

Big Island Field Trip, Spring 2007



When: March 2-4, 2007

Itinerary : Volcanoes National Park Visitors' Center, Kilauea Caldera, Hawaii Volcano Observatory, Halema'uma'u Crater, Keanakekoi Crater, Thurston Lava Tube, Devastation Trail, Mauna Ulu, Chain-of-Craters Road, Sea arches, Flows (if active), Kilauea Iki, Puna/Kalapana, Kapono

Airfare: Purchase individually – arrive Hilo on March 2 before 6pm, depart on March 4 after 3pm

Costs: $150 covers food, lodging, and transportation for three days on the Big Island

Deposits/Payment: By January 26 non-refundable deposit of $75, February 2 remaining $75 due

Pre-trip Meeting: February 23, location and time TBA





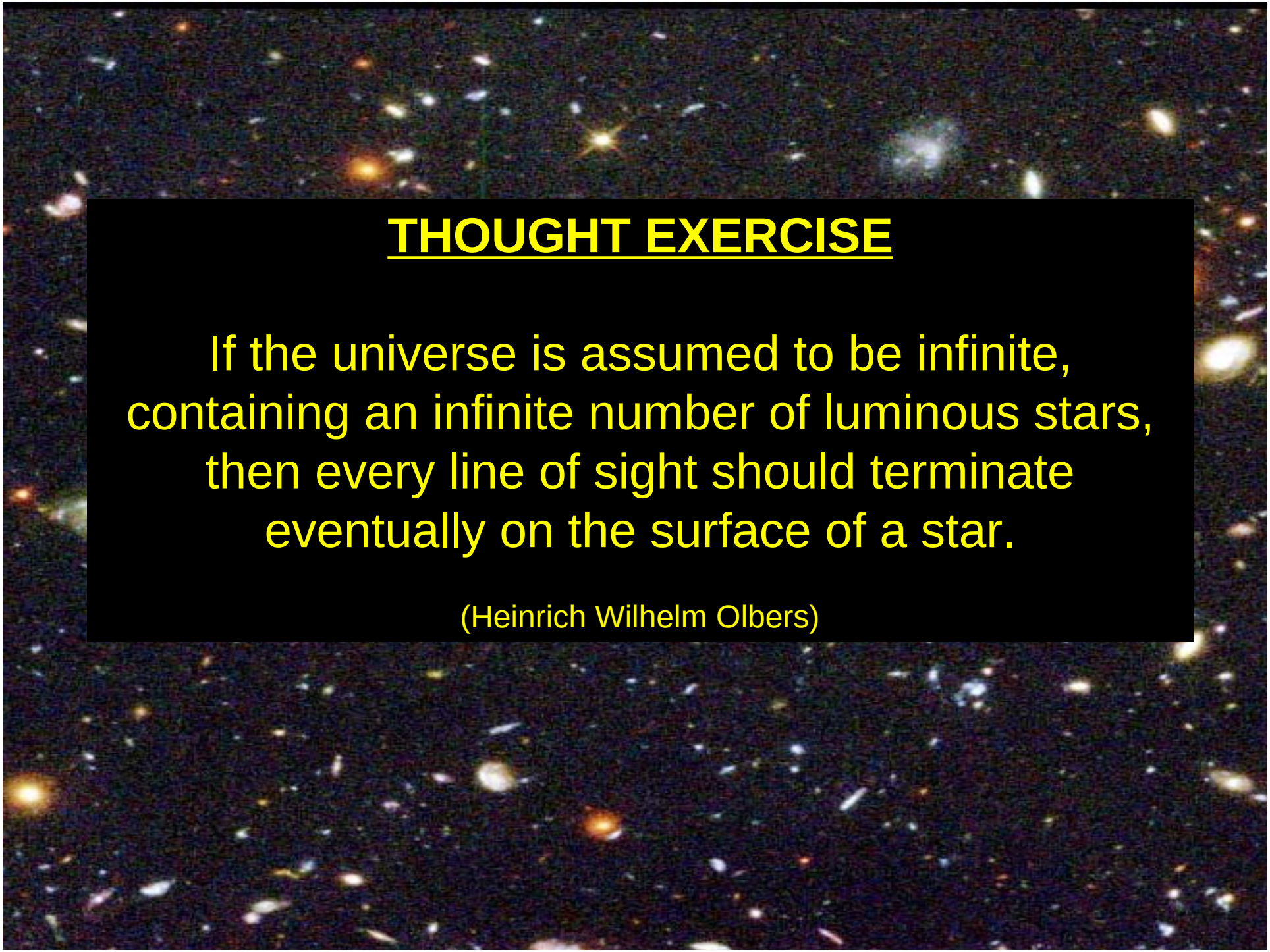





Horsehead Nebula
Image from Hubble telescope
3.5 light years wide (21T miles)
What defines the Universe?


Horsehead Nebula
Image from Hubble telescope
3.5 light years wide (21T miles)
Universe:
1) The sum of all matter
2) The space in which all events occur


Is the Universe infinitely large?



THOUGHT EXERCISE

If the universe is assumed to be infinite, containing an infinite number of luminous stars, then every line of sight should terminate eventually on the surface of a star.

(Heinrich Wilhelm Olbers)



Is the Universe infinitely old?

In the 1920s Edwin Hubble calculated distances to stars outside of the Milky Way galaxy

At the same time Vesto Melvin Slipher was calculating galactic **Red Shifts** *(like Doppler effect)*

Red Orange Yellow Green Blue Indigo Violet

Retreating light source

Stationary light source

Approaching light source

Most galaxies are red shifted

What Hubble noticed was that -

The further away a galaxy is from us,

the larger its Red Shift….

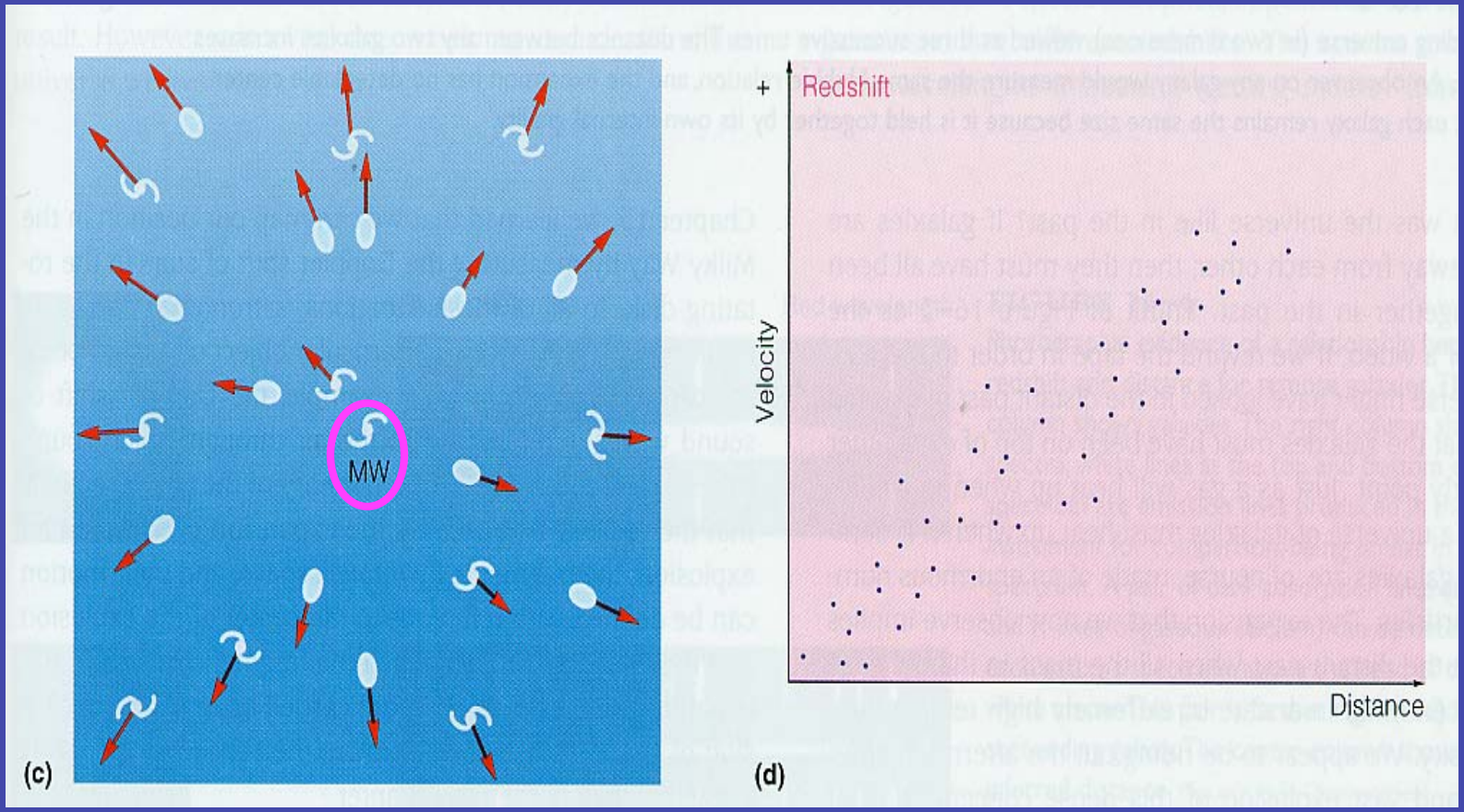
…what does this mean about its speed?

What Hubble noticed was that -

The further away a galaxy is from us,

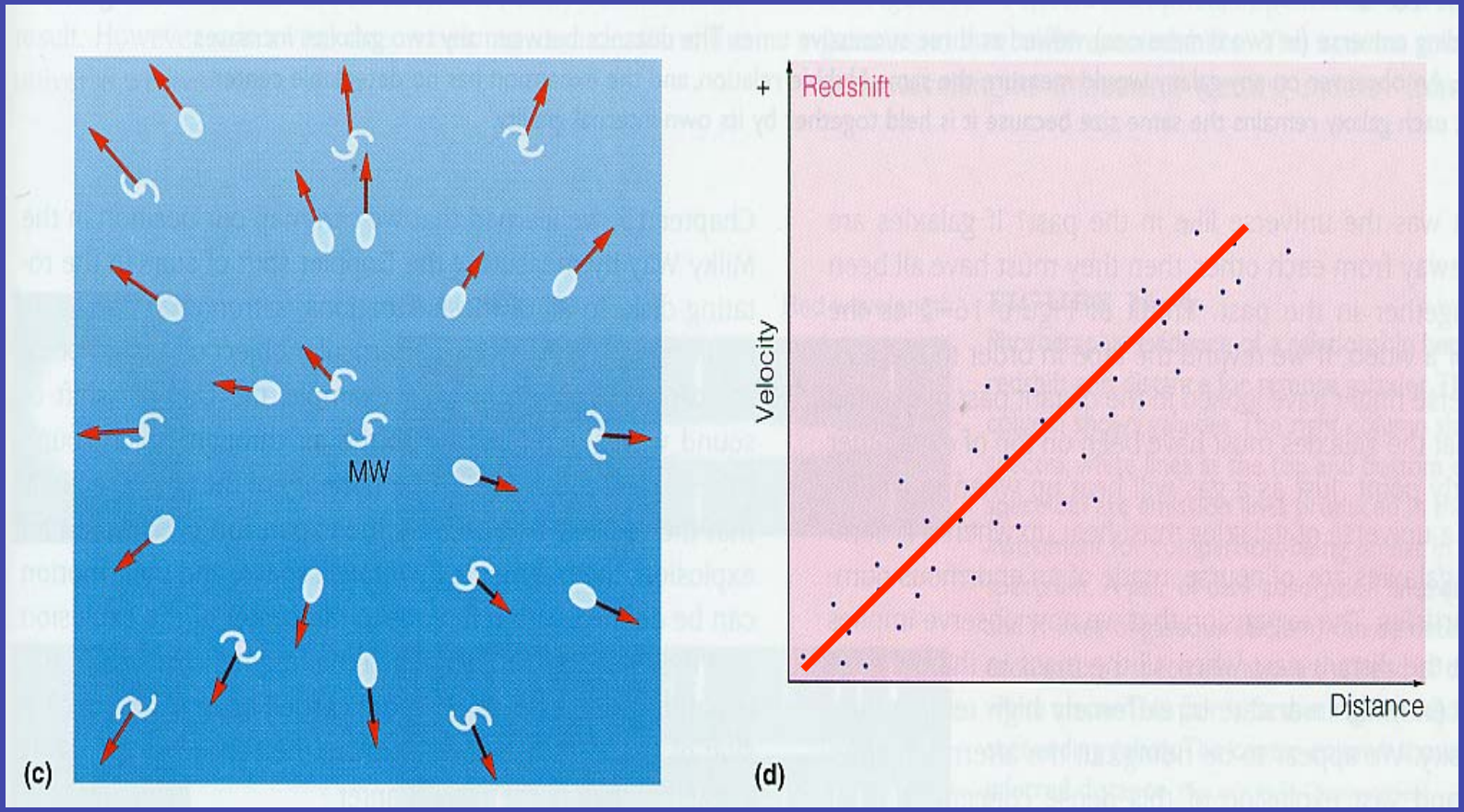
the larger its Red Shift….

….the faster it’s moving away from us.

