Space:
The Final Frontier

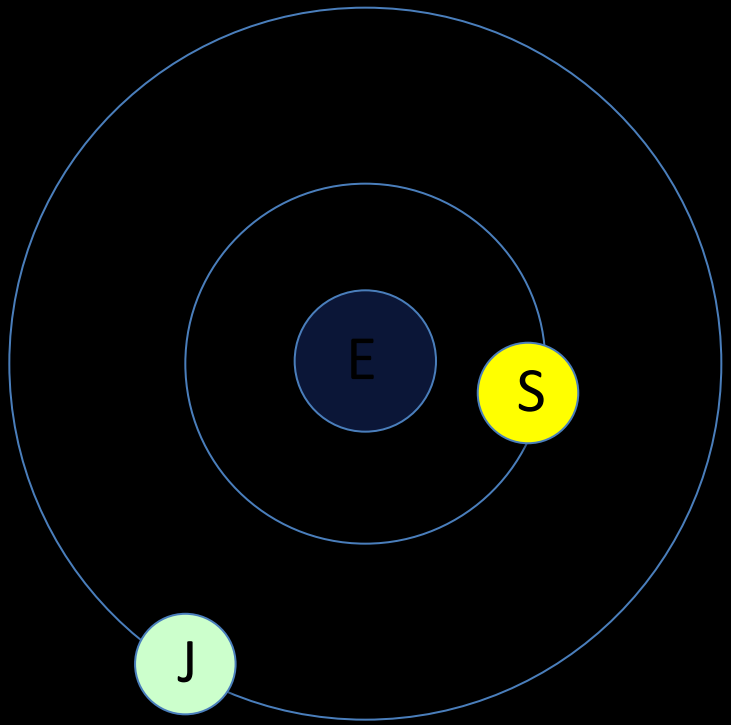
Changing View of the Universe

