrounded by liquid helium and hydrogen with an outer gaseous layer
- 62 moons recognised, 4 are visible in photo



Saturn – image from Cassini spacecraft

Uranus and Neptune



Images taken by Voyager 2 spacecraft

Uranus

- Composed of H_2O, NH_3 and CH_4 with a rocky core
- axis strongly tilted (82°)
- atmosphere composed of H_2, He & CH_4
- 27 moons
- 13 faint rings

Neptune

- Composed of H_2O, NH_3 and CH_4 with a dense solid core
- strongest winds in solar system
- atmosphere composed of H_2, He & CH_4
- 14 moons
- 6 faint rings

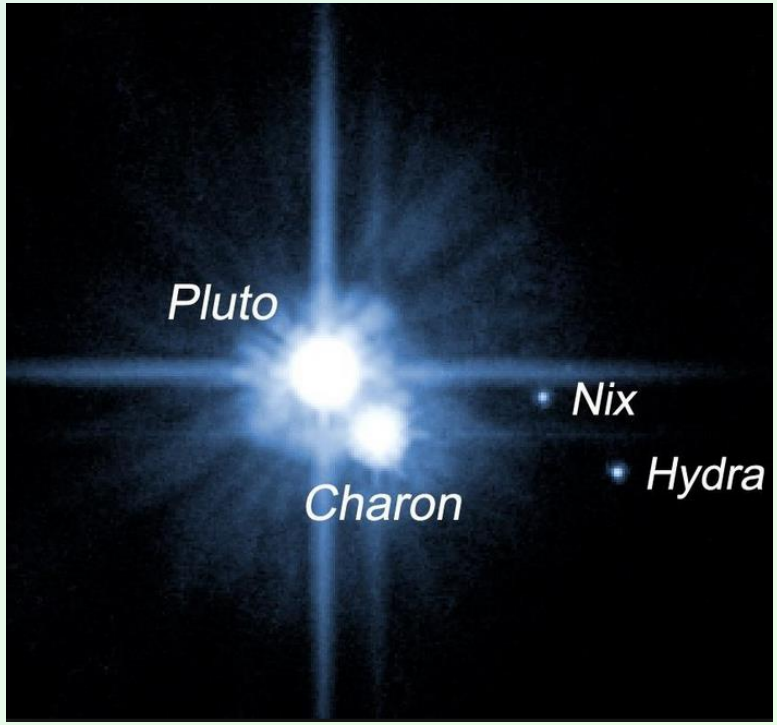
Dwarf planets

- Planetary bodies that are neither a planet nor a moon
- are in direct orbit around the Sun, most in the Kuiper belt*
- have sufficient mass for gravity to overcome rigid body forces

  → assume almost spherical shape
- have not cleared the neighbourhood around their orbit

Pluto

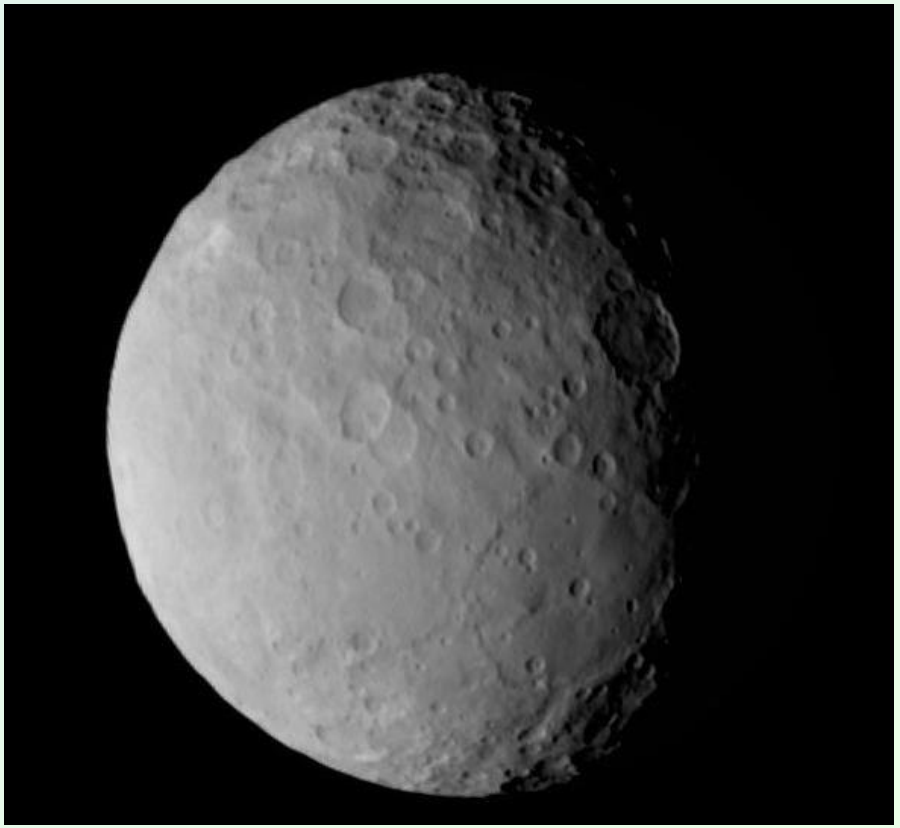
- Pluto has low mass and low density, diameter → 2,300km
- thin atmosphere composed of N, CH_4 and CO
- methane ice covers most of the surface, rocky core
- similar to the larger moons of the gas giants
- highly eccentric and inclined orbit (>30° to ecliptic plane)
- five moons Charon (largest),
  Nix, Hydra, Styx and Kerberos