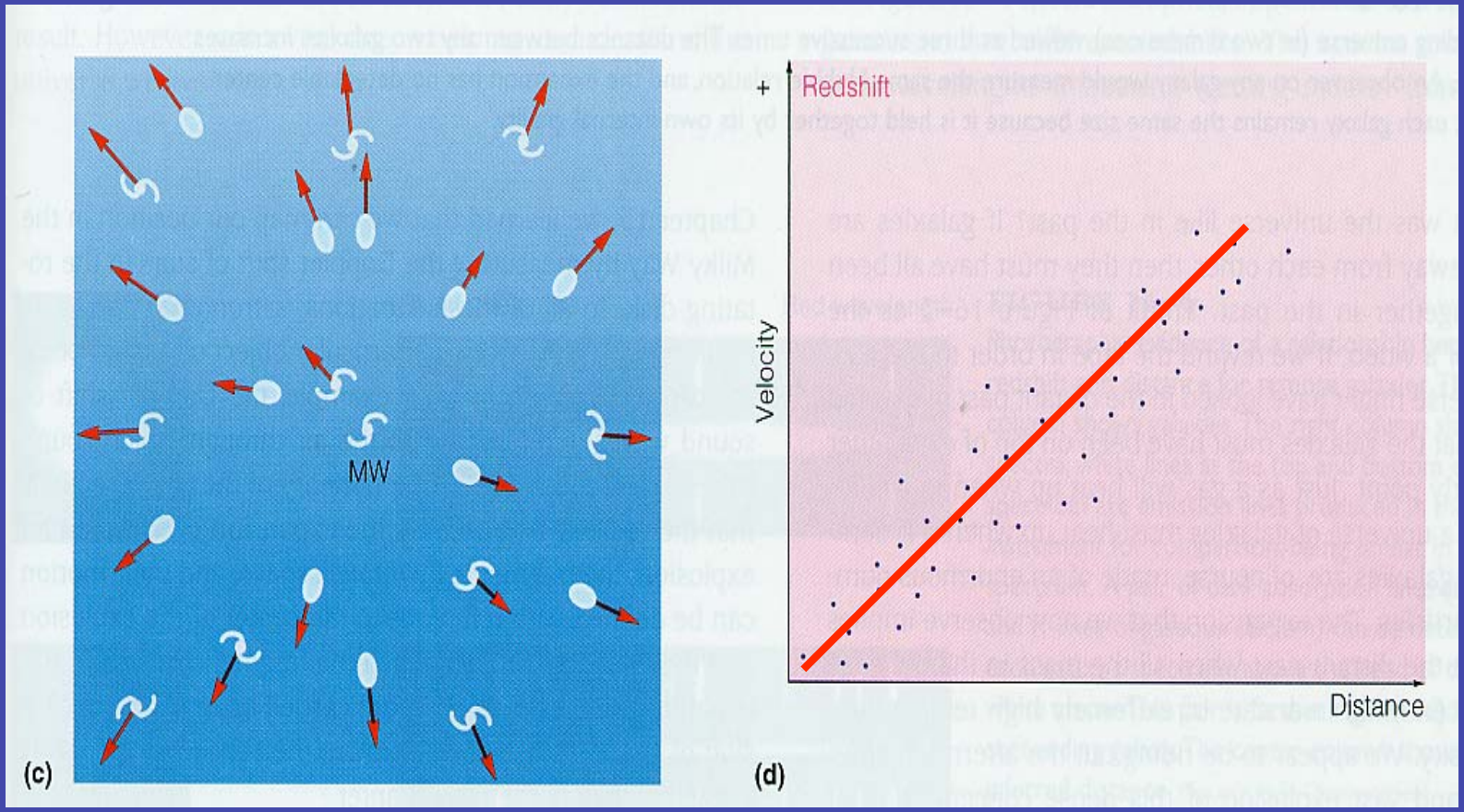


Galaxies close to us are moving away from us slowly

Galaxies that are farther away from us are moving away from us faster

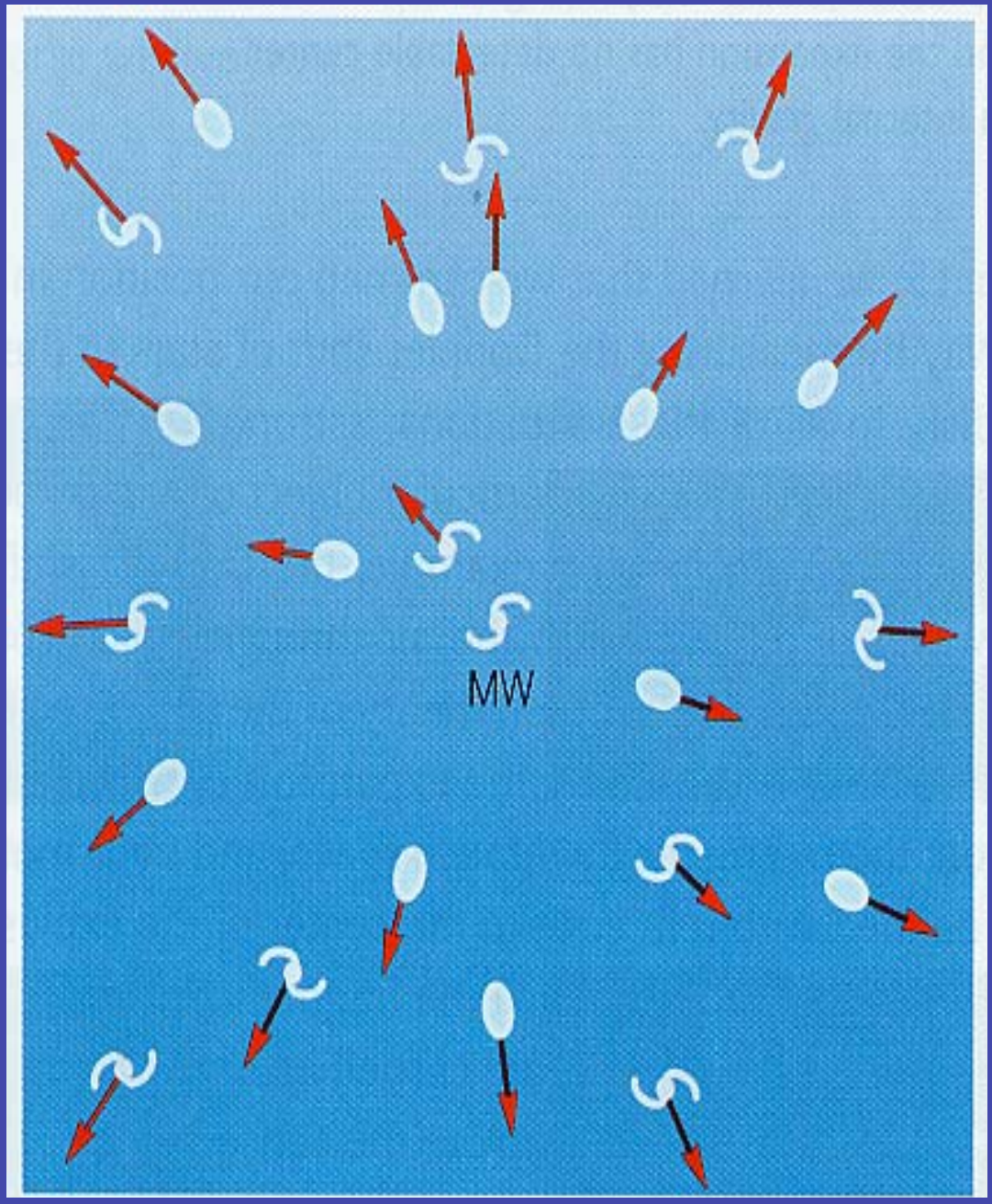


Straight line indicates that DISTANCE and SPEED of recession are…?



Straight line indicates that DISTANCE and SPEED of recession are…

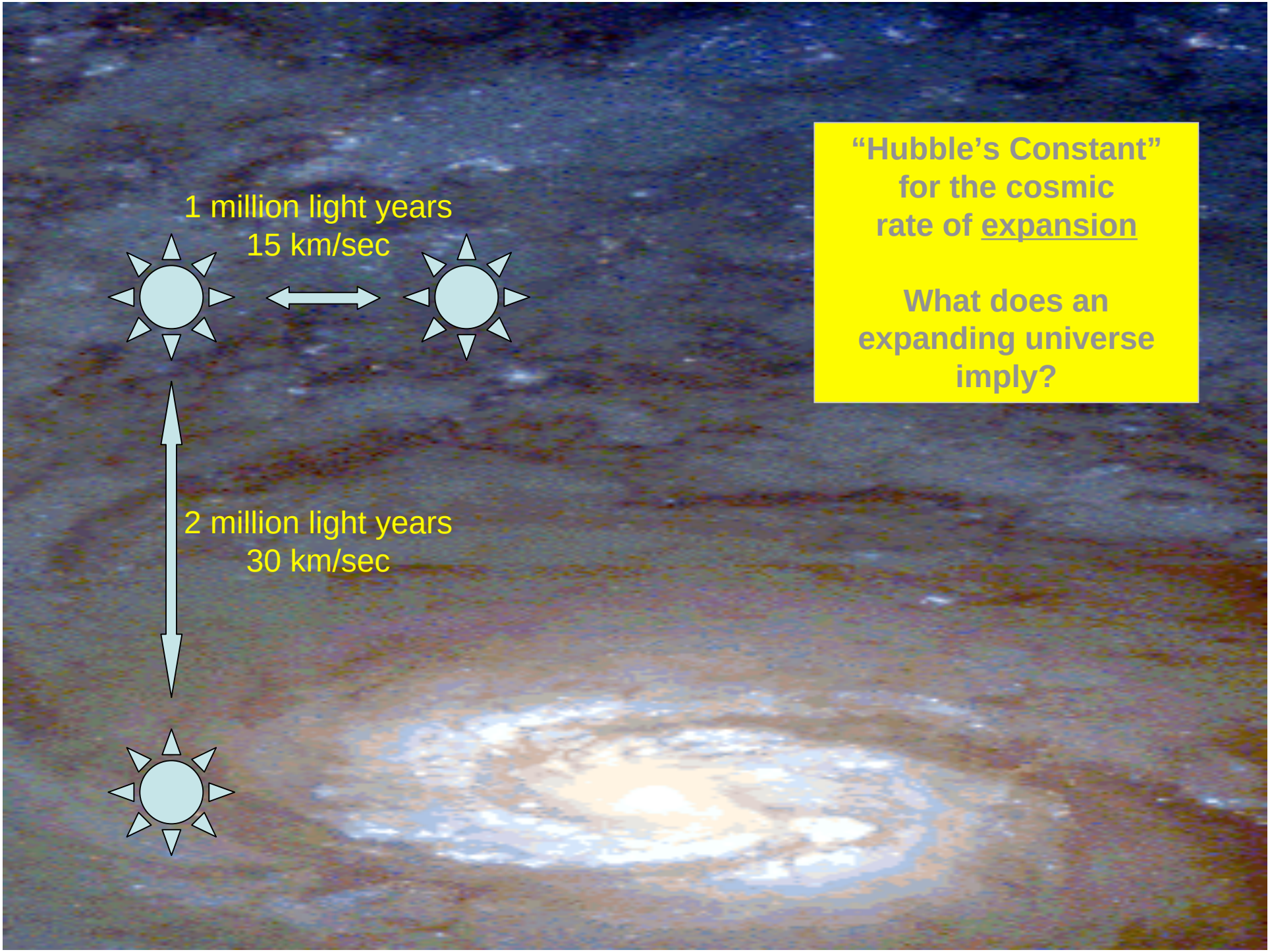
PROPORTIONAL



If all galaxies are moving away from each other…

what shape does the universe have to be?

What's wrong with this picture?



"Hubble's Constant" for the cosmic rate of expansion

What does an expanding universe imply?

Edwin Hubble calculated the rate (R) at which the universe is expanding.

R~15 km/sec for two galaxies that are separated by a distance (D) of 1 million light years (9.46×10^{18} km).

R= D/T

Rate of expansion = distance between two objects/time of expansion

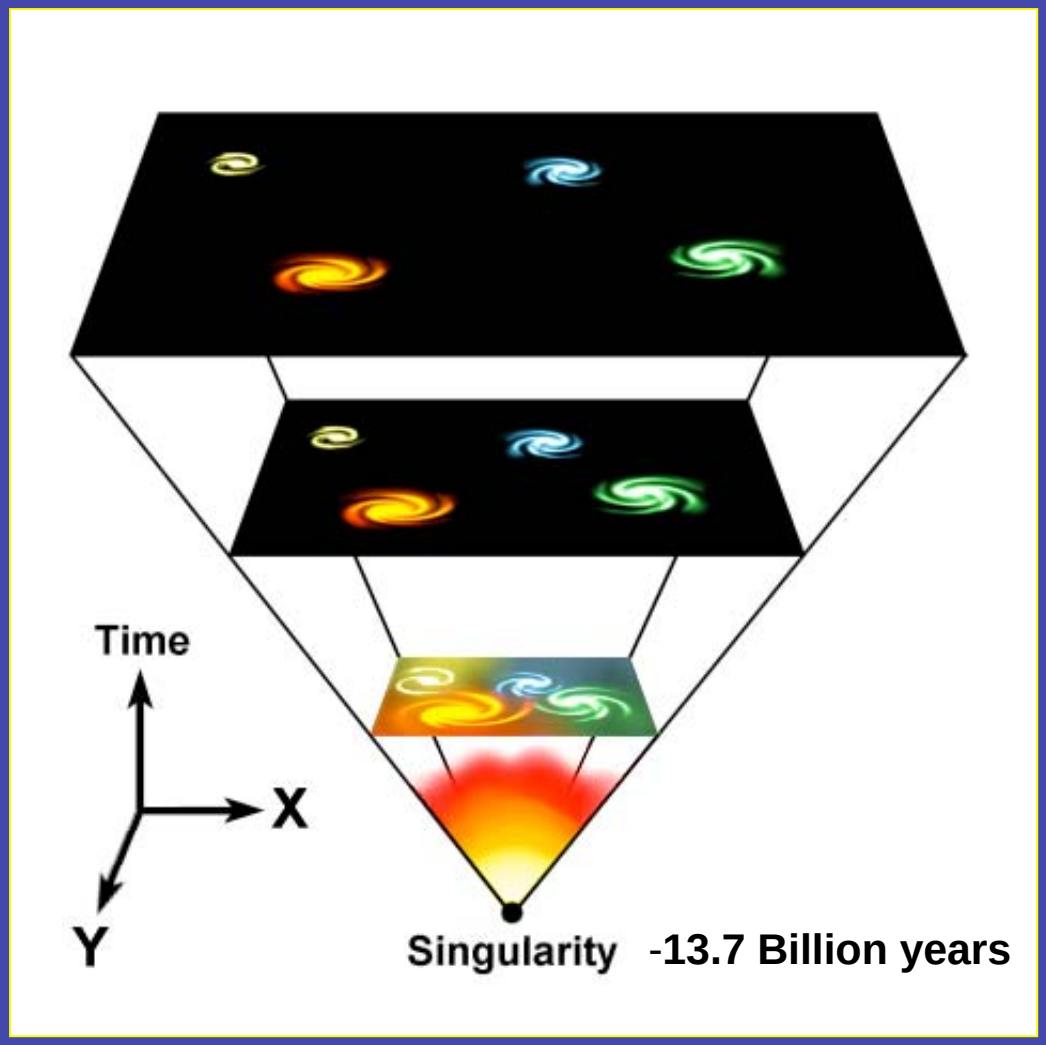
This can be reorganized to T = D/R.

T=age of the universe!

Dividing D by R yields 6.3×10^{17} seconds or 1.99×10^{10} years.
About 20 billion years.

Improvements in estimating the rate of recession have lowered the probable **age of the universe** to the range 13 to 14 billion years.

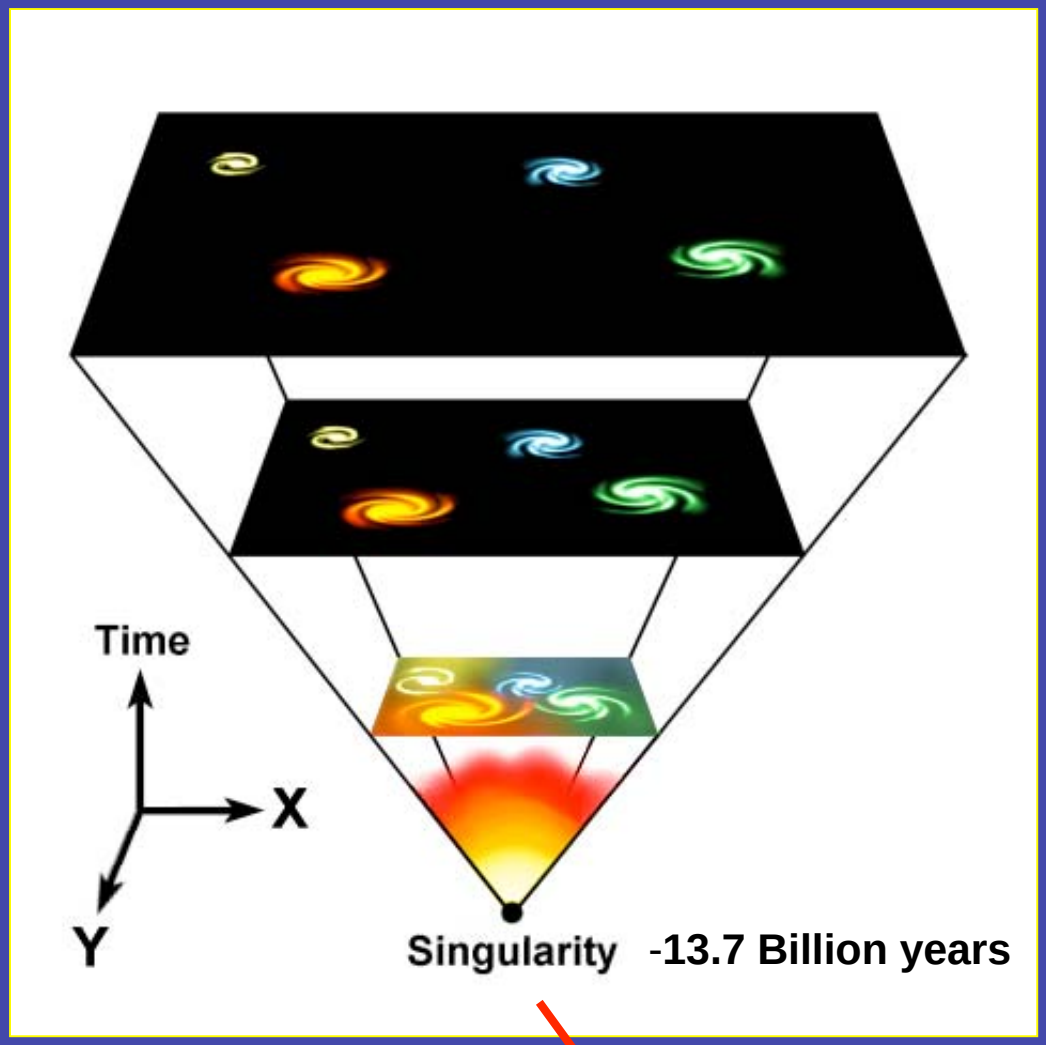
Therefore - the Universe had a beginning – **The "Big Bang"**



The Big Bang vs. Steady-State

1) Cosmic Red Shift

2) …?