Our Solar System

Geocentric Universe

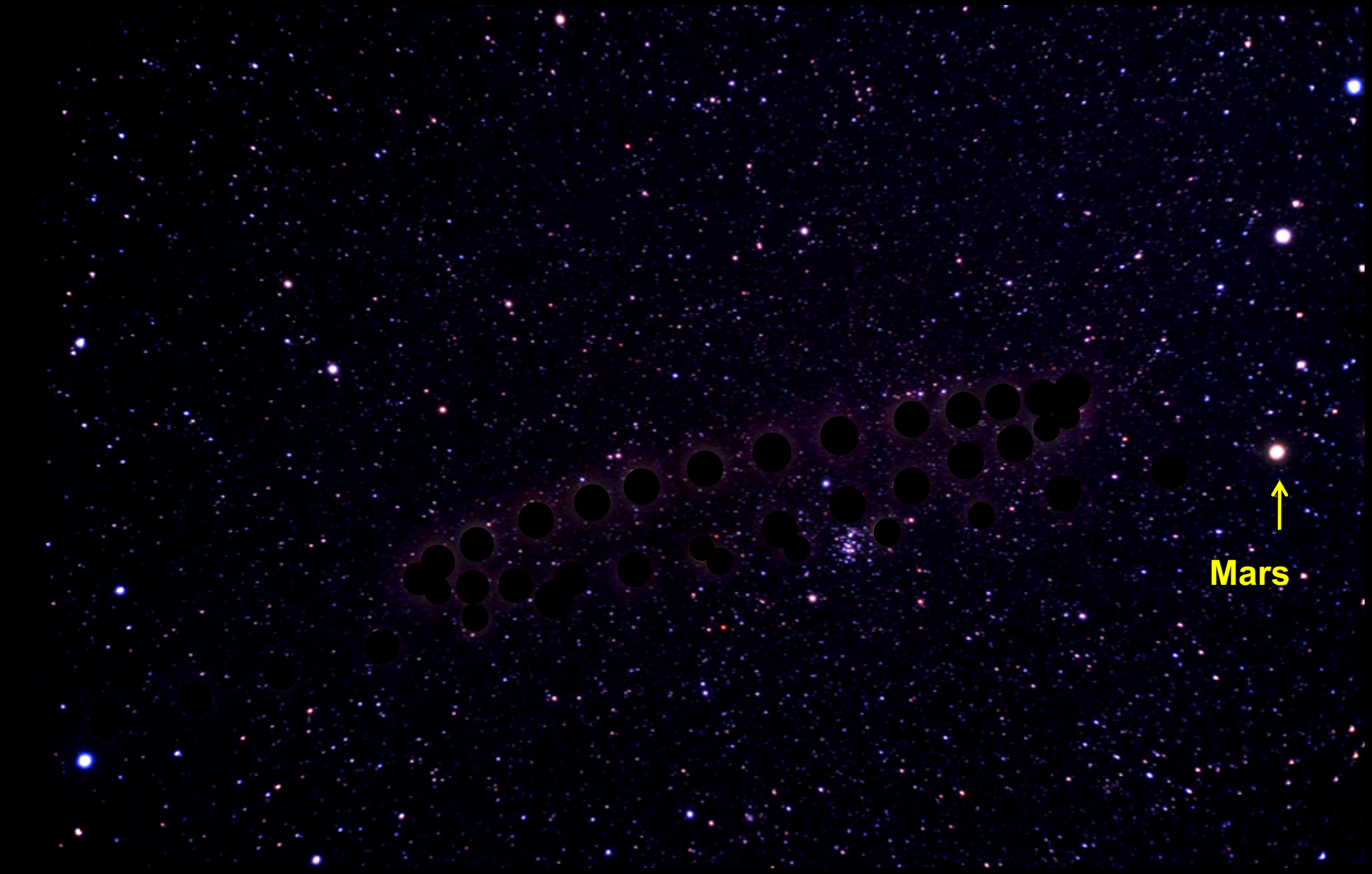


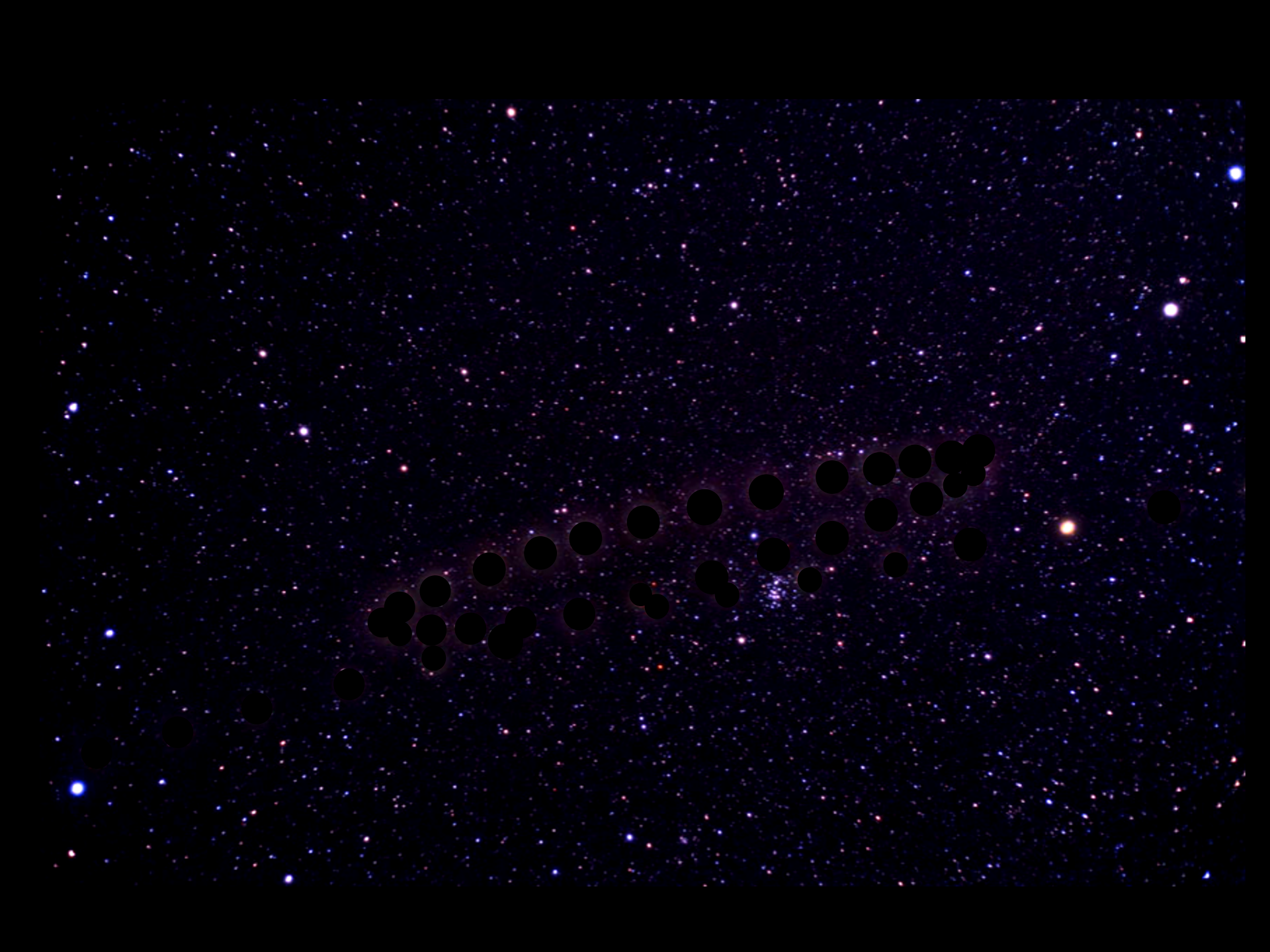