Hubble Space Telescope view
of Pluto and three of its moons

Ceres

- Largest body in asteroid belt (diameter = ~950km)
- composed of rocky core and water-ice mantle
- surface has large number of craters with low relief
- spacecraft Dawn entered orbit around Ceres 6/3/2015
- surface rich in carbonates and ammoniated phyllosilicates

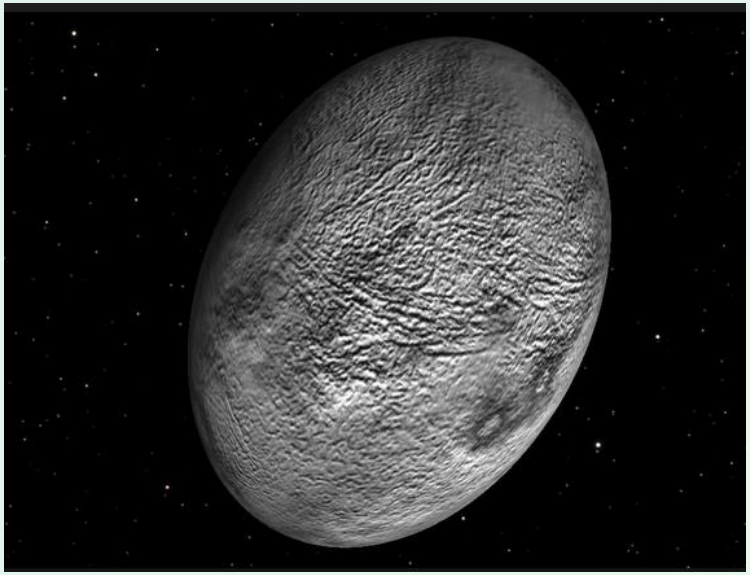


Ceres from spacecraft Dawn February 2015

Dwarf planets

Eris

- Largest dwarf planet (diameter =2,326km)
- highly eccentric highly inclined orbit
- surface composed of methane ice
- surface temperature -217 to -243°C
- one moon (Dysnomia)



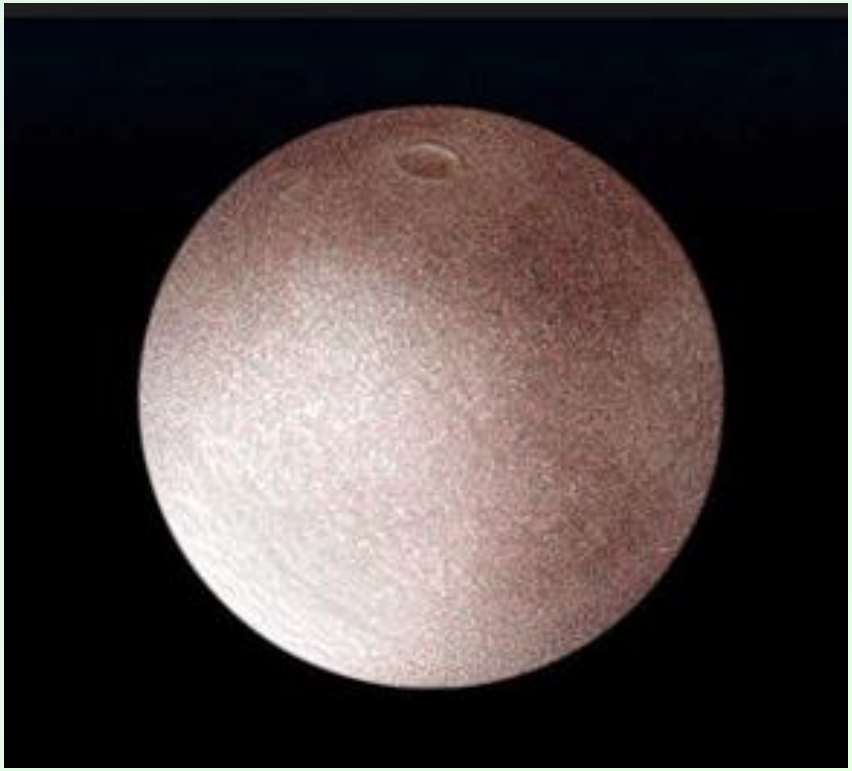
Haumea

- Beyond Neptune's orbit (Kuiper belt)
- ellipsoid shape (diameter ~1400km)
- thick mantle of water ice on rocky core
- surface composed of water ice
- two small moons

Dwarf planets

Makemake

- Located in Kuiper belt
- diameter ~1430km
- surface appears to be composed of methane and ethane (C_2H_6)
- insignificant atmosphere
- no satellites