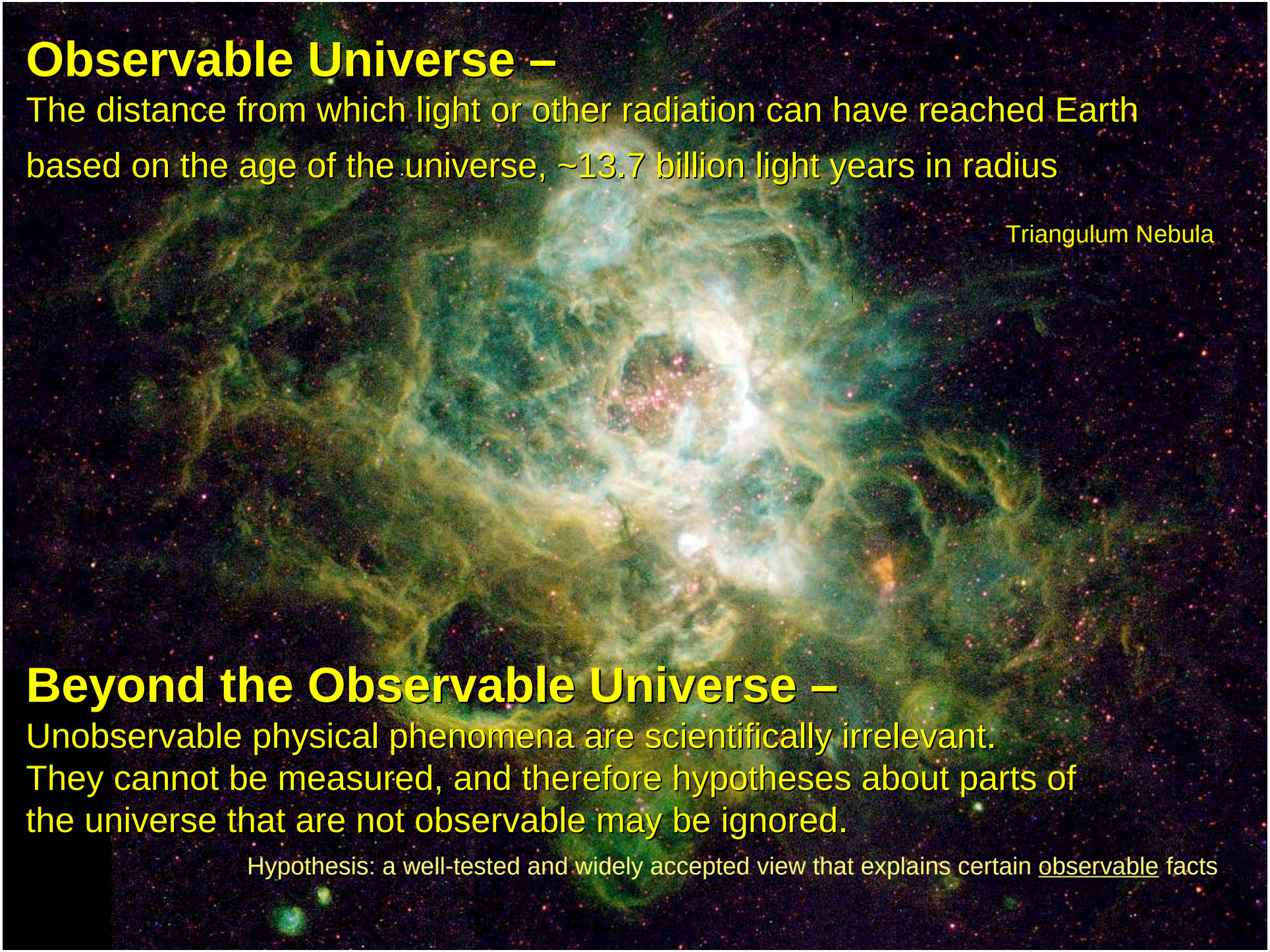
The Big Bang vs. Steady-State

1) Cosmic Red Shift

2) Cosmic Microwave Background Radiation

-2.725° above absolute zero
-extremely uniform distribution
-microwave portion of EM spectrum

Gravitational singularity
Immensely hot and dense



Observable Universe –

The distance from which light or other radiation can have reached Earth based on the age of the universe, ~13.7 billion light years in radius

Triangulum Nebula

Beyond the Observable Universe –

Unobservable physical phenomena are scientifically irrelevant. They cannot be measured, and therefore hypotheses about parts of the universe that are not observable may be ignored.

Hypothesis: a well-tested and widely accepted view that explains certain observable facts

Universe summary:

1) **Universe has a finite size and a known shape**

(expanding sphere)

2) **Therefore, it must have a finite age**

(13.7 billion years)

3) **And therefore, there must have been a beginning**

(the “Big Bang”, *not Steady State system*)

4) **Evidence: galactic Red Shifts, CMBR**

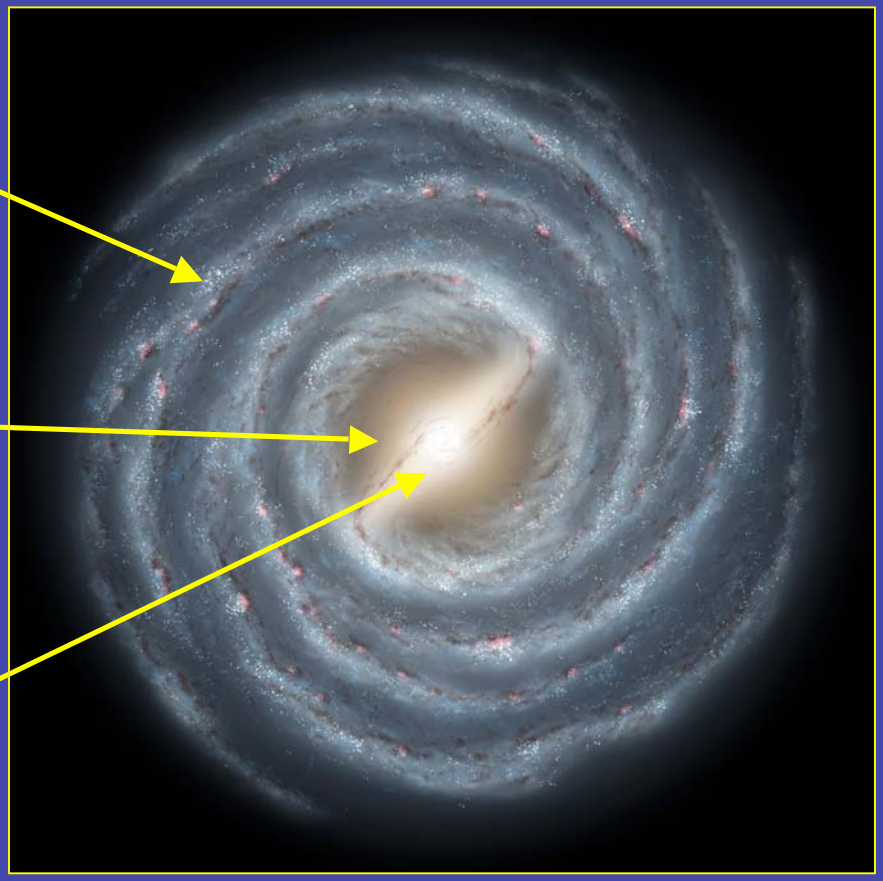


Milky Way Galaxy – barred spiral galaxy

Approximate location of our sun

Central bulge or nucleus

Supermassive black hole: 100,000s to 10s of billions of solar masses



The **Milky Way Galaxy**, one of billions of other galaxies in the universe, contains about 400 billion stars and countless other objects.

Democritus first suggested the Milky Way was made of stars about 400 BC

Width ~100,000 light years, thickness ~1,000 light years

(One light year = ~5,878,482,164,161 miles)
~979 x the world's population
69% of U.S. National Debt

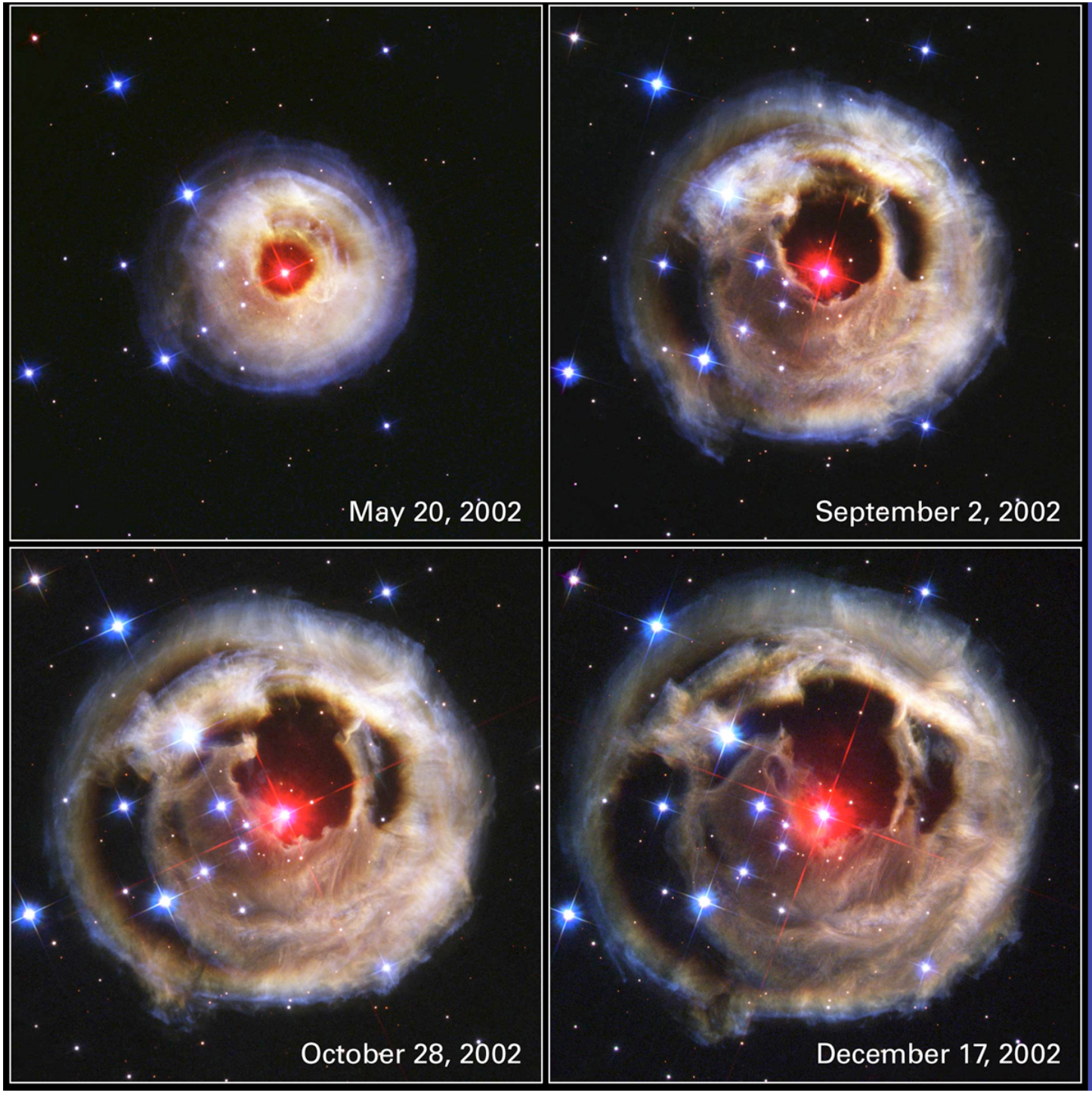
Solar Nebula Hypothesis

The beginning of the Solar System 6.9 billion years ago

Explosion of ancestral star creates giant cloud of cold interstellar gas

Composition same as our modern Sun
=
98% hydrogen and helium,
2% heavier elements
from previous
solar explosions