Geocentric Universe

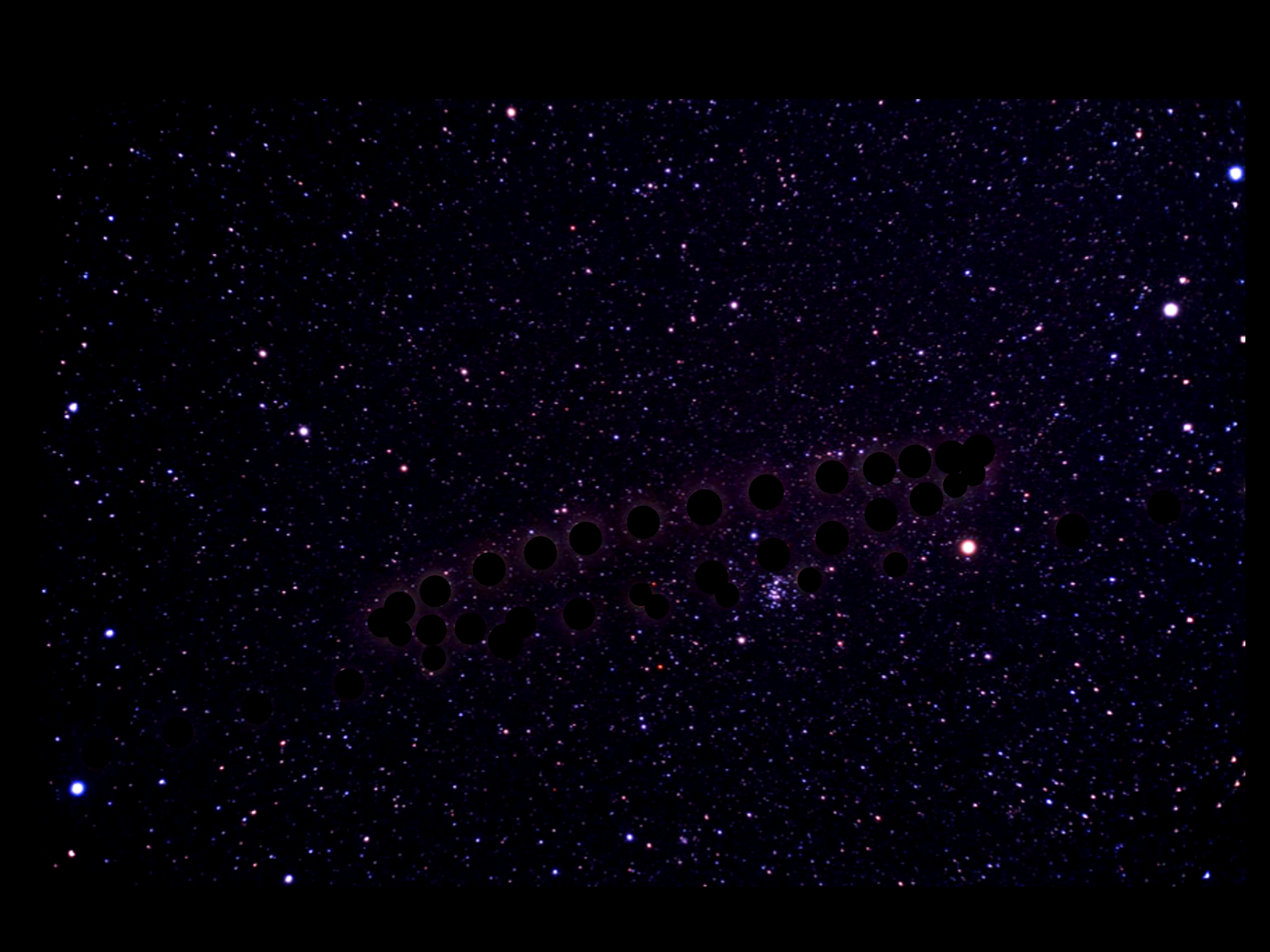


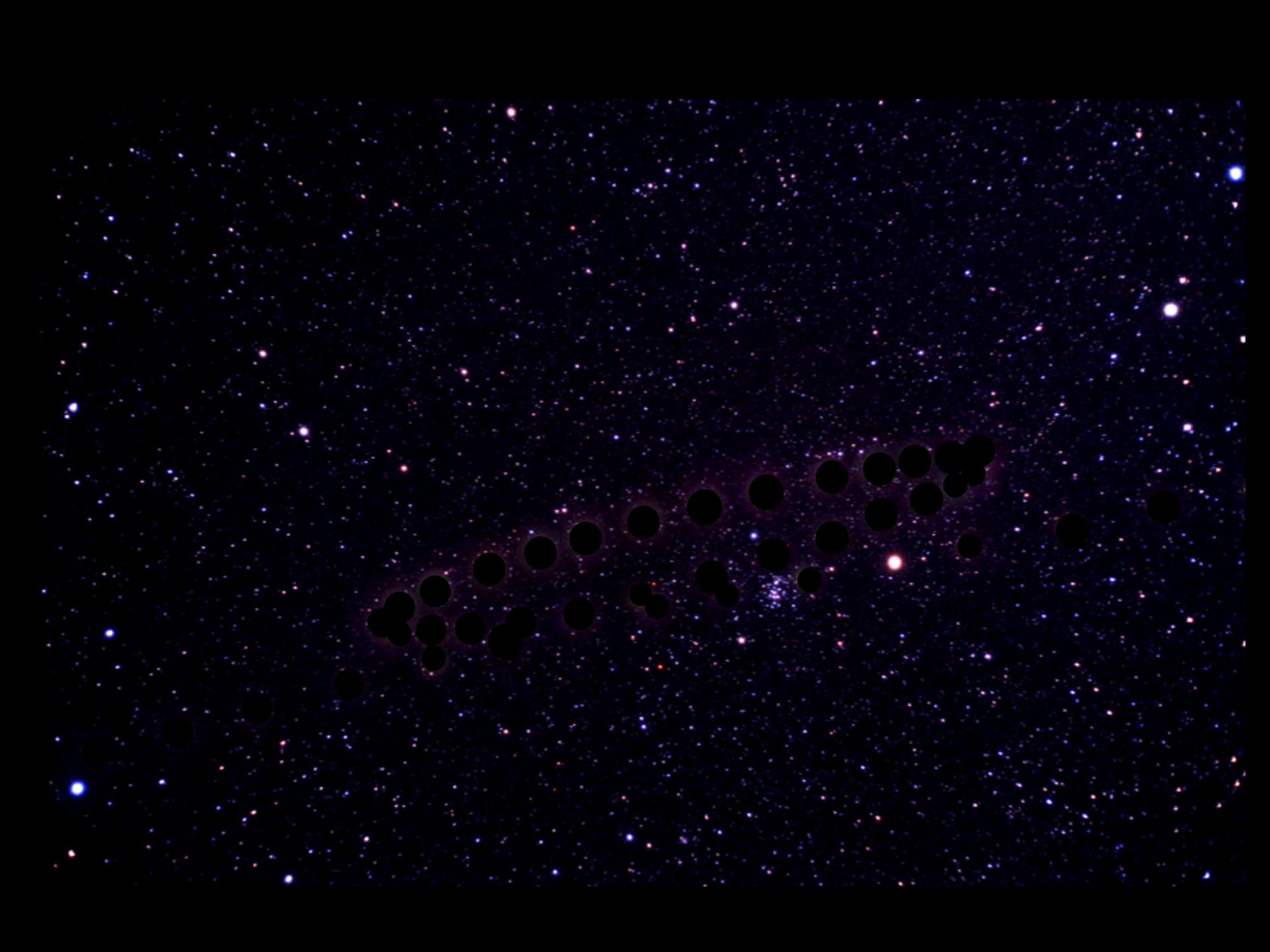