Makemake

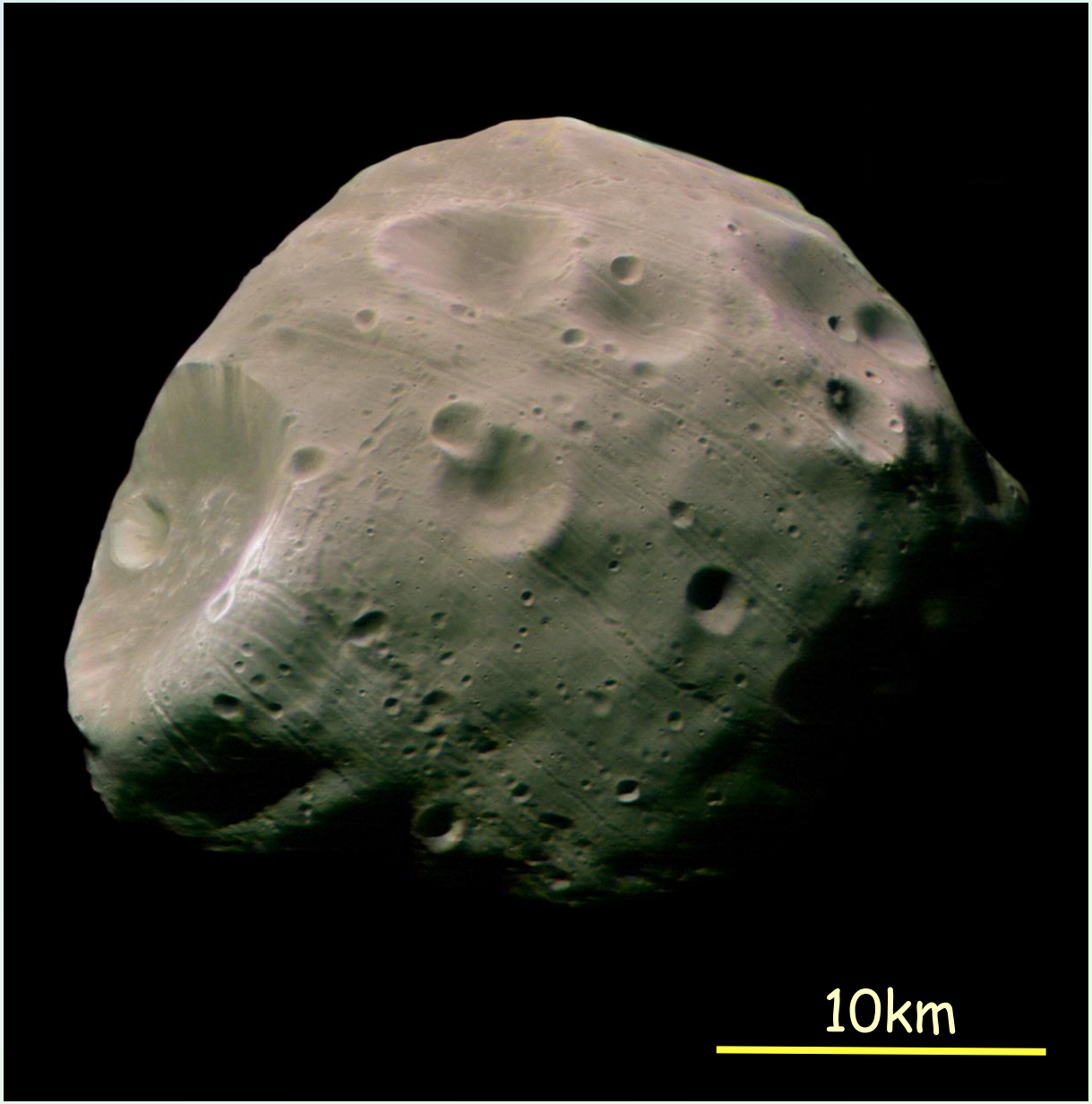
Lesser bodies of the solar system

- Moons
  - satellite bodies that orbit planets, dwarf planets and asteroids
  - highly diverse character e.g Io
- Asteroids
  - millions discovered, mostly occupy orbits between Mars and Jupiter
  - 26 larger than 200km across
  - mostly made of rocky materials
- Comets
  - billions in outer solar system
  - composed mostly of ices and dust
- Meteorites
  - small fragments of asteroid-type materials

Moons

- ~150 moons in solar system → more being discovered
- vast majority orbiting gas giant planets
- Mars – 2
  Earth - 1
  Pluto – 5
  Eris - 1
  Haumea – 2
- moons of gas giants highly diverse in character
- some minor moons of outer gas giants → captured asteroids