Formation of a nebula

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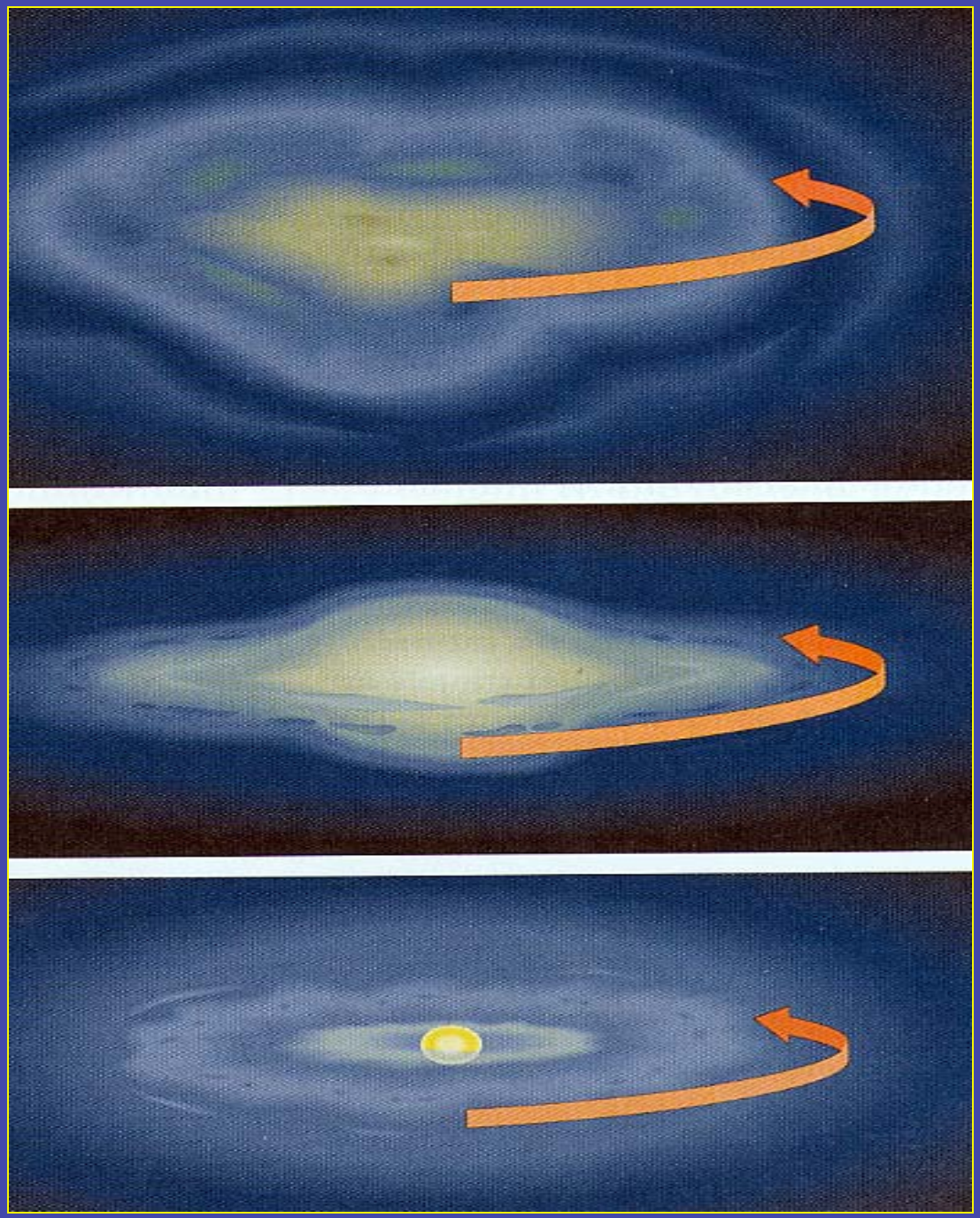
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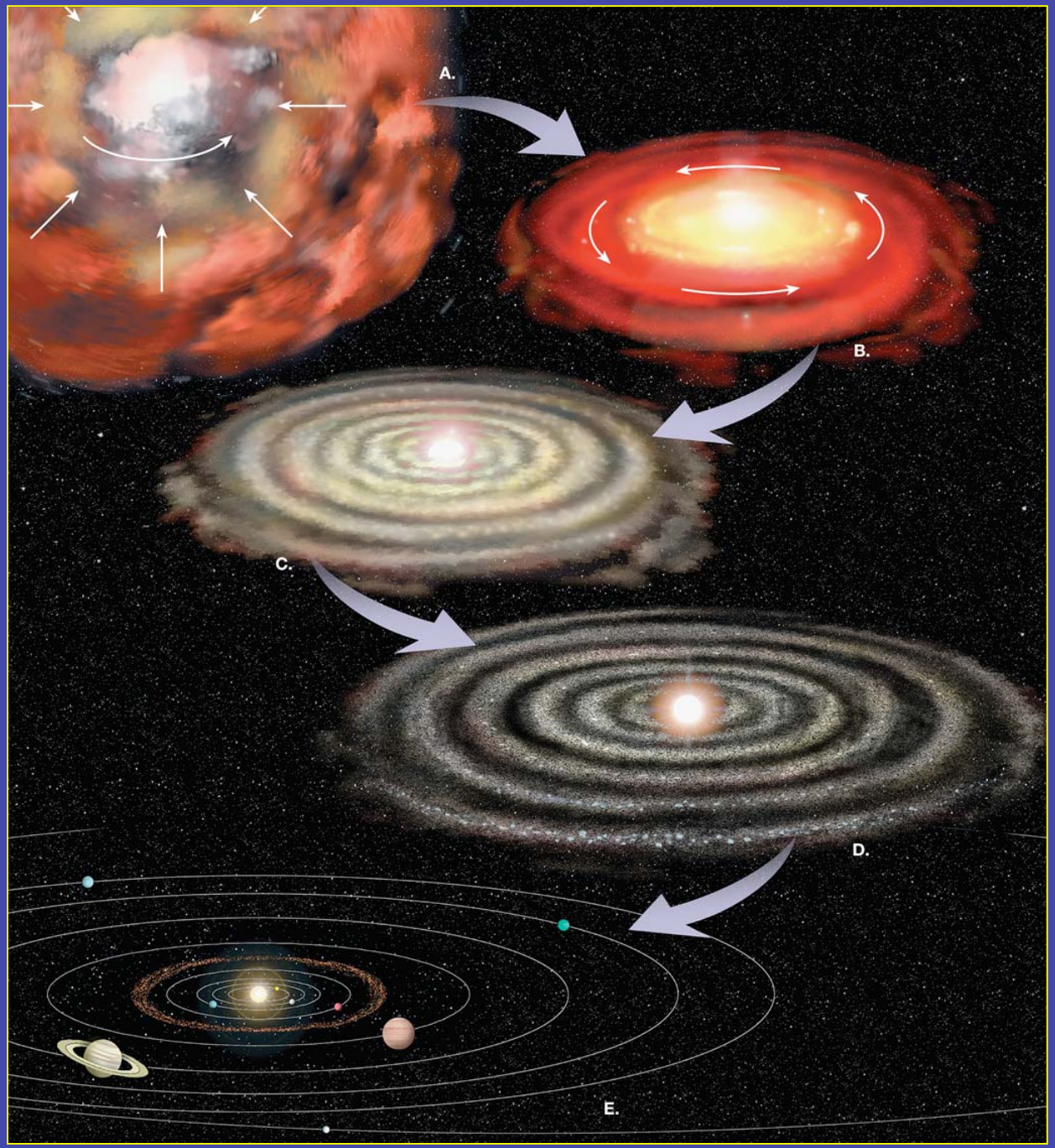
What causes this gas cloud to <u>stop</u> expanding?



1) Nebula collapses and condenses

2) Rotation started by shockwaves from a nearby explosion (?)

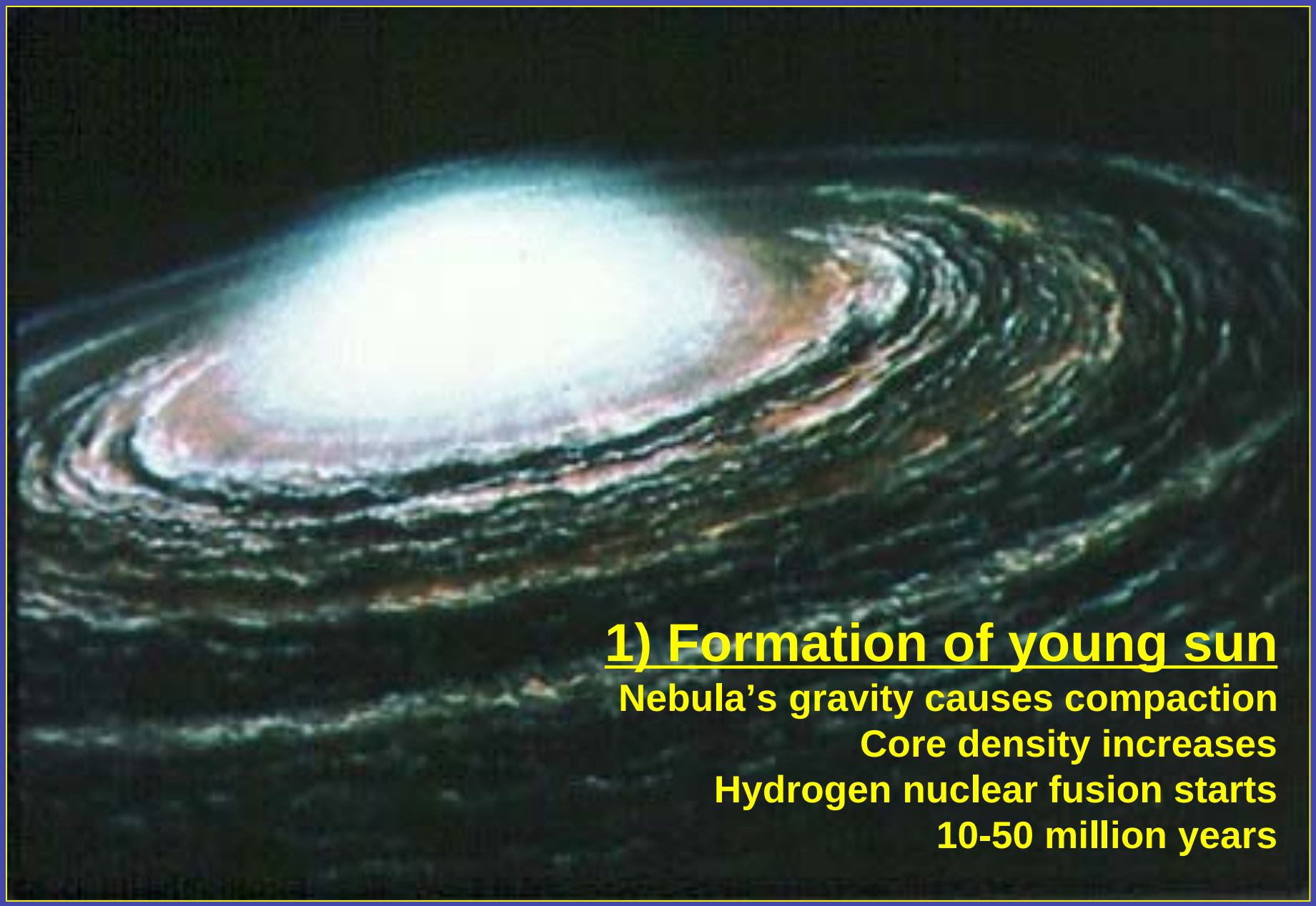
3) Because the solar nebula was rotating, it contracted into a disc, and the planets formed with orbits lying in nearly the same plane.



The spinning solar nebula segregated into:

1) the inner nebula core that was to become the Sun

2) a cooling outer accretion disc of rocky fragments and dust



1) Formation of young sun

Nebula's gravity causes compaction

Core density increases

Hydrogen nuclear fusion starts

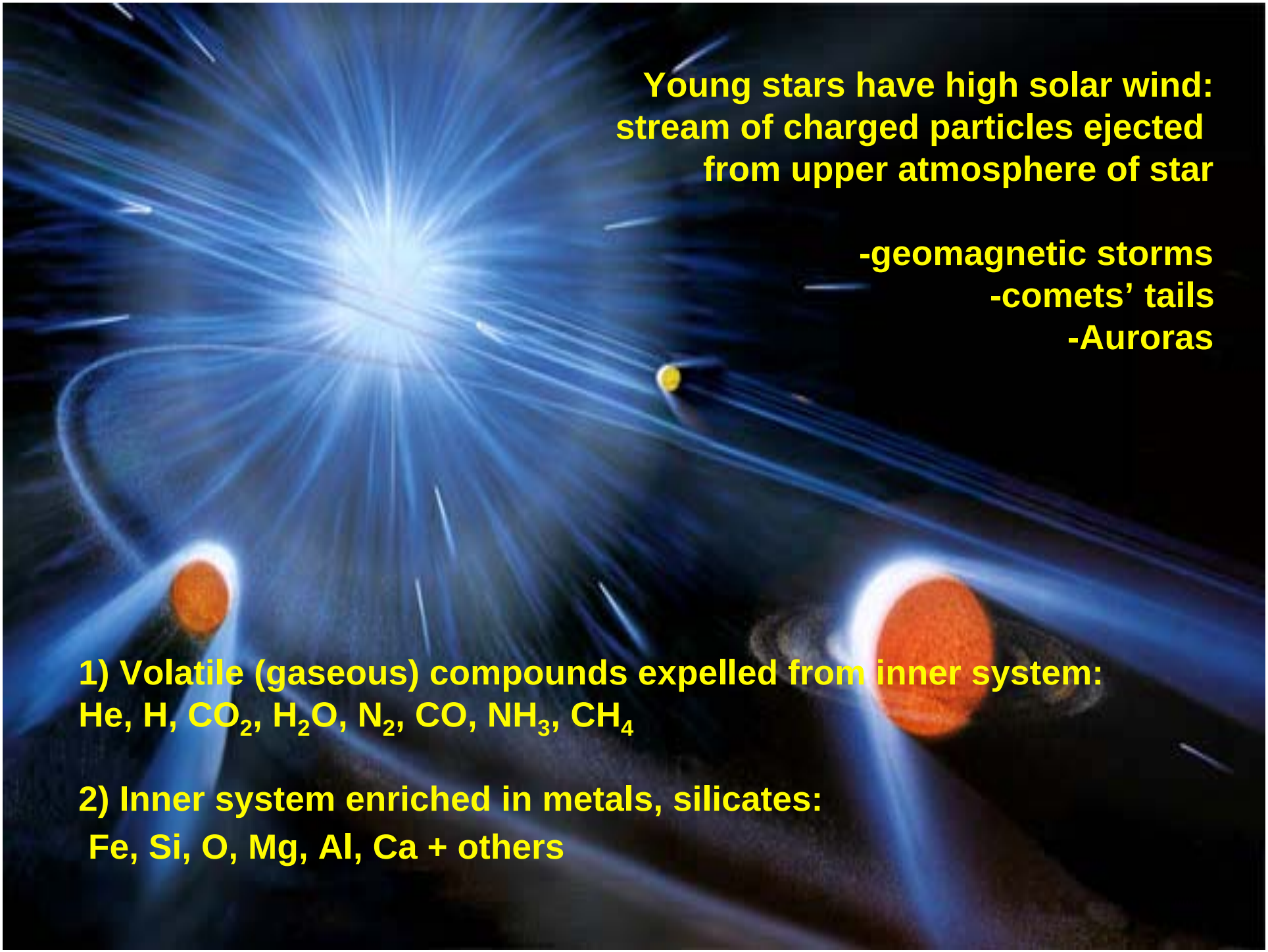
10-50 million years

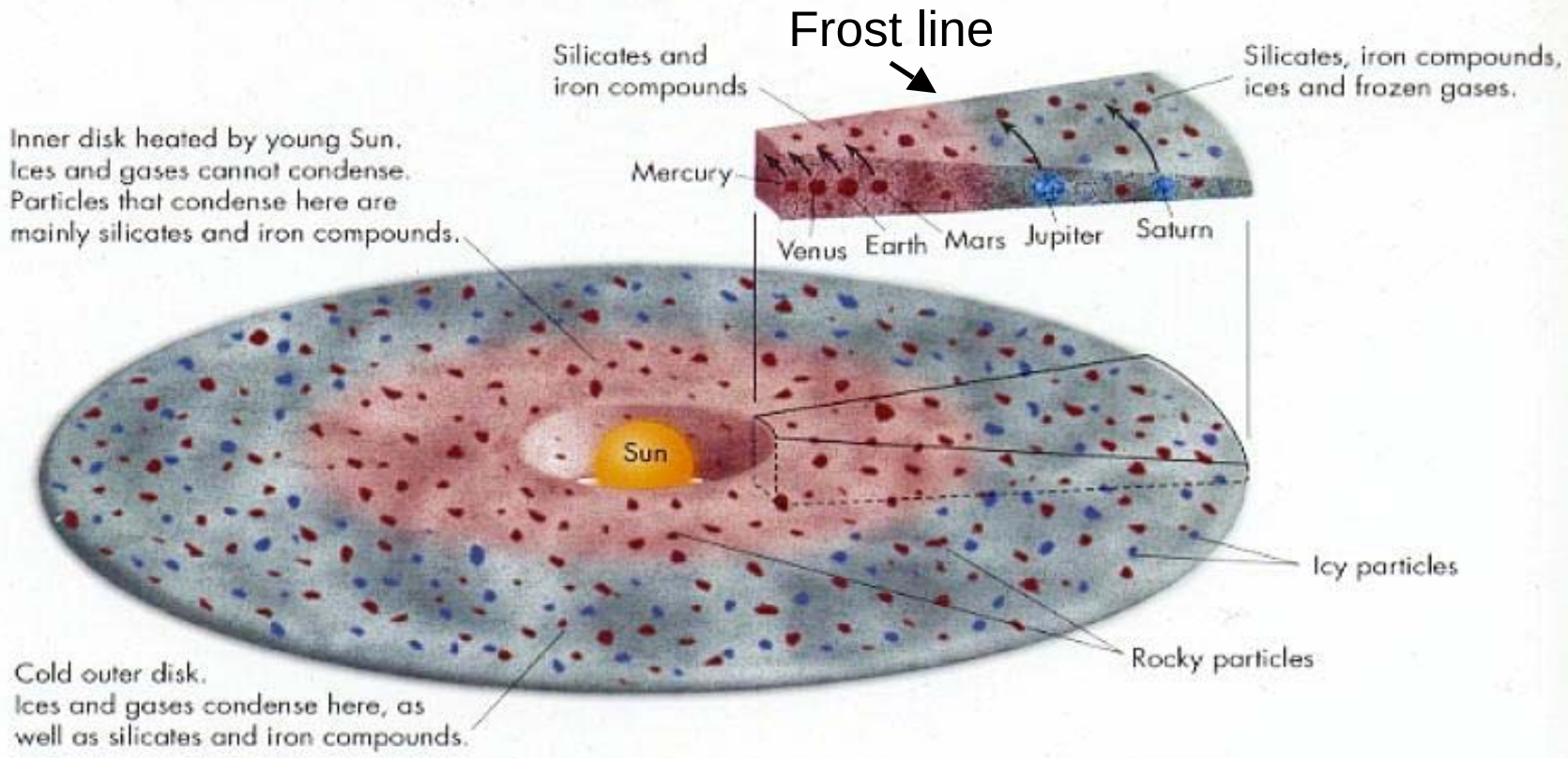


2) Planetesimal accretion

- Dust (metals and silicates)
- Ices (water, methane, ammonia)
- Grains condense, collide, accrete electrostatically
- Increasing gravity attracts more material