sun and planets move around Earth

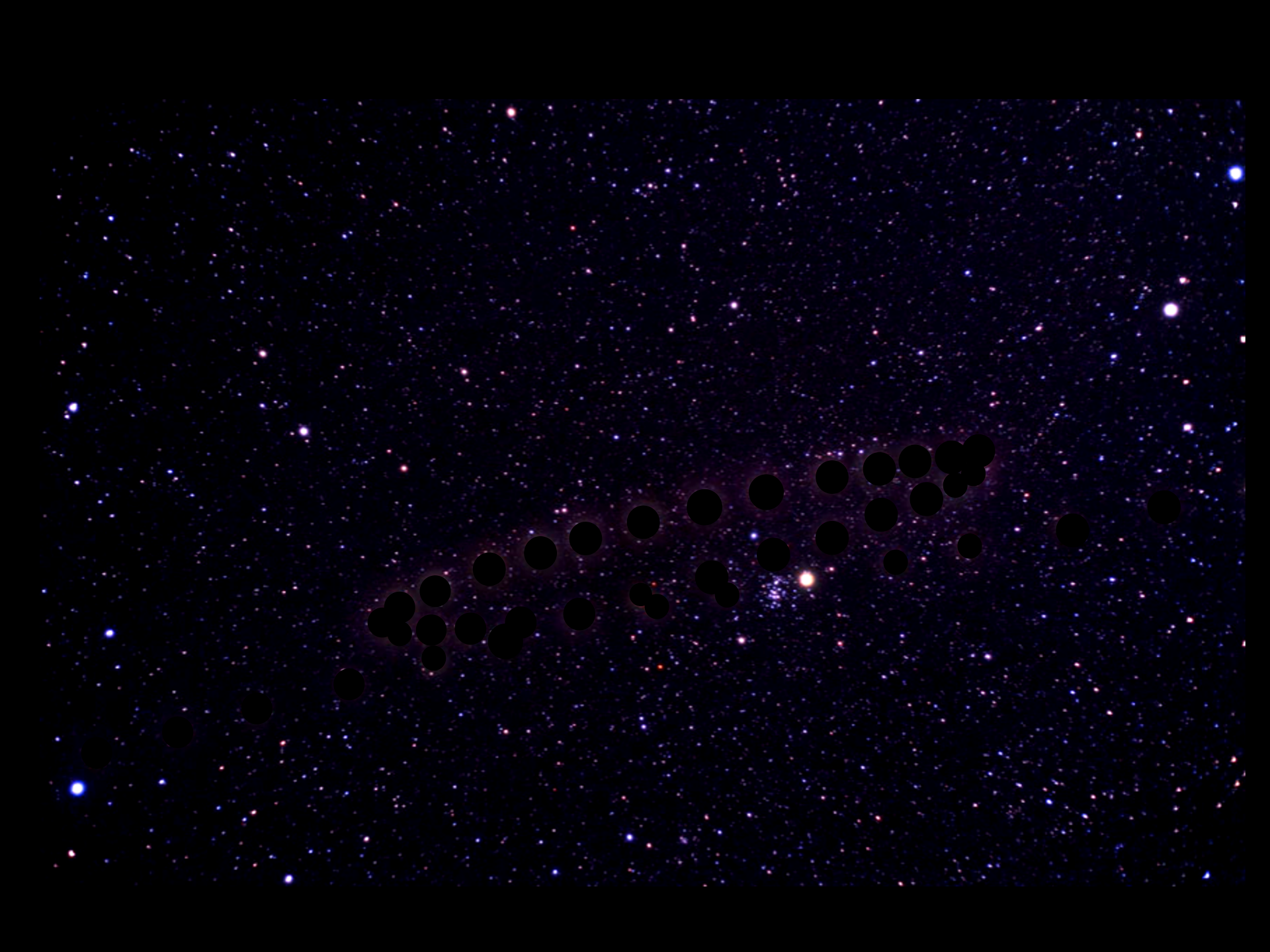
Retrograde Motion of Mars