Phobos, one of Mars' two moons



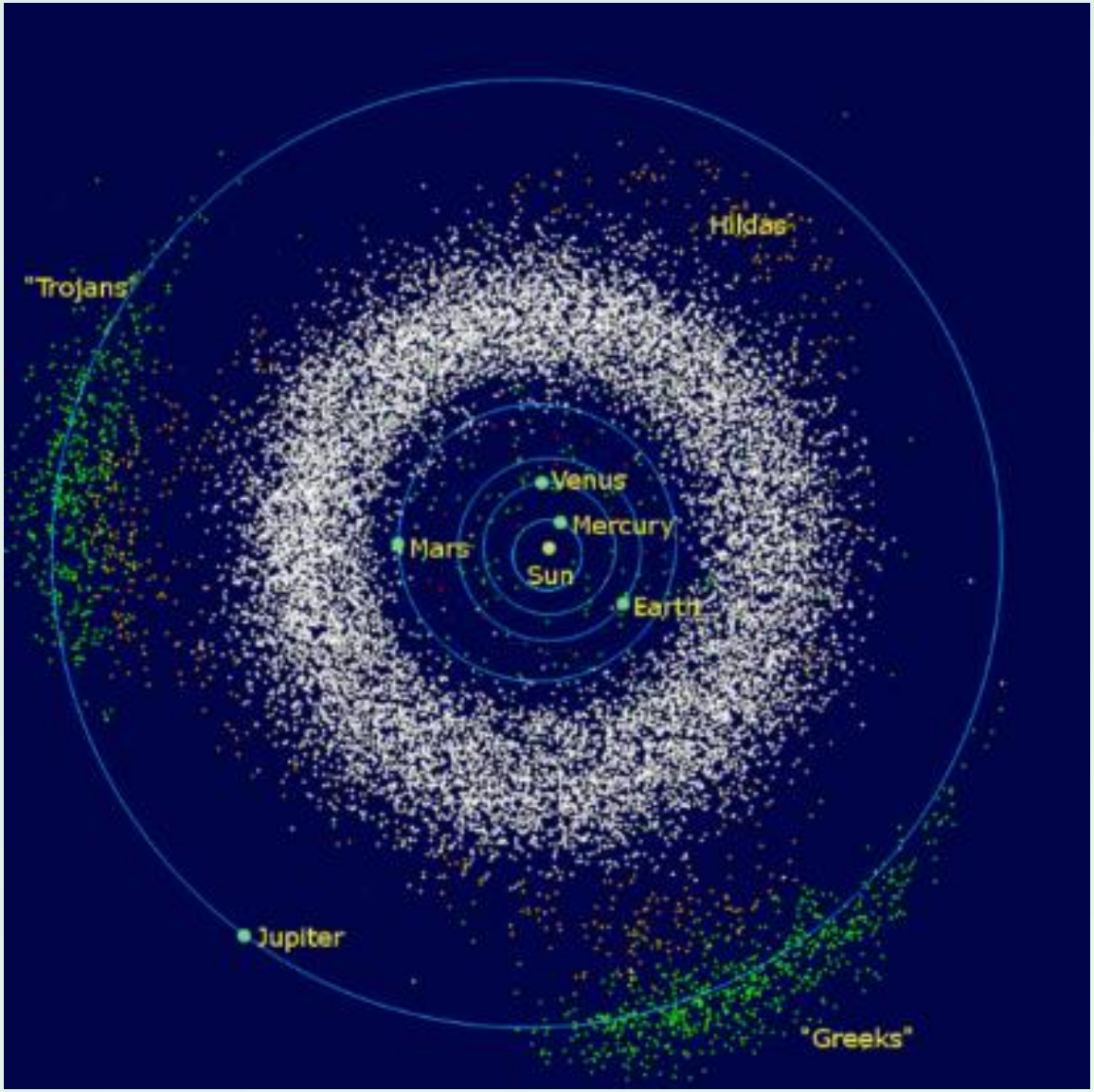
Galilean moons of Jupiter

Relative diameter size of the moons and planets

Asteroids

- Millions occur in doughnut-shaped asteroid belt located between the orbits of Mars and Jupiter
- Trojan asteroids share Jupiter's orbit in two groups
- Ceres → Dwarf planet-asteroid (~950km across)
- ~ 200,000 › 10km across → largest asteroid is Vesta (525km)*
- collisions caused early asteroids to fragment → smaller asteroids
- asteroids tumble in different directions (but individually consistent)
- some disturbed from their orbit (collisions, gravitational)*
- ~150 occupy orbits that cross the orbit of Earth

Trojan asteroids



Asteroids

- Impact on Earth of an asteroid 10km in diameter would be catastrophic, the consequence of 200km diameter impacting is almost beyond comprehension
- impacts of small asteroids and comets on Earth in the past → profound influence on development of life
- major extinction event at end of Cretaceous → impact of Chixulub asteroid on northern Yucatan Peninsula, Mexico*
- asteroids provide evidence for the beginning of Solar System
- asteroids are believed to be a planet that never formed
- mostly composed of rocky material (same as terrestrial planets)

Asteroids Gaspra and Ida

- Photographed by the Galileo spacecraft
- Gaspra is very irregular 19 x 11 x 12km across
- Ida is also very irregular 56 x 24 x 21km across
- Ida has a tiny moon called Dactyl about 1.5km across
- both tumble on a single axis*
- similar composition to small moons of Mars and Jupiter

Asteroid families

- Kiyotsugu Hirayama a Japanese astronomer proposed the concept of asteroid families

- families → groups of asteroids that share similar orbital properties (semi-major axis, eccentricity, orbital inclination)

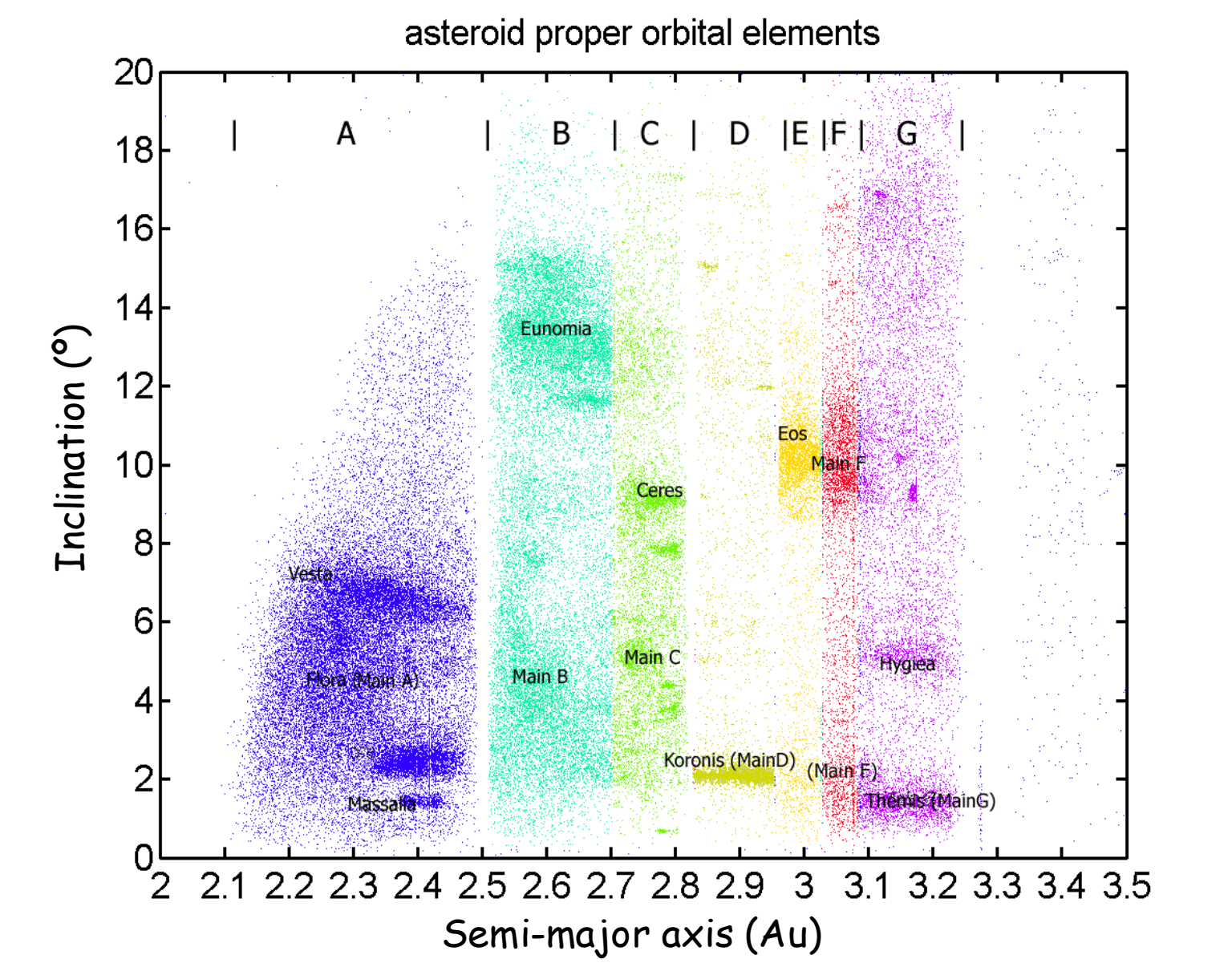
- members of each family thought to have formed by fragmentation of a common parent