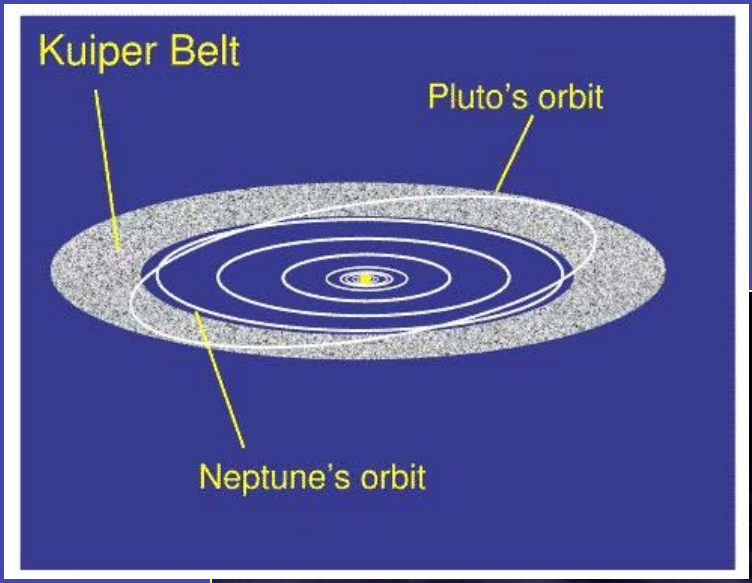
~5 to 4.6 billion yrs ago


Young stars have high solar wind:
stream of charged particles ejected
from upper atmosphere of star
-geomagnetic storms
-comets' tails
-Auroras
1) Volatile (gaseous) compounds expelled from inner system:
He, H, CO_2, H_2O, N_2, CO, NH_3, CH_4
2) Inner system enriched in metals, silicates:
Fe, Si, O, Mg, Al, Ca + others



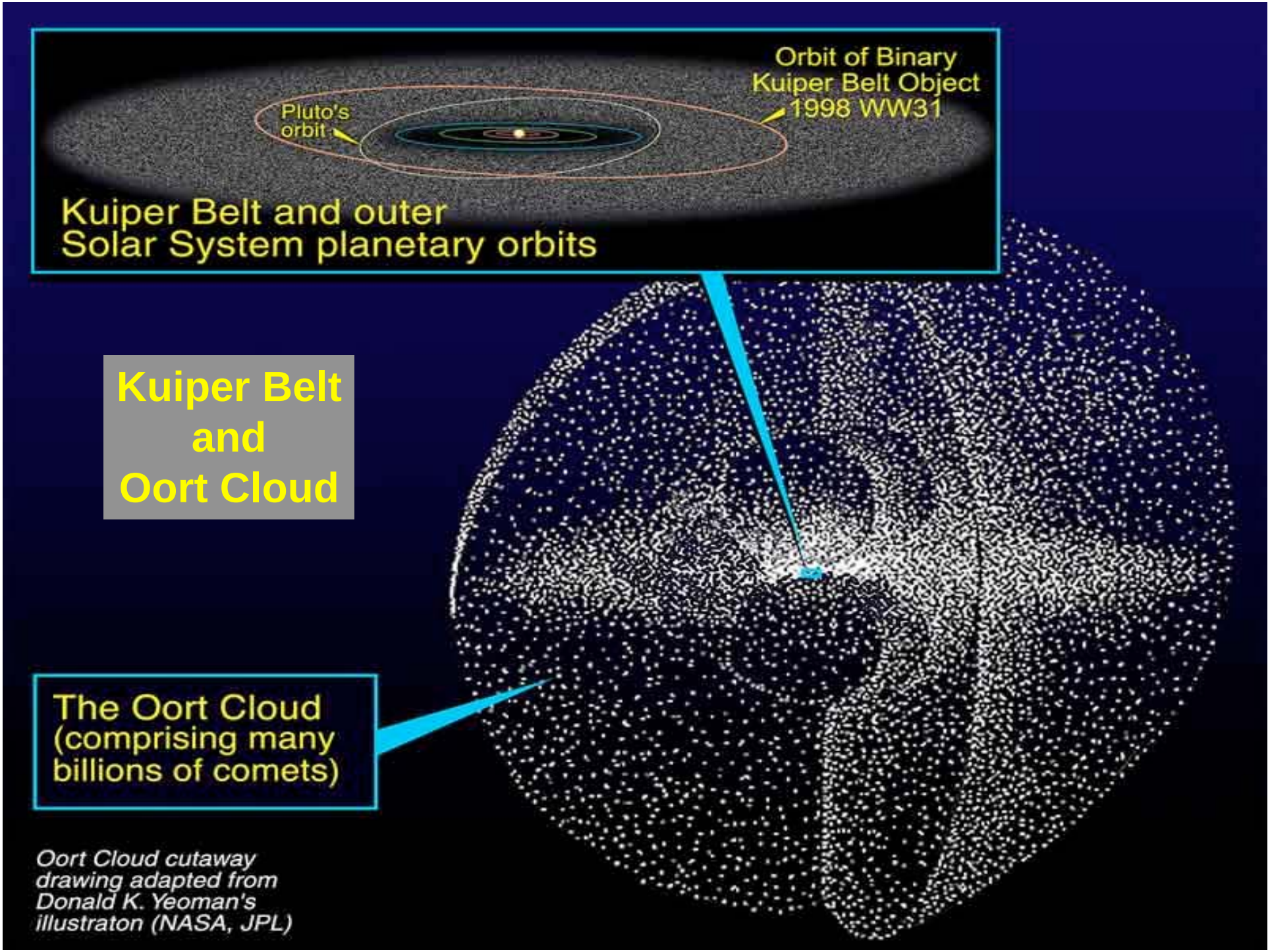
1) Inner Rocky Planets – Fe, Mg, Si, O, Ca, Na, K, Al (nonvolatile)
Mercury, Venus, Earth, Mars

2) Outer Gas Giants – He, H, CO_2, H_2O, N_2, CO, NH_3, CH_4 (volatile)
Jupiter, Saturn, Uranus, Neptune



Kuiper Belt Objects (KBOs) are usually icy planetoids native to the outer solar system




Orbit of Binary
Kuiper Belt Object
1998 WW31
Pluto's
orbit
Kuiper Belt and outer
Solar System planetary orbits
Kuiper Belt
and
Oort Cloud
The Oort Cloud
(comprising many
billions of comets)
Oort Cloud cutaway
drawing adapted from
Donald K. Yeoman's
illustraton (NASA, JPL)



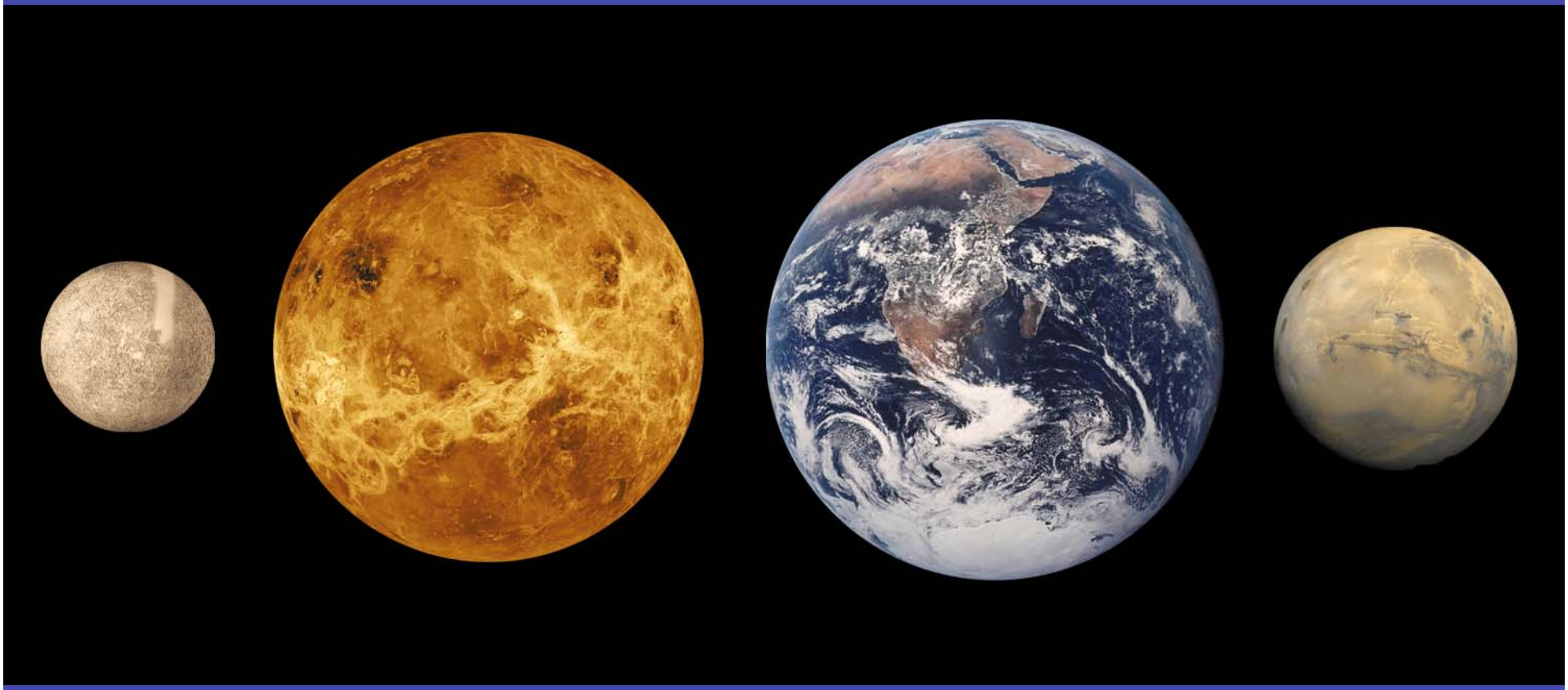
PLANET (2006!)

A celestial body that:

(1) Is in orbit around the Sun

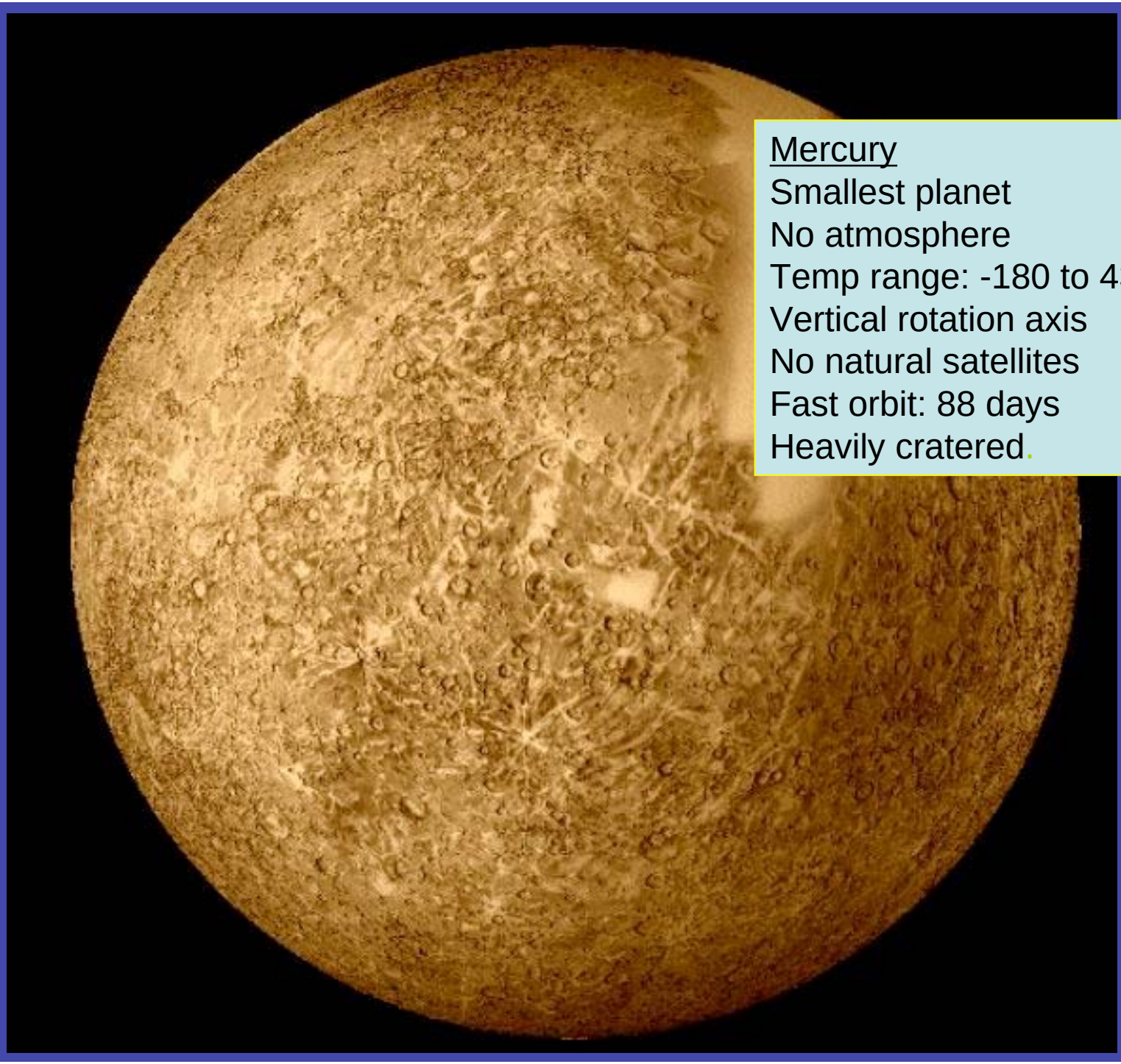
(2) Has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape