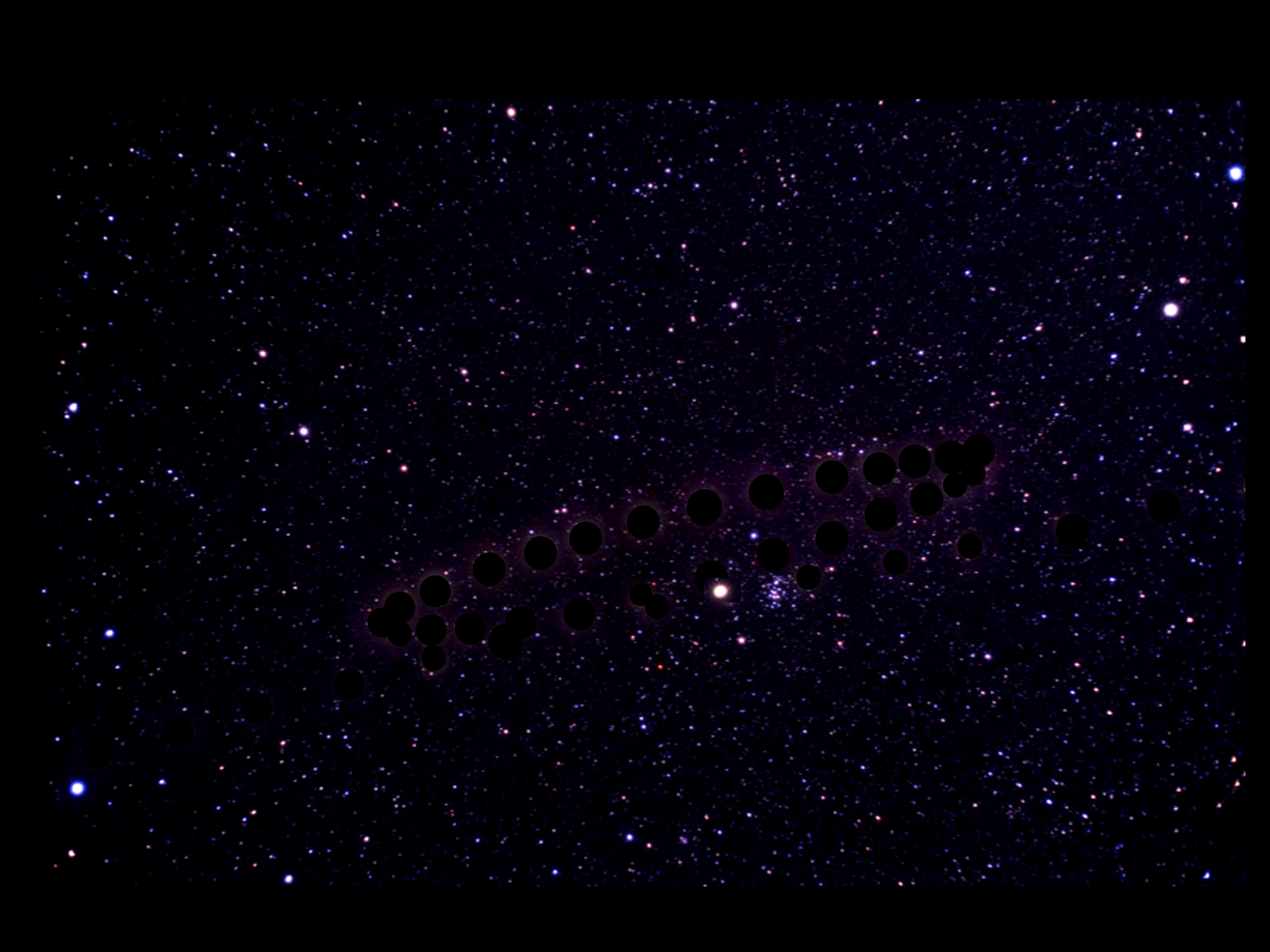


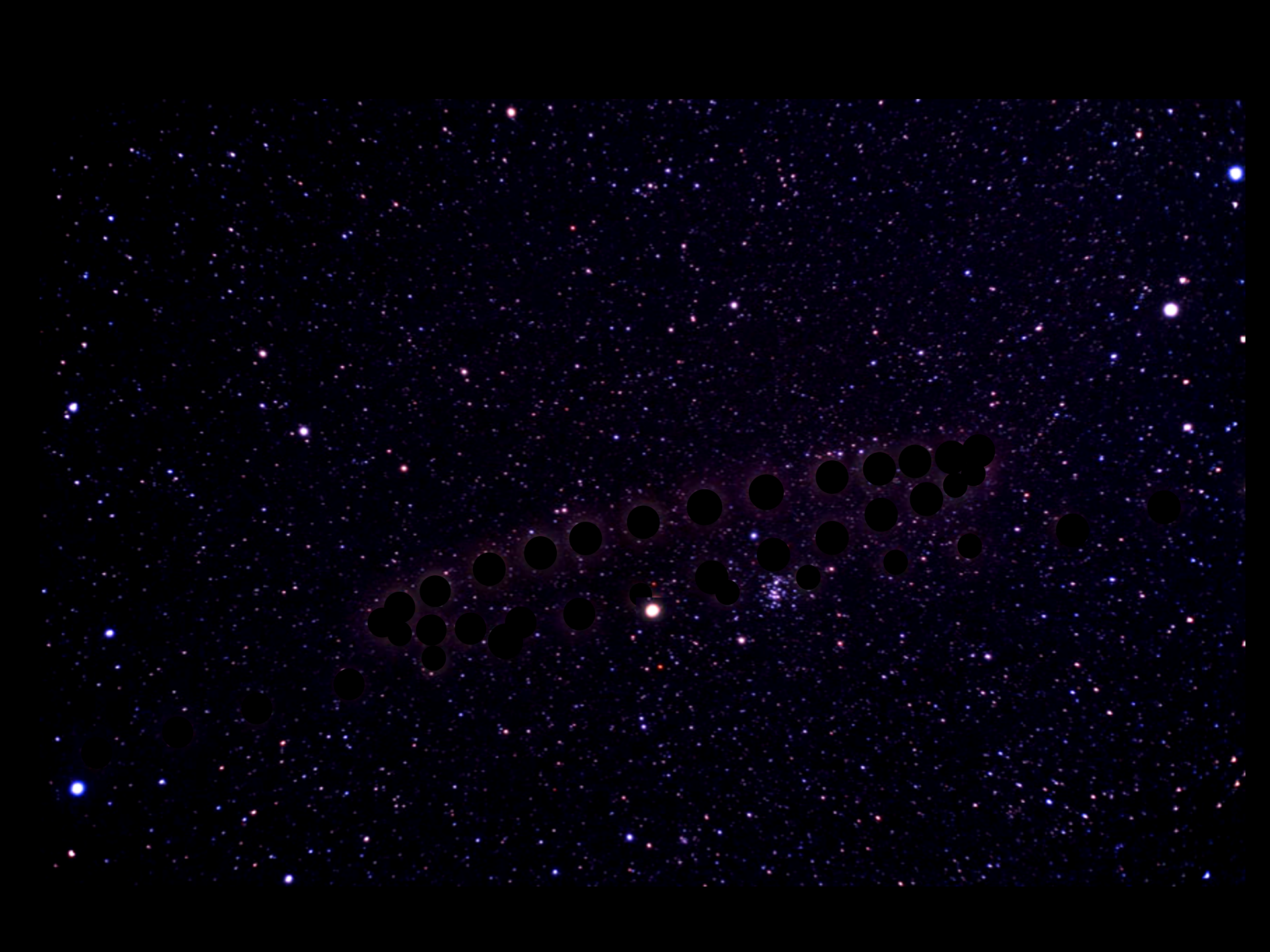








