- surface compositions of asteroids within a family are also similar e.g.
  Koronis family → bright silicate asteroids
  Themis family → dark carbonaceous asteroids

Formation of asteroid families

1. Asteroid impacts larger asteroid → shatters it
2. combined gravitational pull cannot bring fragments back together
3. family of asteroids formed that spreads around orbit of original asteroid

Asteroid families



Meteorites

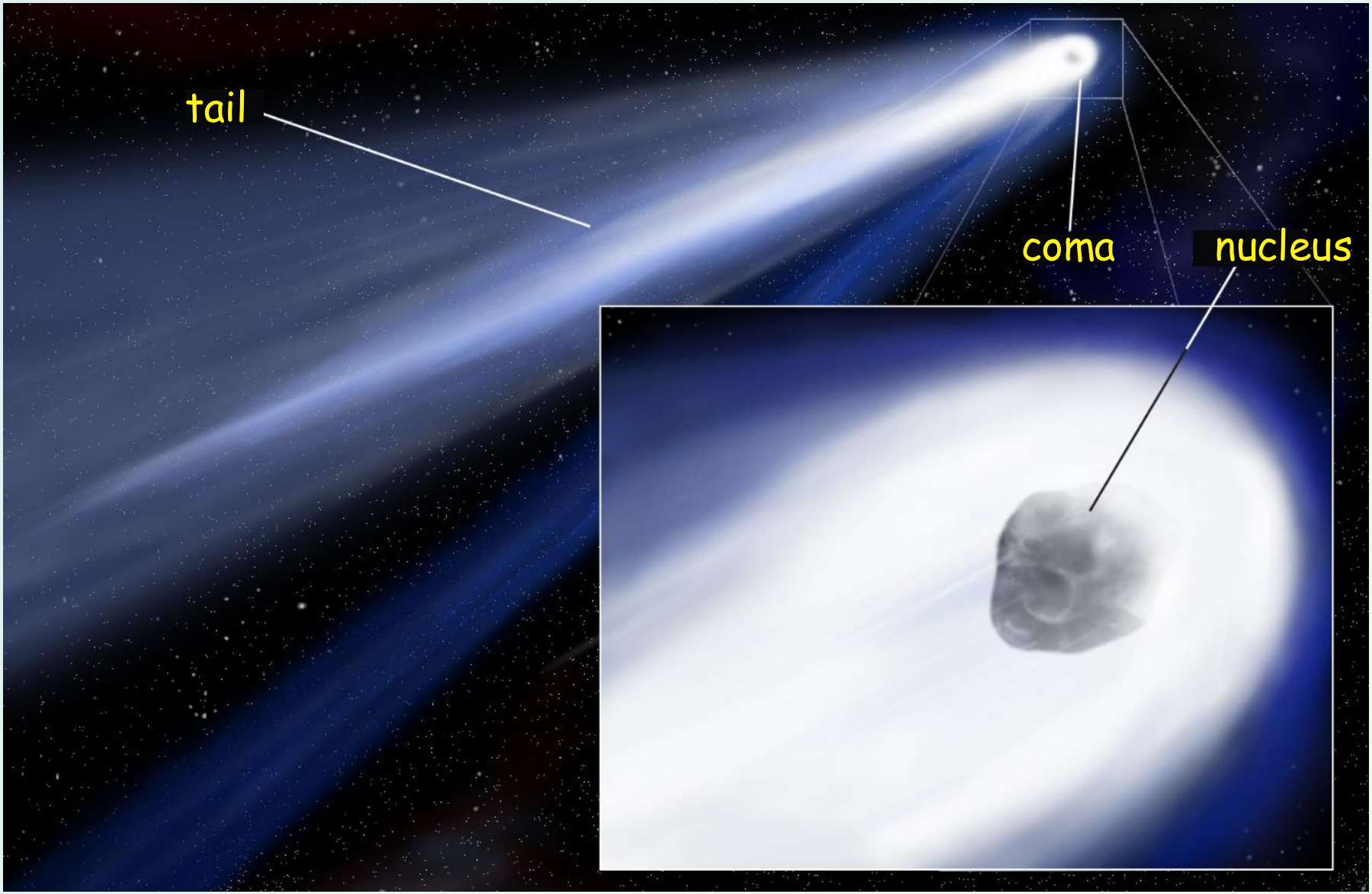
- Meteorites → fragments of asteroids
- fragments form from asteroid collisions
- virtually all meteorite trajectories have been traced back to the asteroid belt
- meteorites provide important samples of planetary material