(3) Has cleared the neighborhood around its orbit

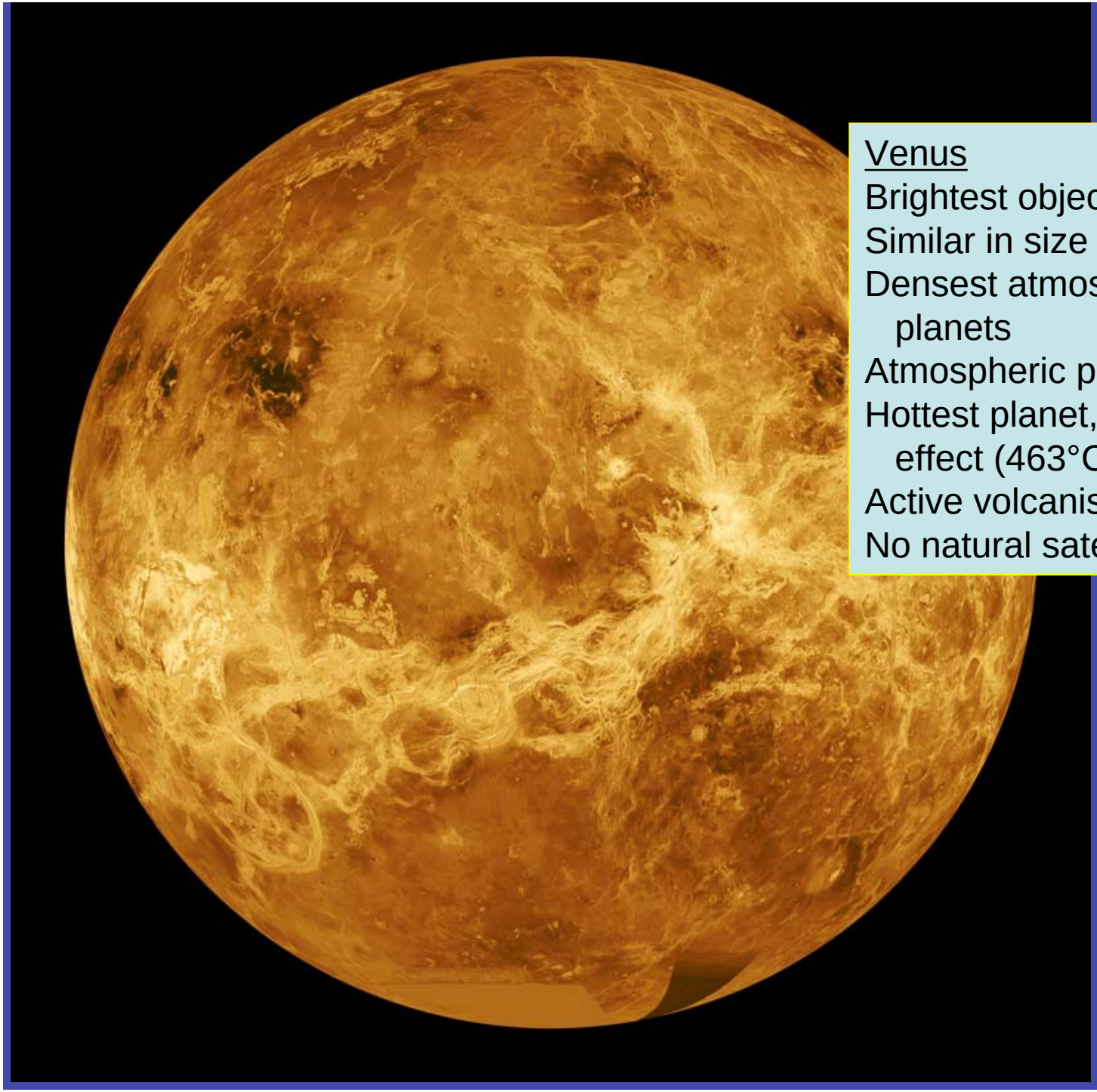


Inner Rocky Planets

(image to scale)



Mercury
Smallest planet
No atmosphere
Temp range: -180 to 430°C
Vertical rotation axis
No natural satellites
Fast orbit: 88 days
Heavily cratered.



Venus

Brightest object in night sky

Similar in size to Earth

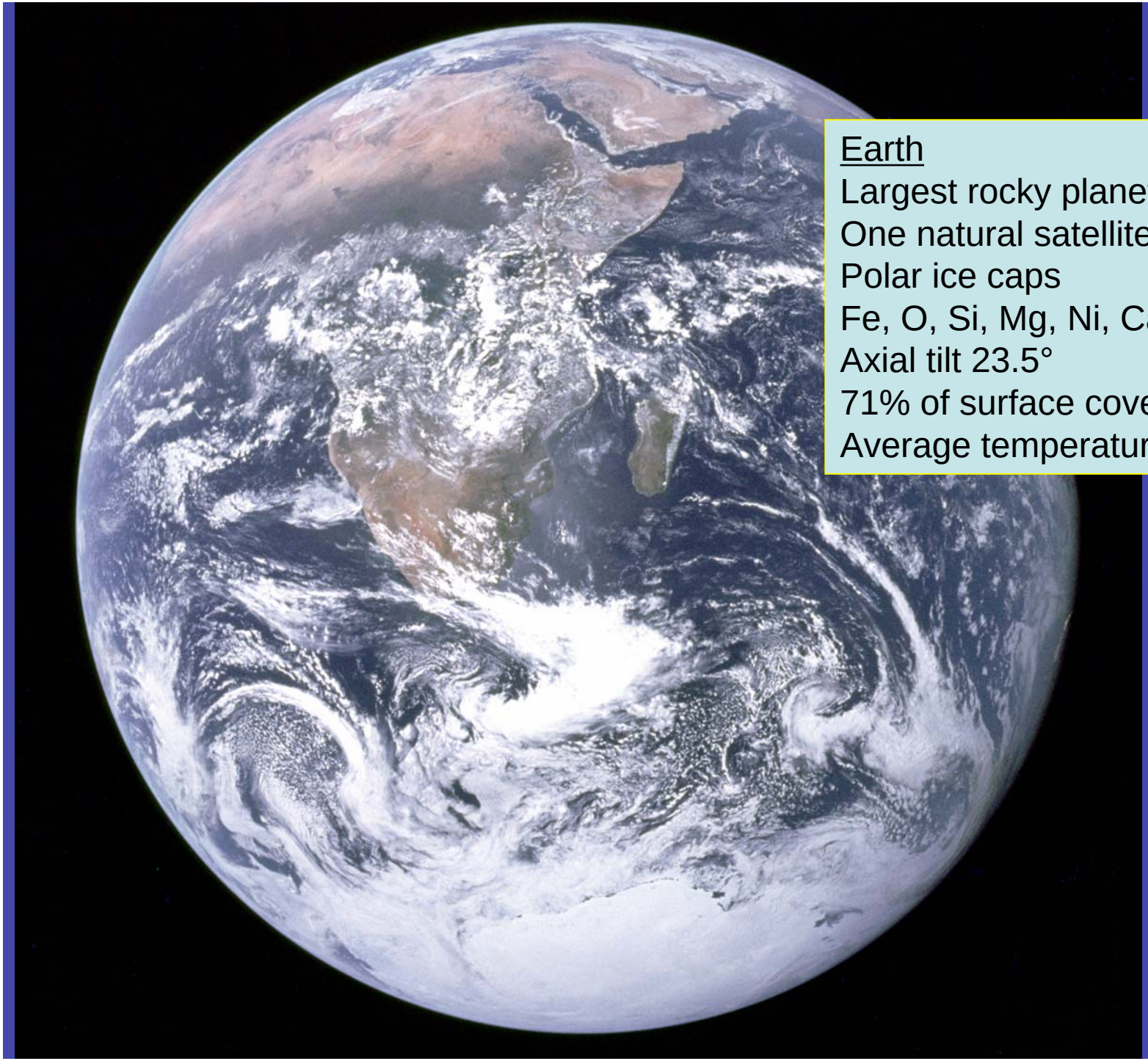
Densest atmosphere of inner planets

Atmospheric pressure 90x Earth's

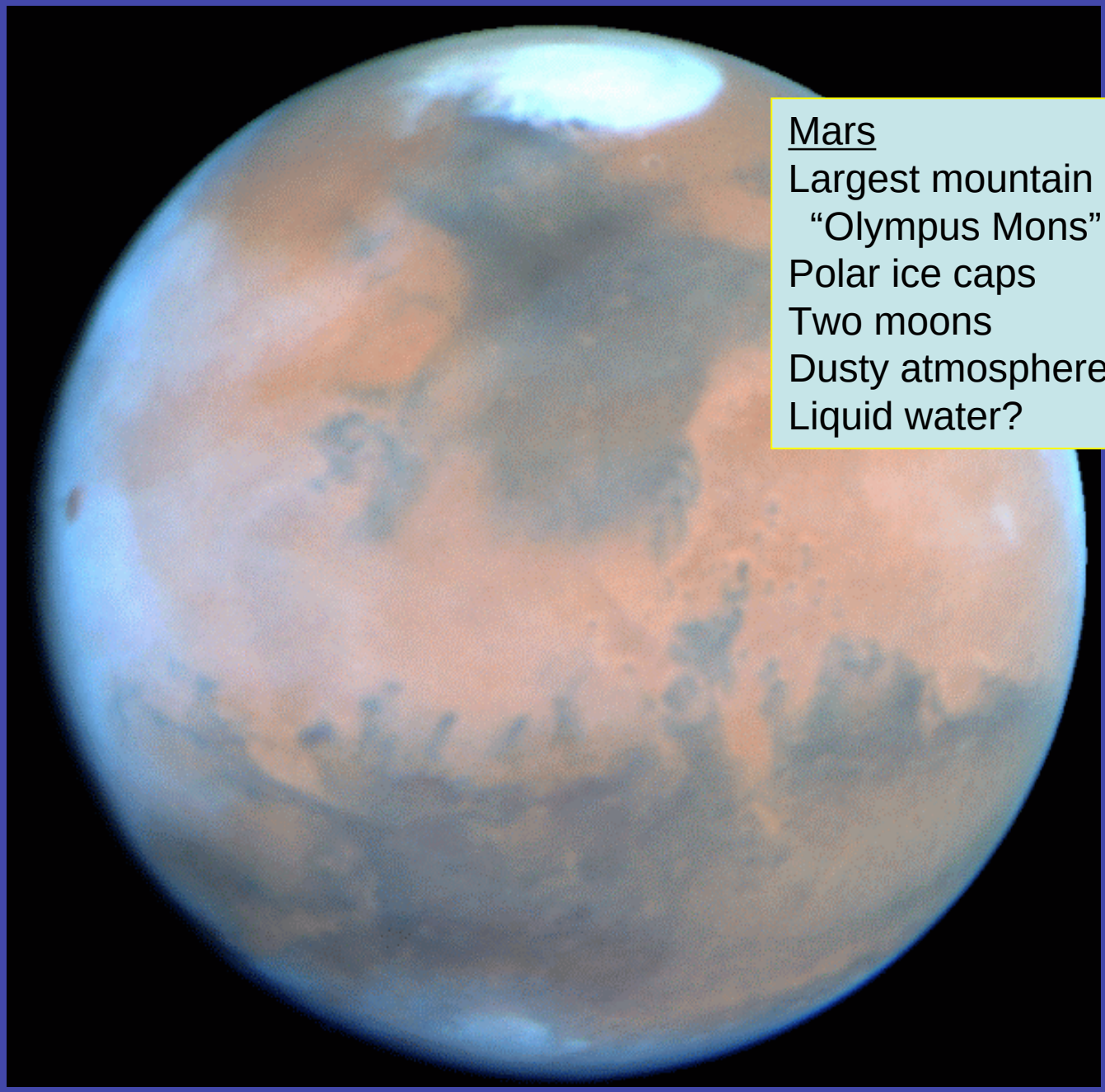
Hottest planet, biggest Greenhouse effect (463°C)

Active volcanism, plate tectonics?

No natural satellites



Earth
Largest rocky planet
One natural satellite: Moon
Polar ice caps
Fe, O, Si, Mg, Ni, Ca, Al
Axial tilt 23.5°
71% of surface covered by oceans
Average temperature 14°C



Mars

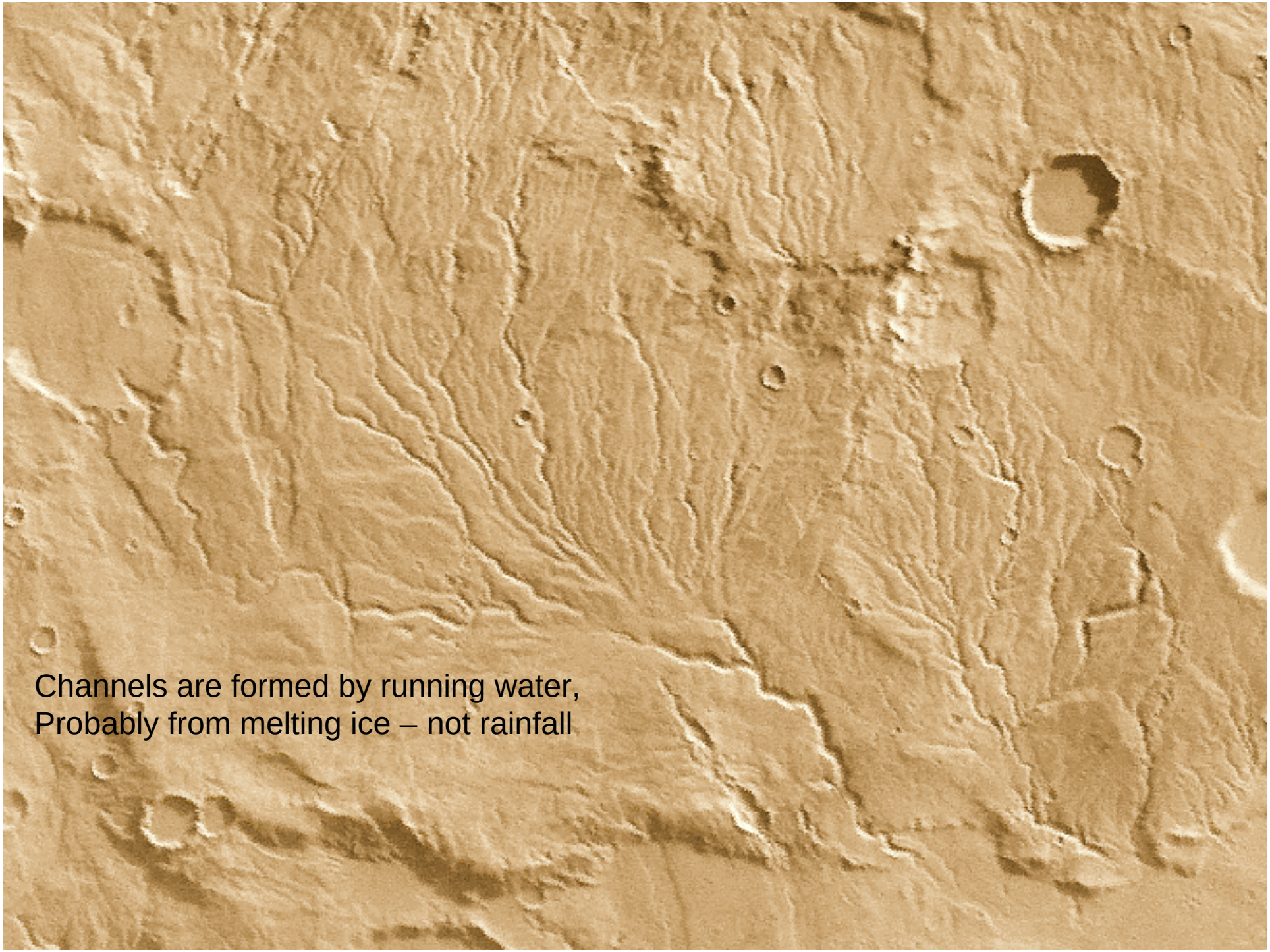
Largest mountain in solar system:
"Olympus Mons"