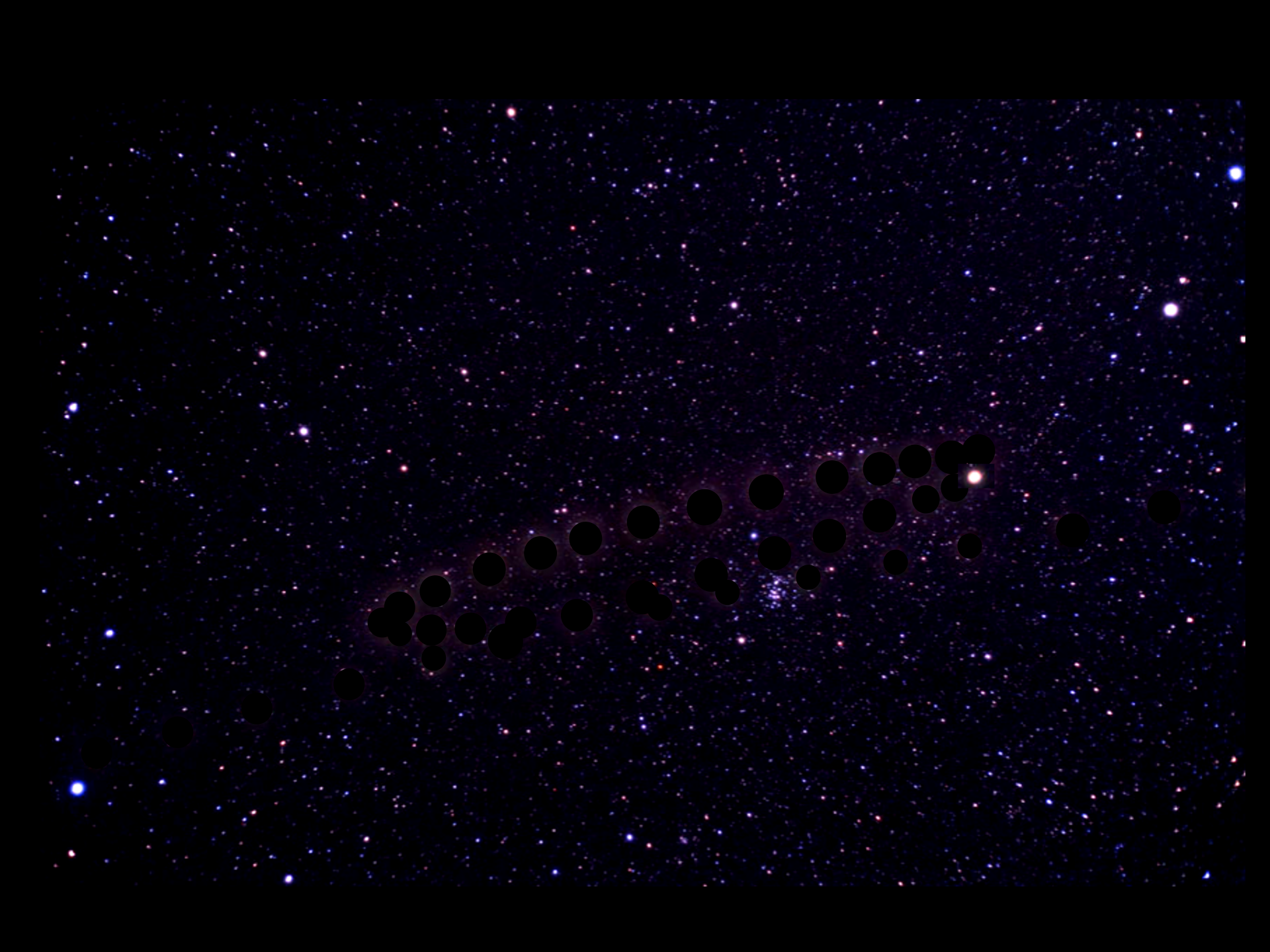








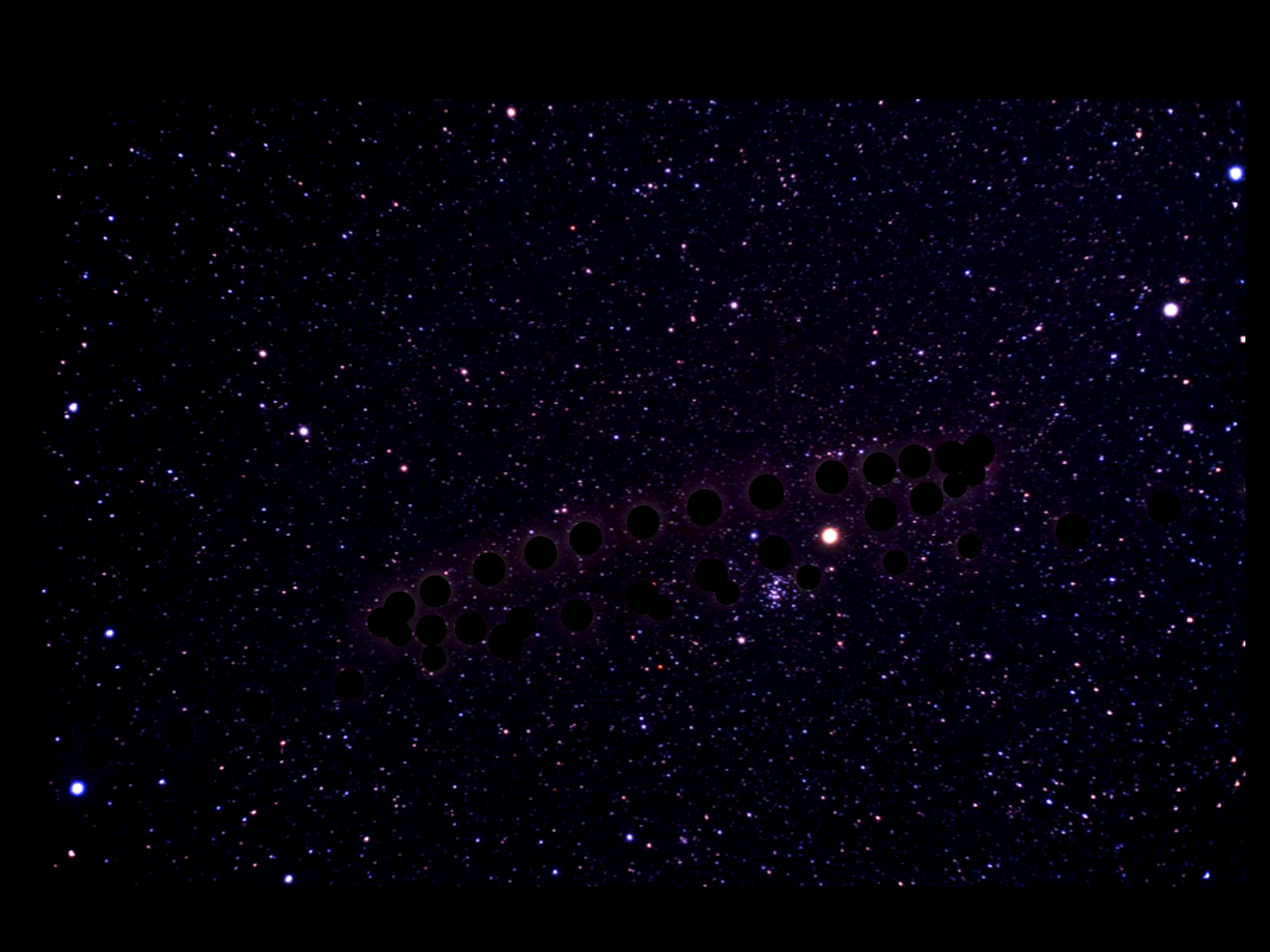