Comets

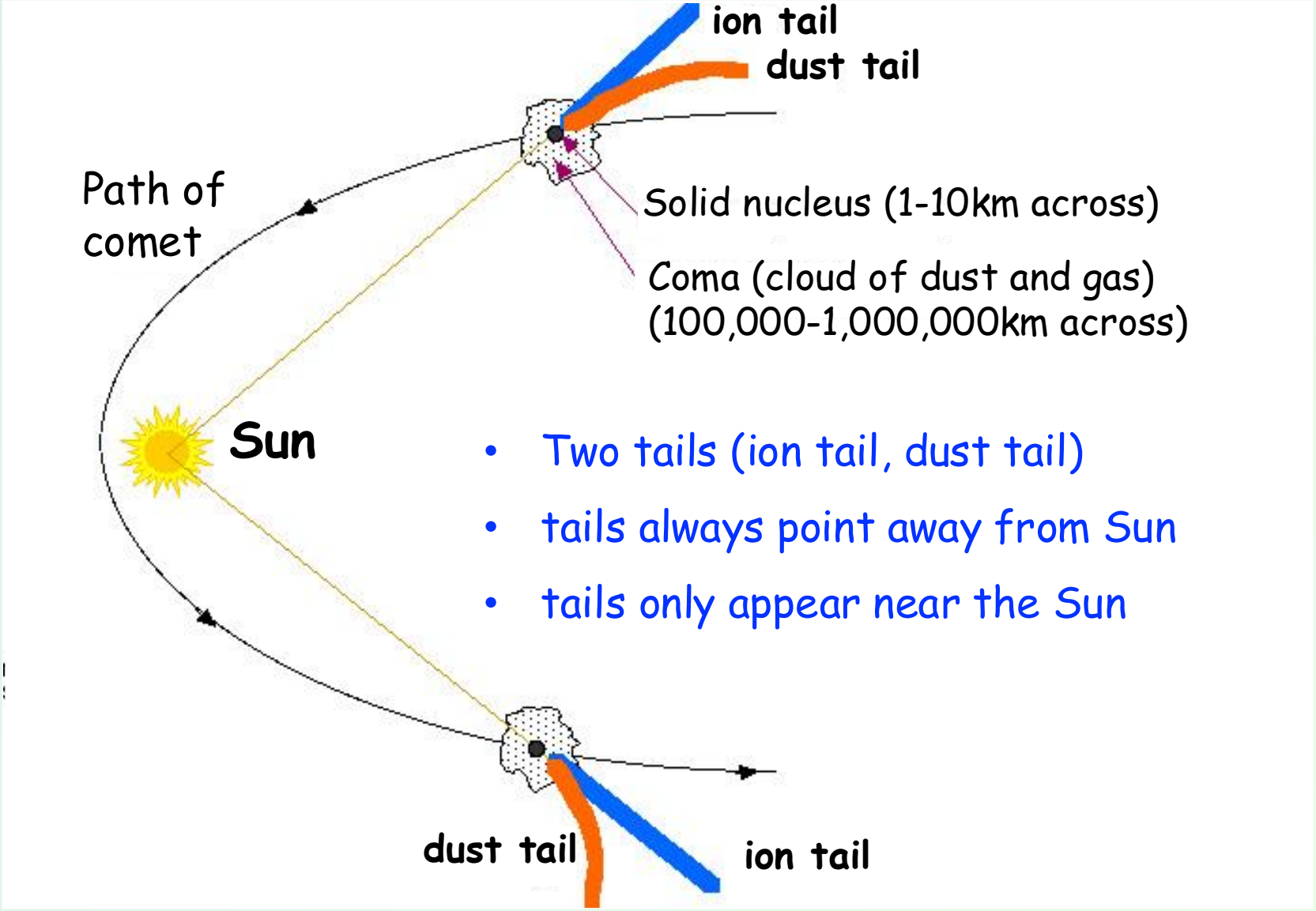
- Formed at same time as the Sun and the planets
- hundreds of billions of them*
- composed mainly of ices of H_2O, CO, CO_2, CH_4, NH_3 and carbon-rich dust (not rocky bodies)
- appear as fuzzy balls (comas) of gas & dust with spectacular luminous tails
- nucleus is a small solid body → kms to tens of kms across
- travel in highly elliptical orbits
- originate from outer reaches of solar system