Polar ice caps

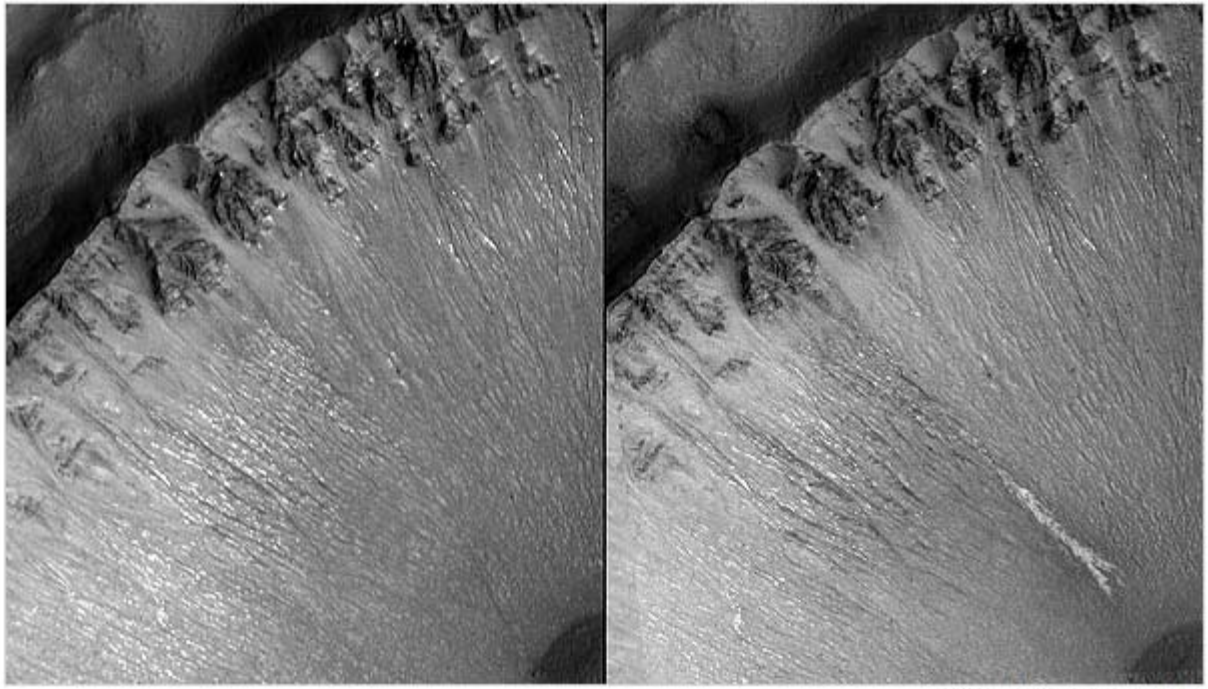
Two moons

Dusty atmosphere gives red color

Liquid water?


Channels are formed by running water,
Probably from melting ice – not rainfall

Mars Spacecraft Finds Evidence of Water



NASA via AFP --Getty Images

Scientists compared images of the Martian surface taken seven years ago, left, and in Sept. 2005, right, and found evidence suggesting liquid water trickling down crater walls.

By WARREN E. LEARY
Published: December 6, 2006

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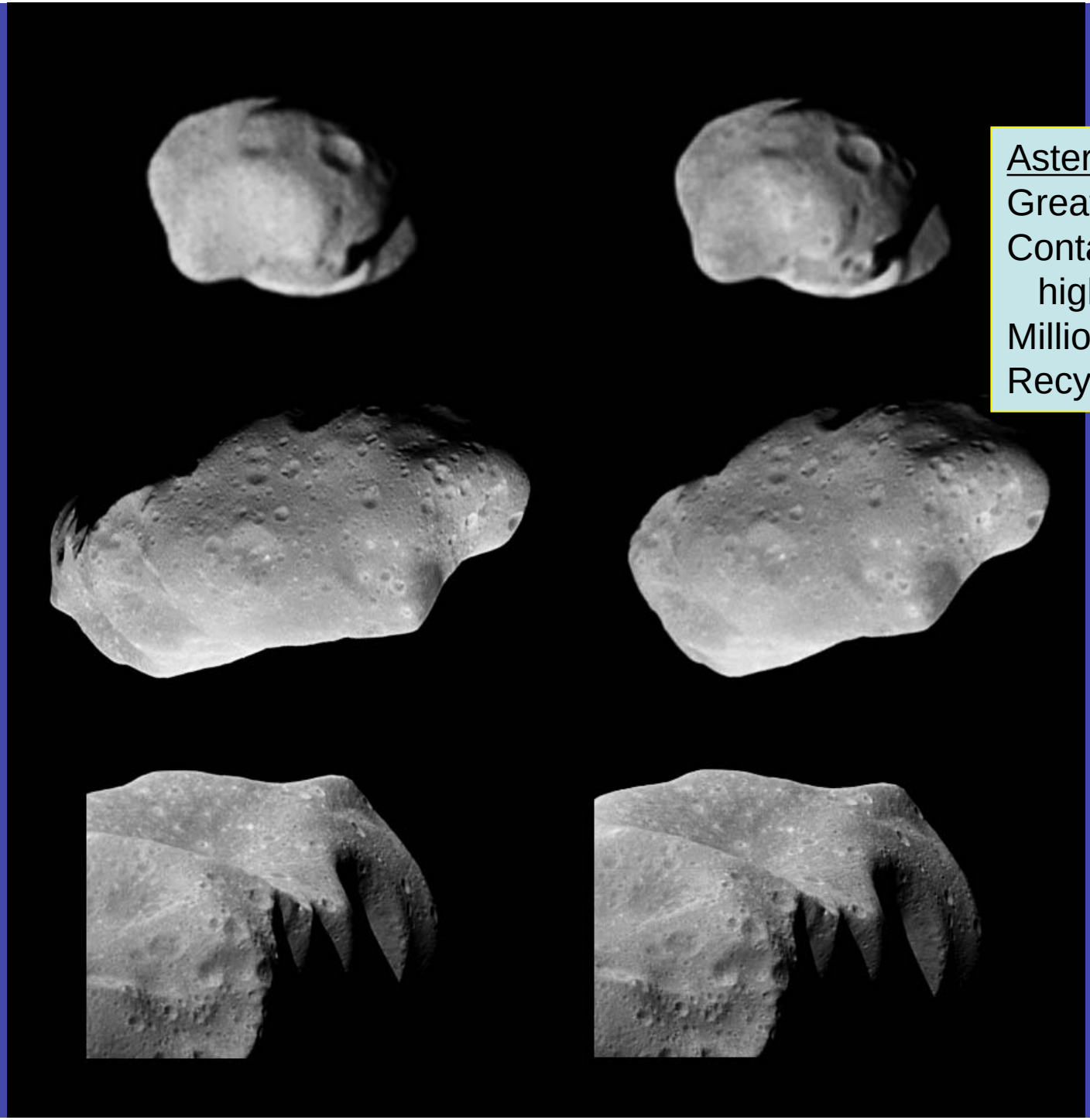
WASHINGTON, Dec. 6 — Pictures of Martian gullies taken years apart strongly suggest that liquid water still flows on the surface of the planet, scientists announced on Wednesday.

Related

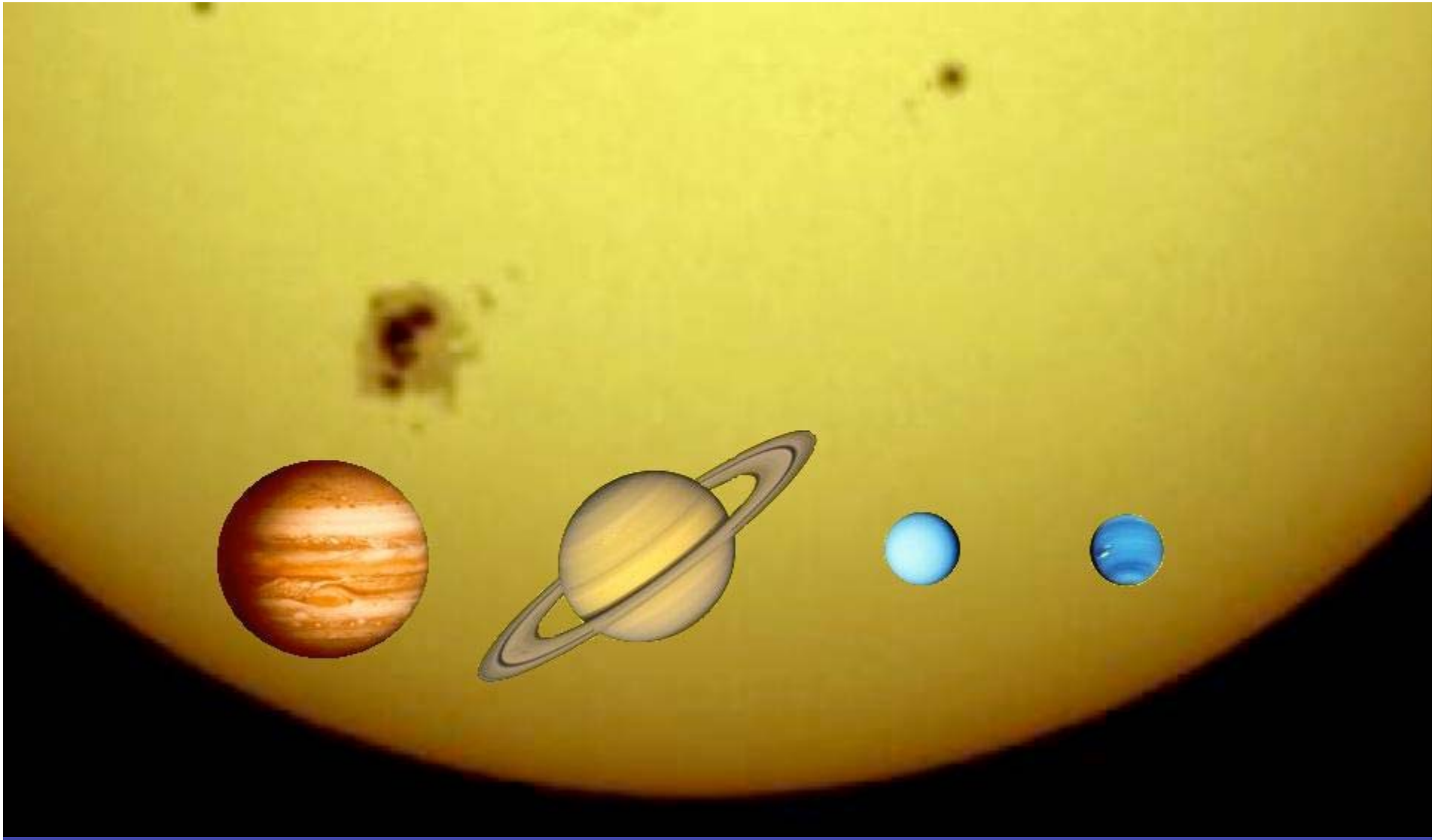
Life on Mars? Could Be, but How Will They Tell? (March 29, 2003)

Complete Coverage: Mars

The photographs by NASA's Mars Global Surveyor spacecraft, which fell silent last month after almost 10 years of observing the planet from orbit, show what appear to be light-colored deposits in two gullies on crater walls. They were not present in earlier photographs

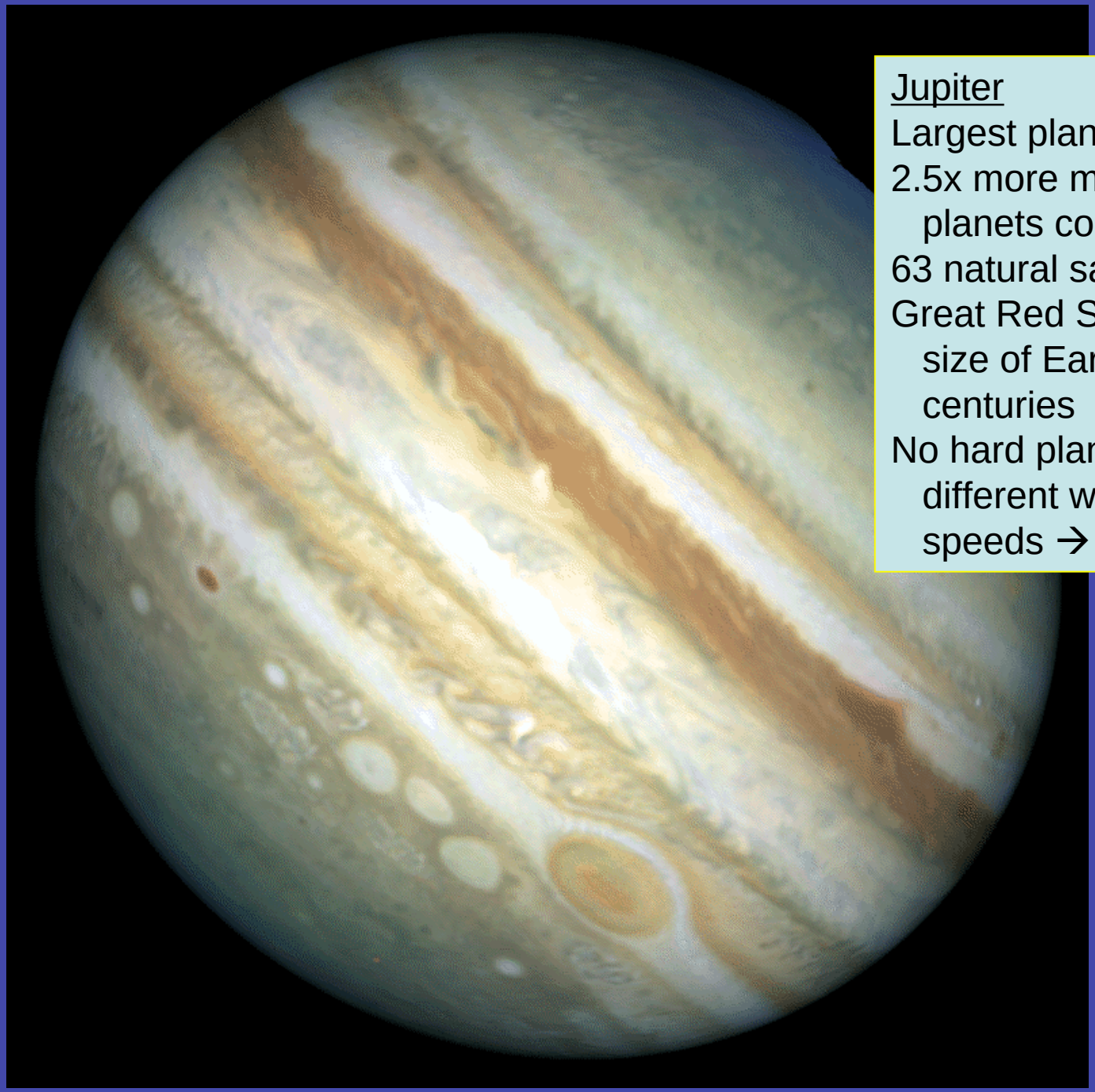


Asteroid Belt
Greatest concentration
Contact velocities too high for accretion
Millions of individuals
Recycling every ~5by



Outer Gas Giants with Sun

(image to scale)