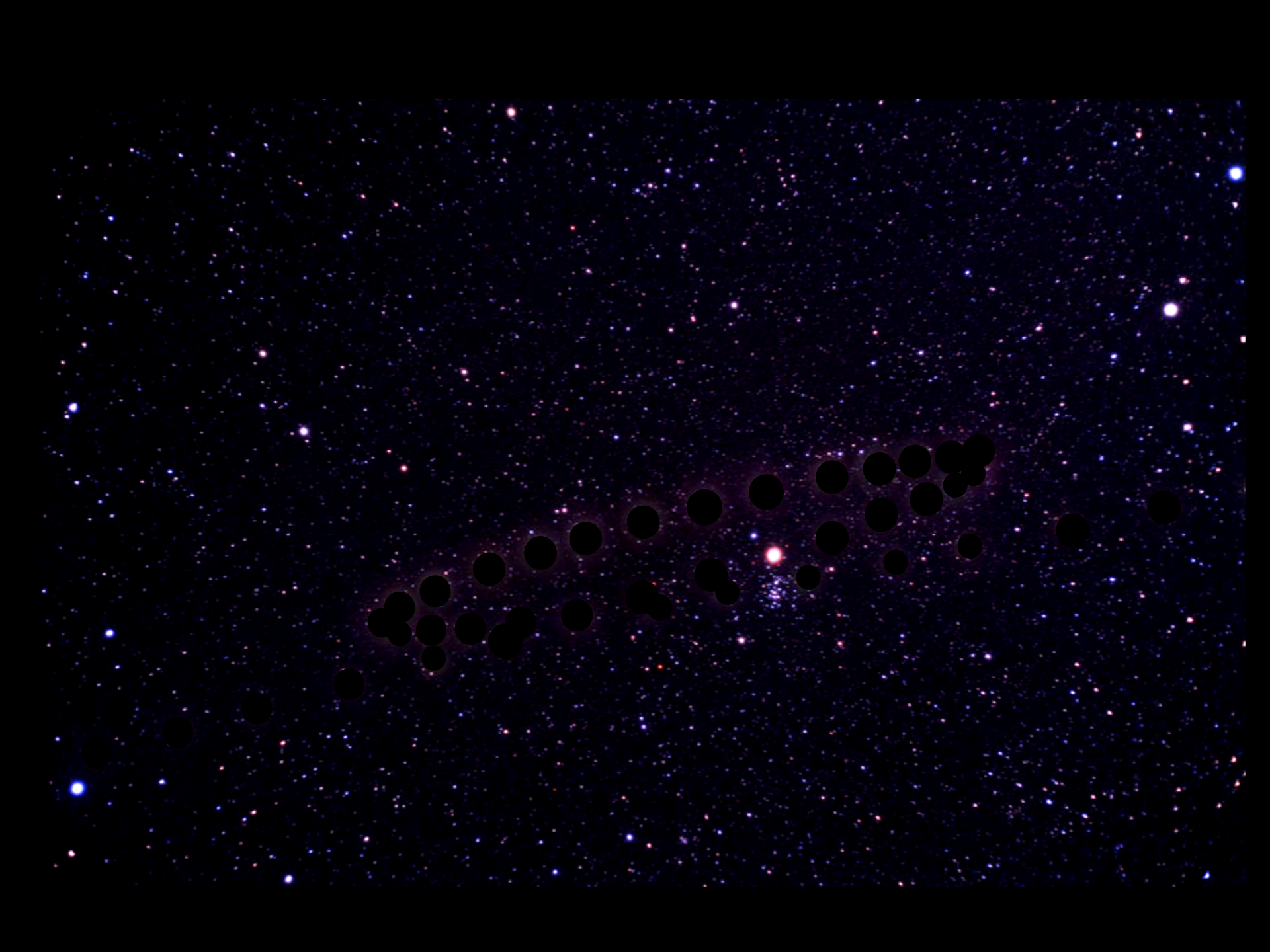


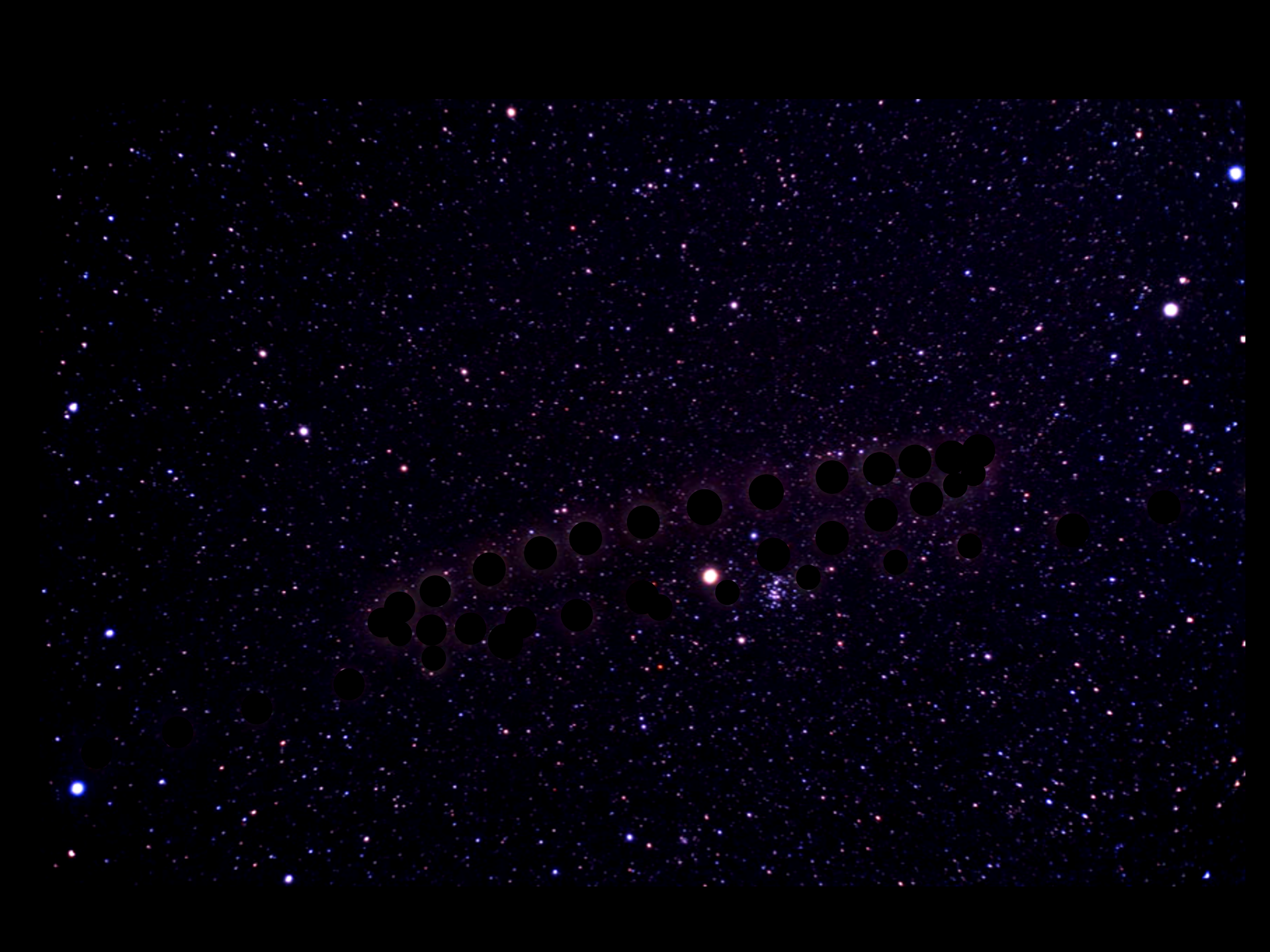




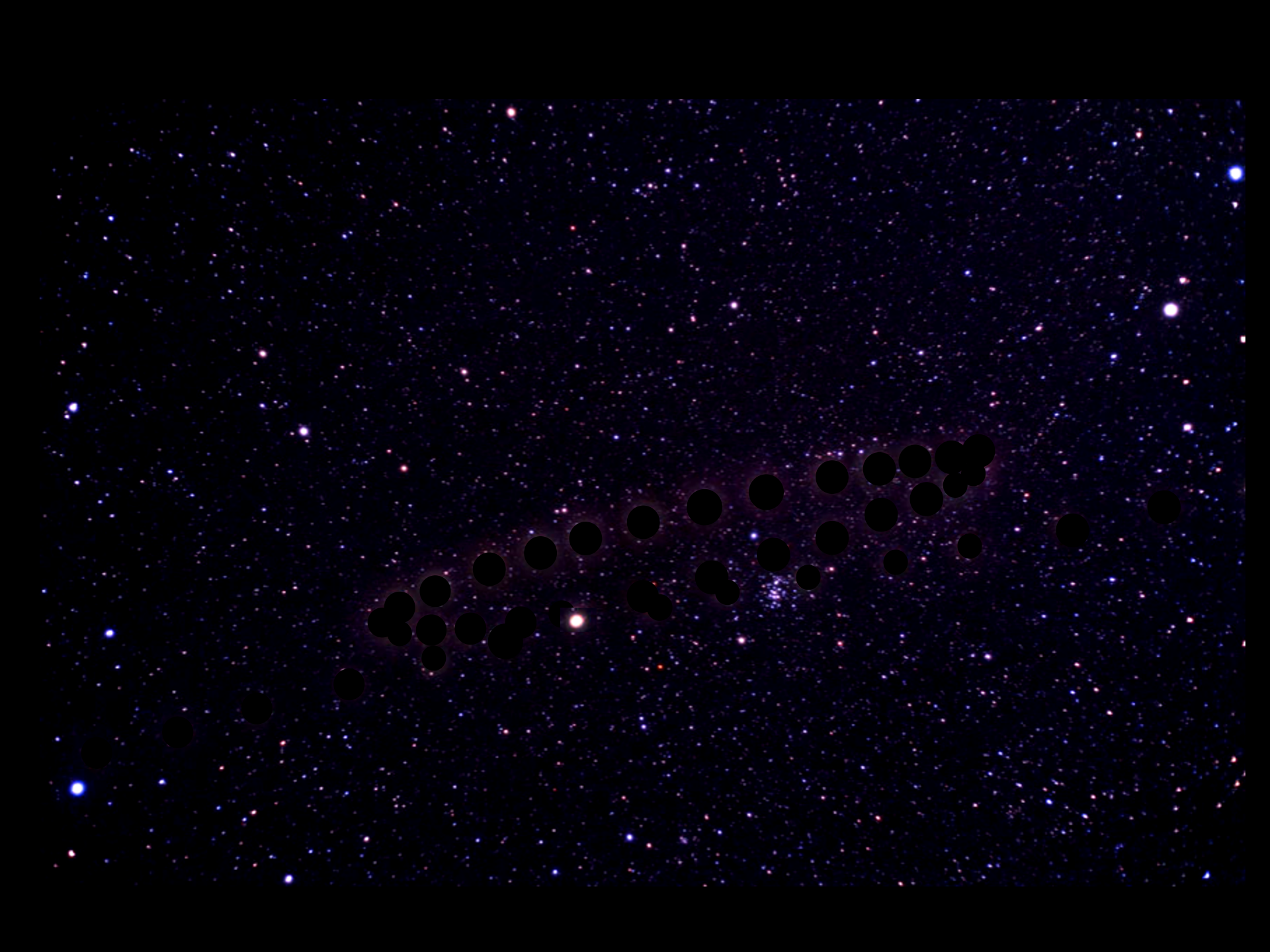