Halley's Comet

Comet components



Comet tails

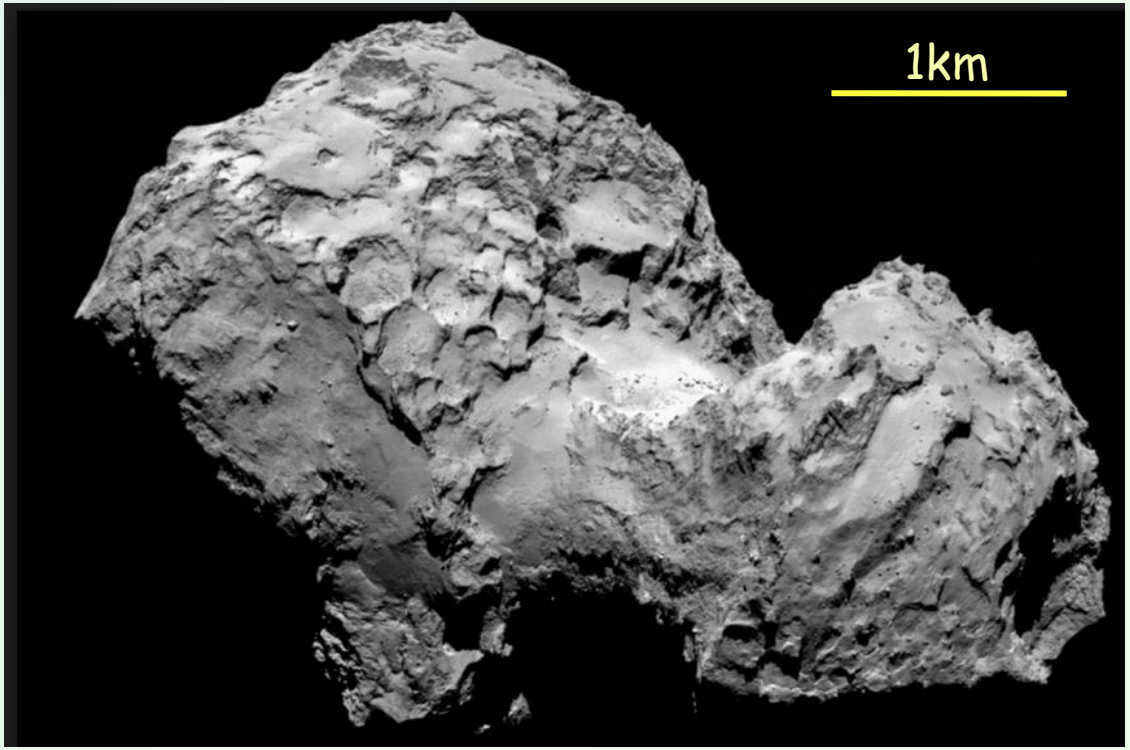


- Two tails (ion tail, dust tail)
- tails always point away from Sun
- tails only appear near the Sun

Two tails of the comet Hale-Bopp

Nucleus of Comet Churyumov-Geryasimenko

- Spacecraft Rosetta went into orbit around the comet in 2014
- small robotic probe (Philae) was landed on comet
- composition → water-ice 80%, frozen *CO* 15%, plus frozen CO_2, methane and ammonia



Nucleus of comet Churyumov-Geryasimenko

Comet types

- Three groups of comets:

  (1) Long period comets → orbital period >200 years

  (2) Halley-type comets → orbital periods 20 – 200 years

  (3) Jupiter-family comets → orbital periods < 20 years

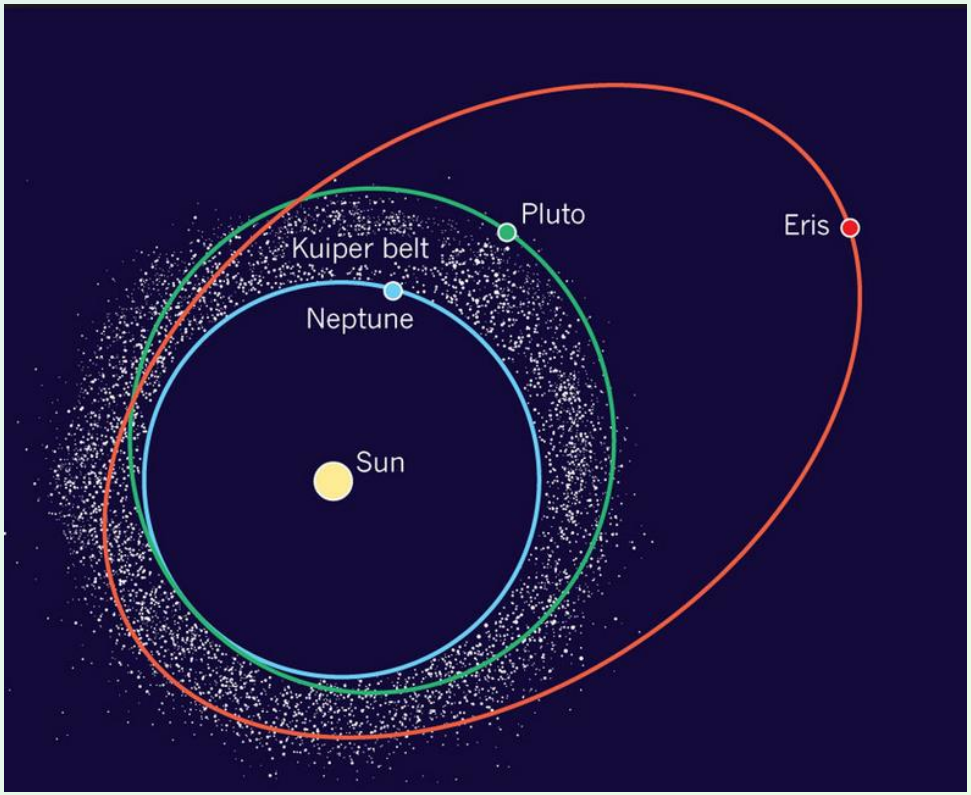
- Comets originate from two source regions

  (1) Oort cloud → (long period, Halley-type)