Jupiter

Largest planet in solar system

2.5x more massive than all other planets combined

63 natural satellites

Great Red Spot - A hurricane the size of Earth lasting several centuries

No hard planet may allow for different winds at different speeds → banding



Saturn

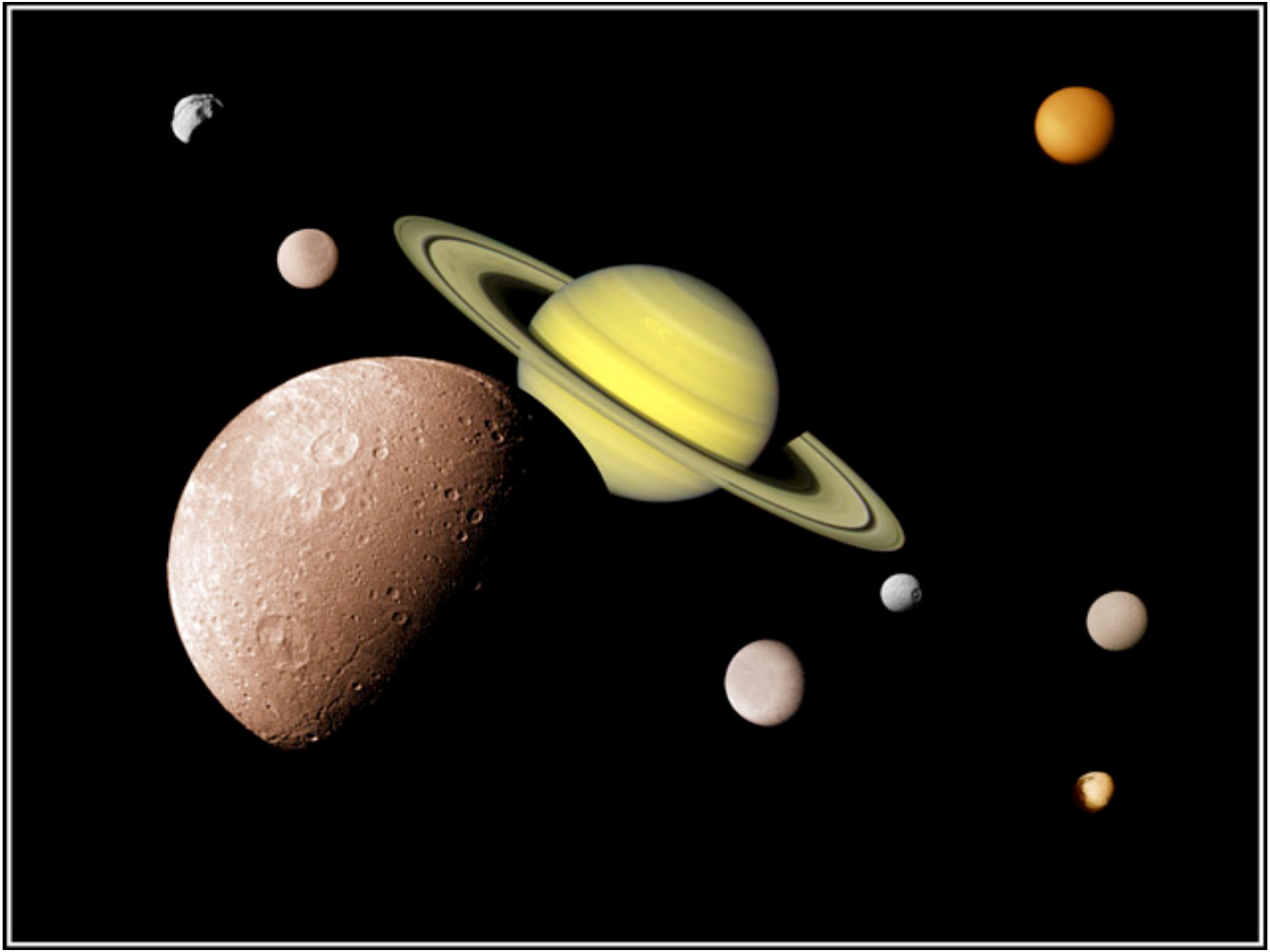
2nd largest planet

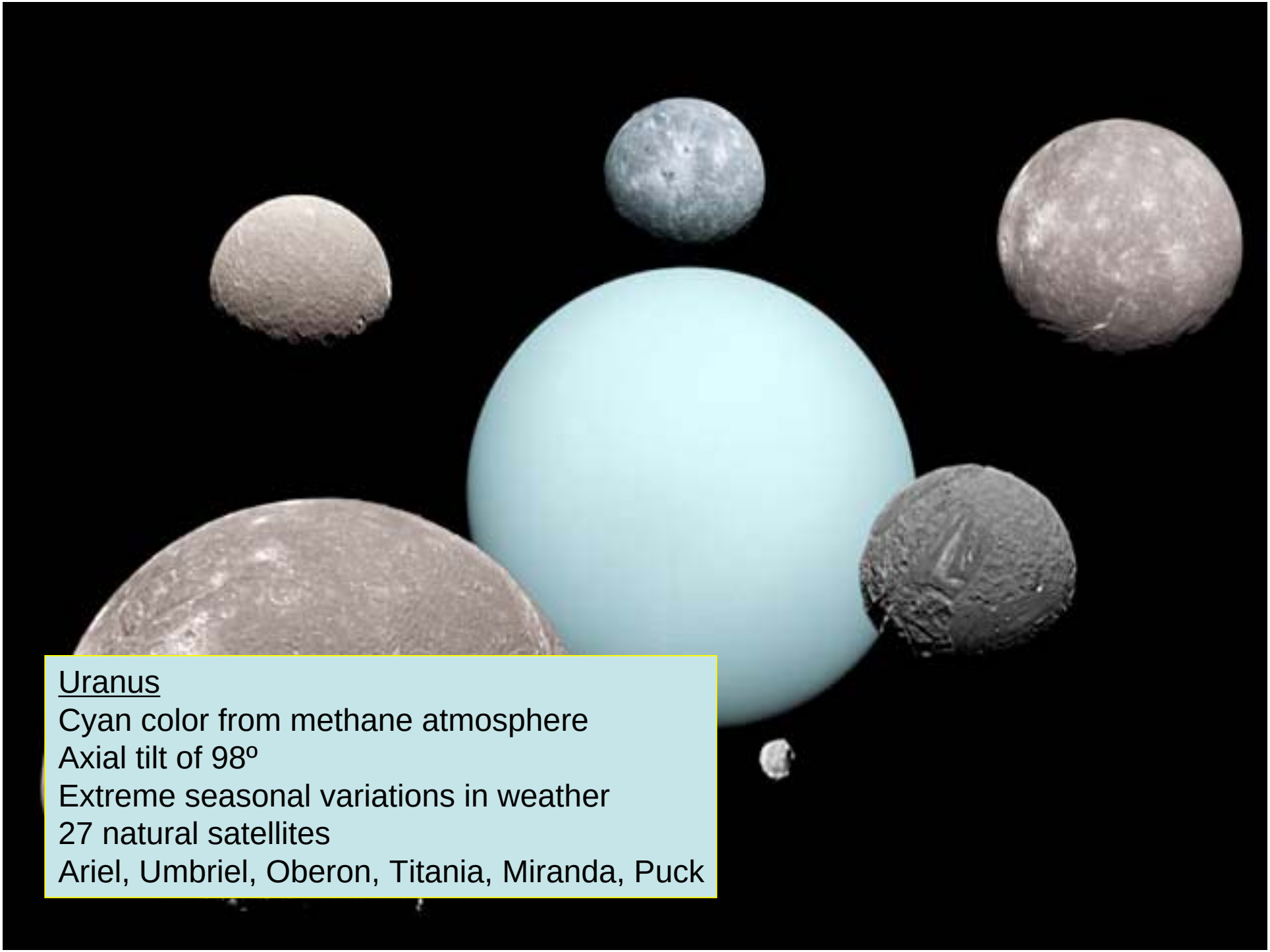
Rings: ice and rocky debris

56 natural satellites

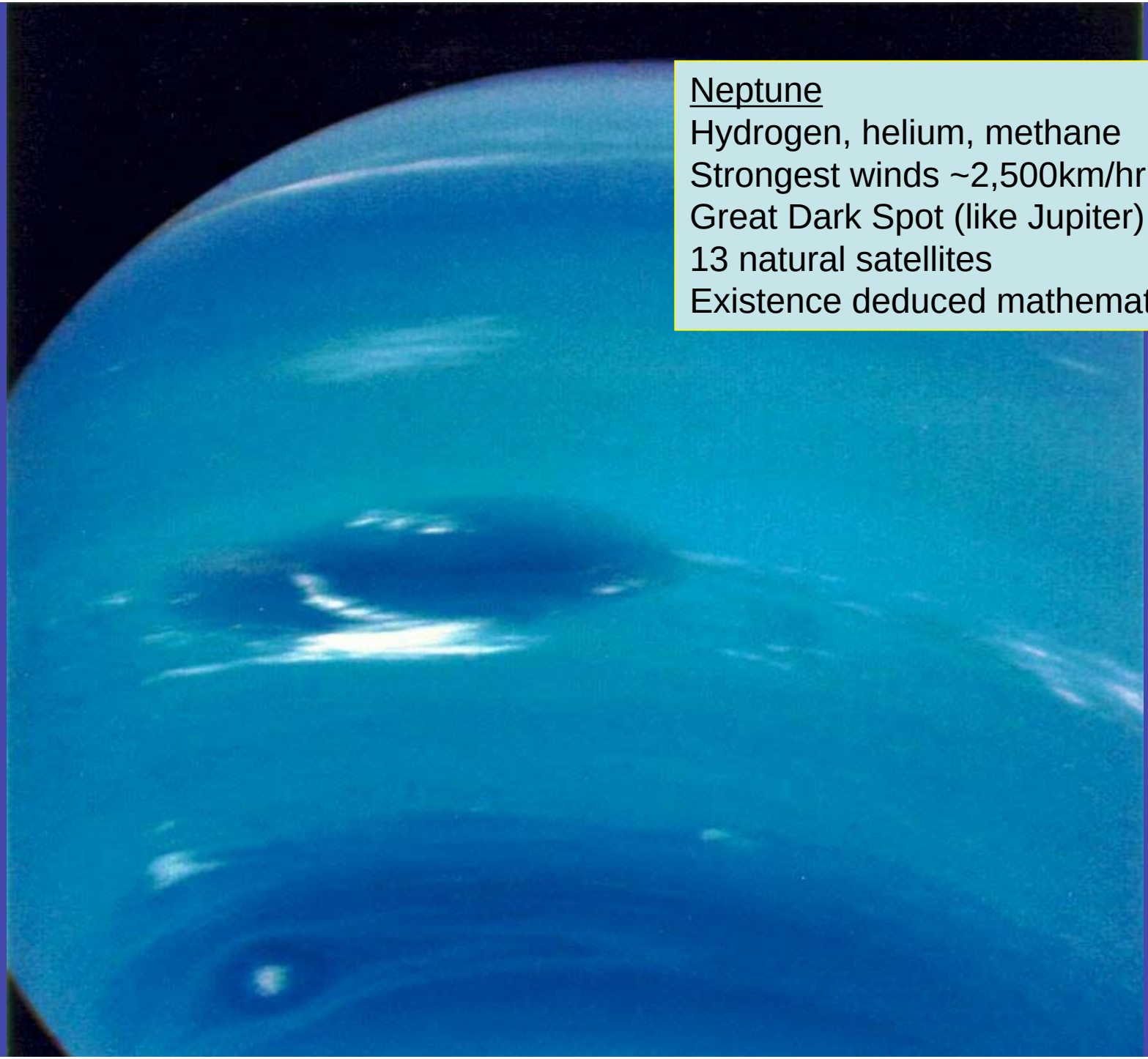
Banding similar to Jupiter

Density of planet less than water





Uranus
Cyan color from methane atmosphere
Axial tilt of 98º
Extreme seasonal variations in weather
27 natural satellites
Ariel, Umbriel, Oberon, Titania, Miranda, Puck



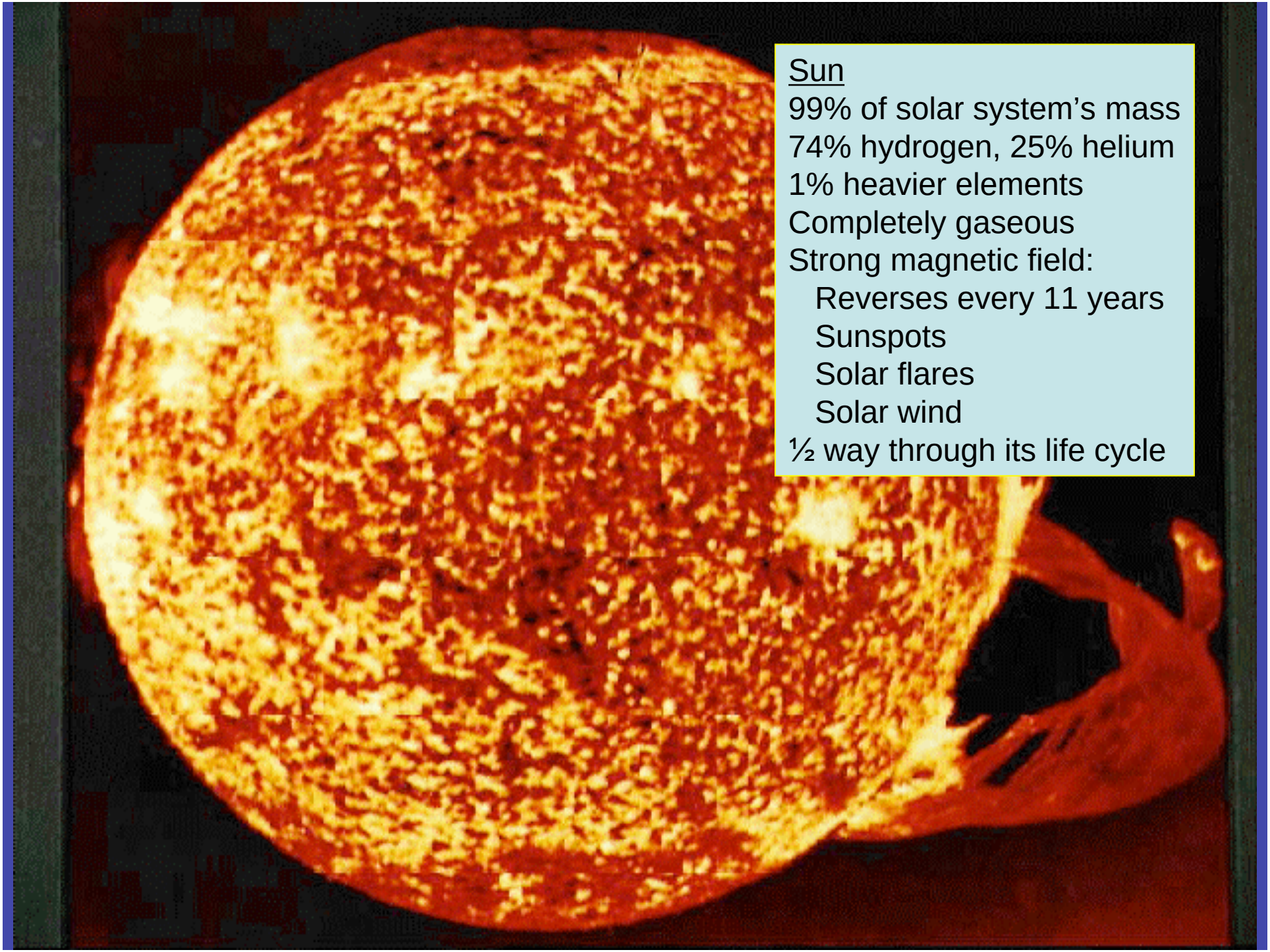
Neptune
Hydrogen, helium, methane
Strongest winds ~2,500km/hr
Great Dark Spot (like Jupiter)
13 natural satellites
Existence deduced mathematically



A rare image of tiny Pluto with its moon Charon, which is slightly smaller.

Pluto's surface is believed to reach temperatures as low as -240°C.

Pluto is
NOT A PLANET!



Sun

99% of solar system's mass

74% hydrogen, 25% helium

1% heavier elements

Completely gaseous

Strong magnetic field:

- Reverses every 11 years
- Sunspots
- Solar flares
- Solar wind

½ way through its life cycle

Early Earth