  (2) Kuiper belt → Jupiter-family

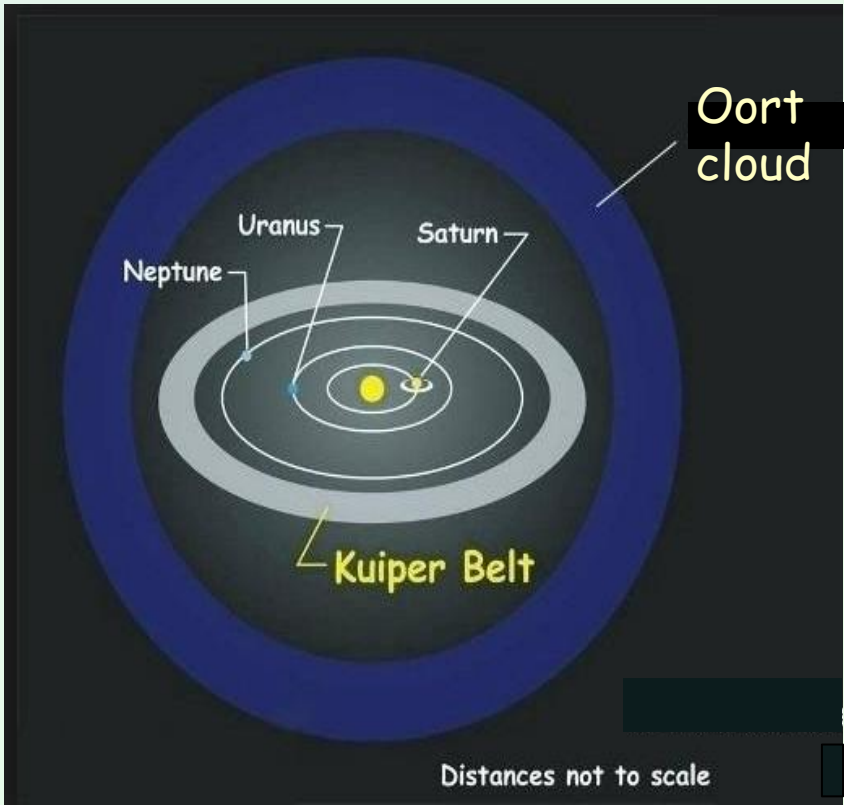
Kuiper belt

- Region of solar system beyond the planets (30 – 50AU)
- comprises abundant small and large icy objects
- objects are composed of a mixture of rock and frozen volatiles (methane, ammonia and water)
- 10s of thousands >100km diam.
- home to 3 dwarf planets (Pluto, Haumea and Makemake)
- objects in belt not significantly perturbed since beginning of solar system



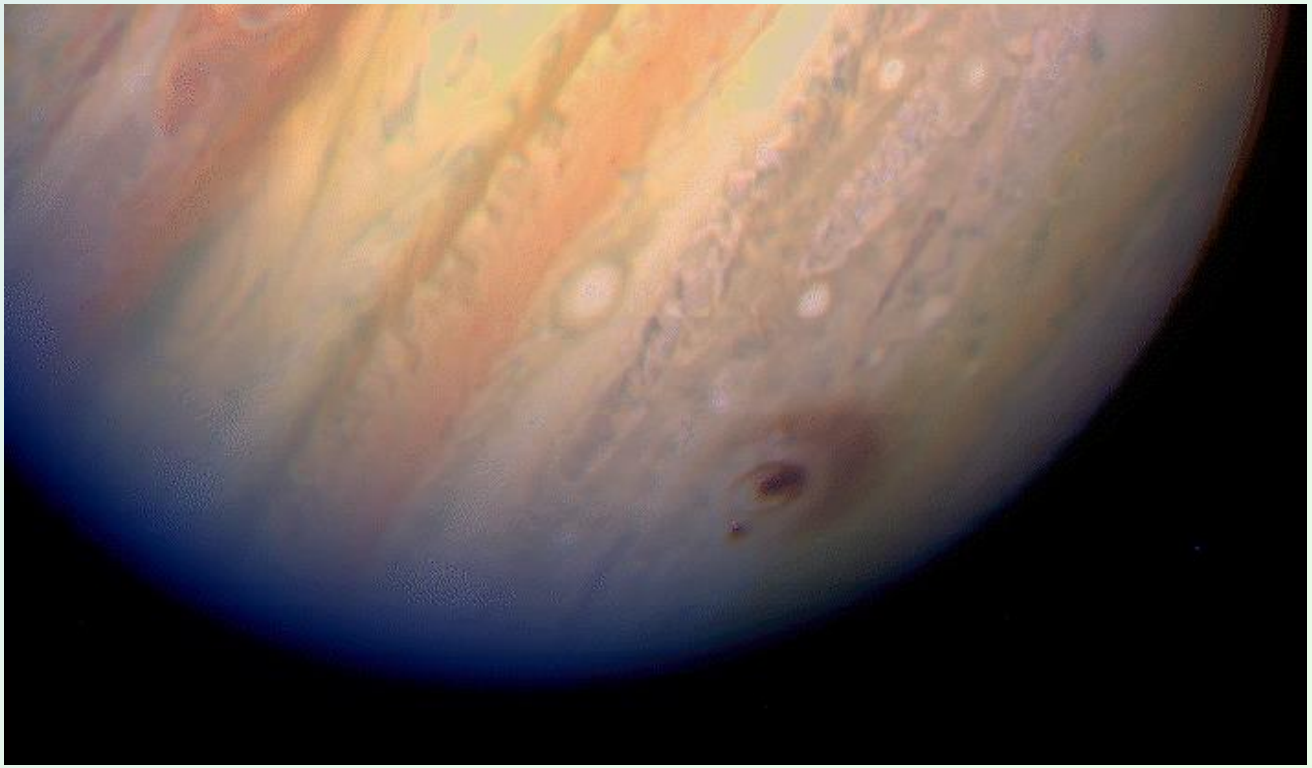
Oort cloud

- Trajectories of long period and Halley-type comets indicate that they originate from deep outside the Kuiper belt
- this vast source of comets is called the Oort cloud
- Oort cloud → immense spherical cloud 30 trillion km from the Sun
- subdivided into outer (spherical) & inner (doughnut-shaped) clouds
- outer cloud trillions (?) of objects >1km across in slow, chaotic orbit around Sun



Comet Shoemaker-Levy impact on Jupiter

- Periodically comets are perturbed → diverted from their orbits
- some comets move towards Sun passing across orbits of planets
- more likely to impact planets than asteroids
- Comet Shoemaker-Levy impacted on Jupiter in 1994



Hubble telescope image of Shoemaker-Levy impact site