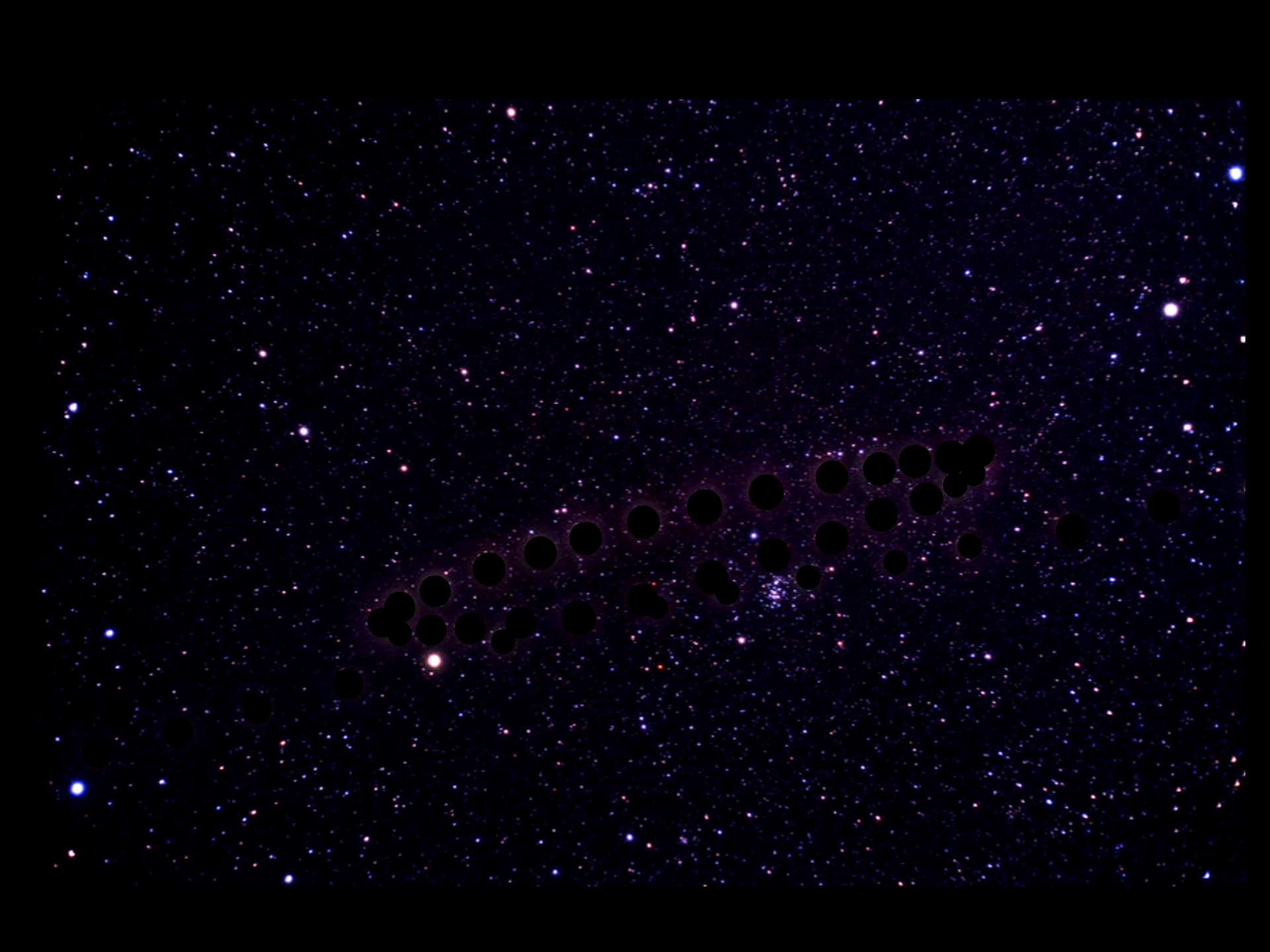


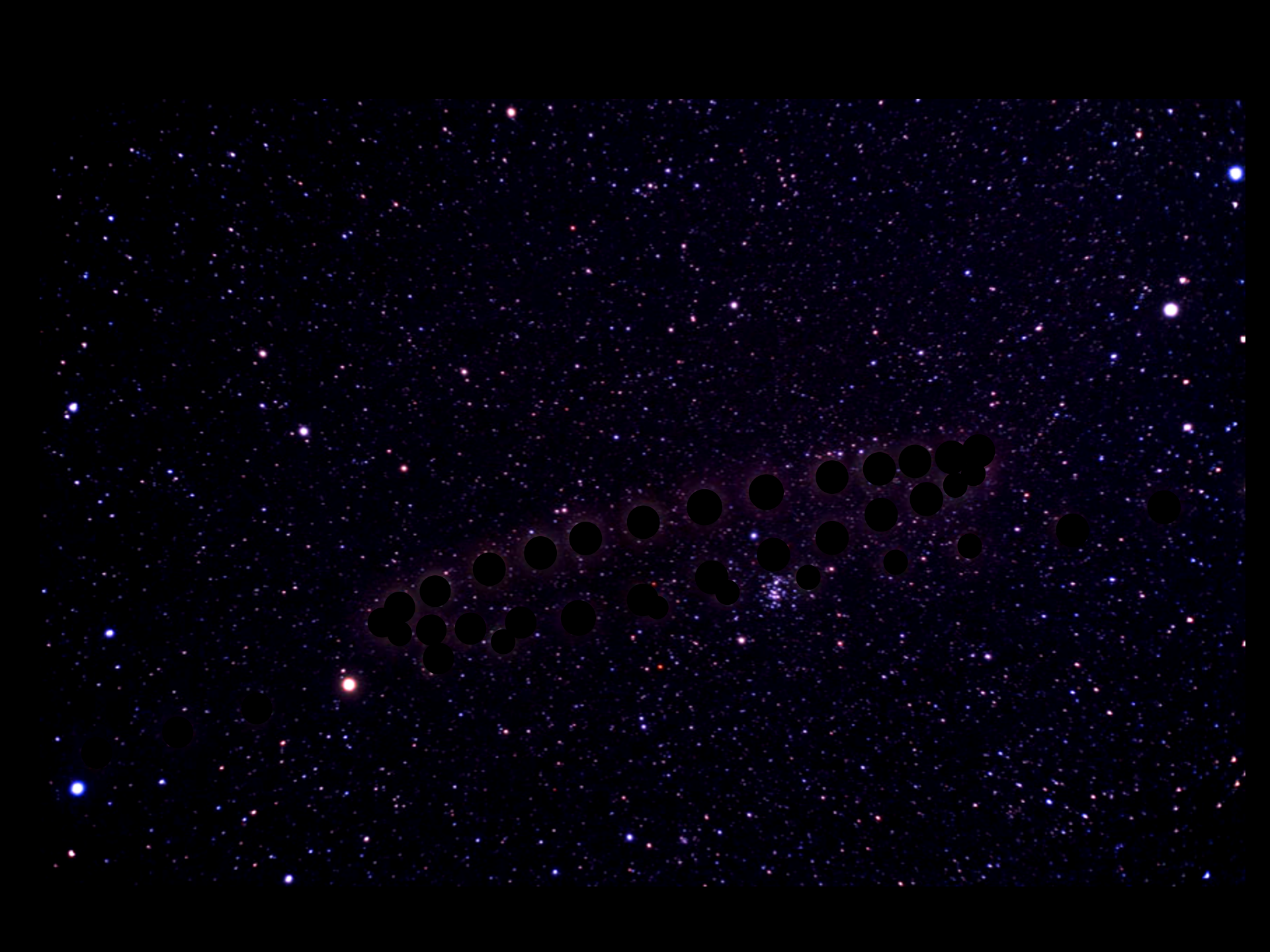


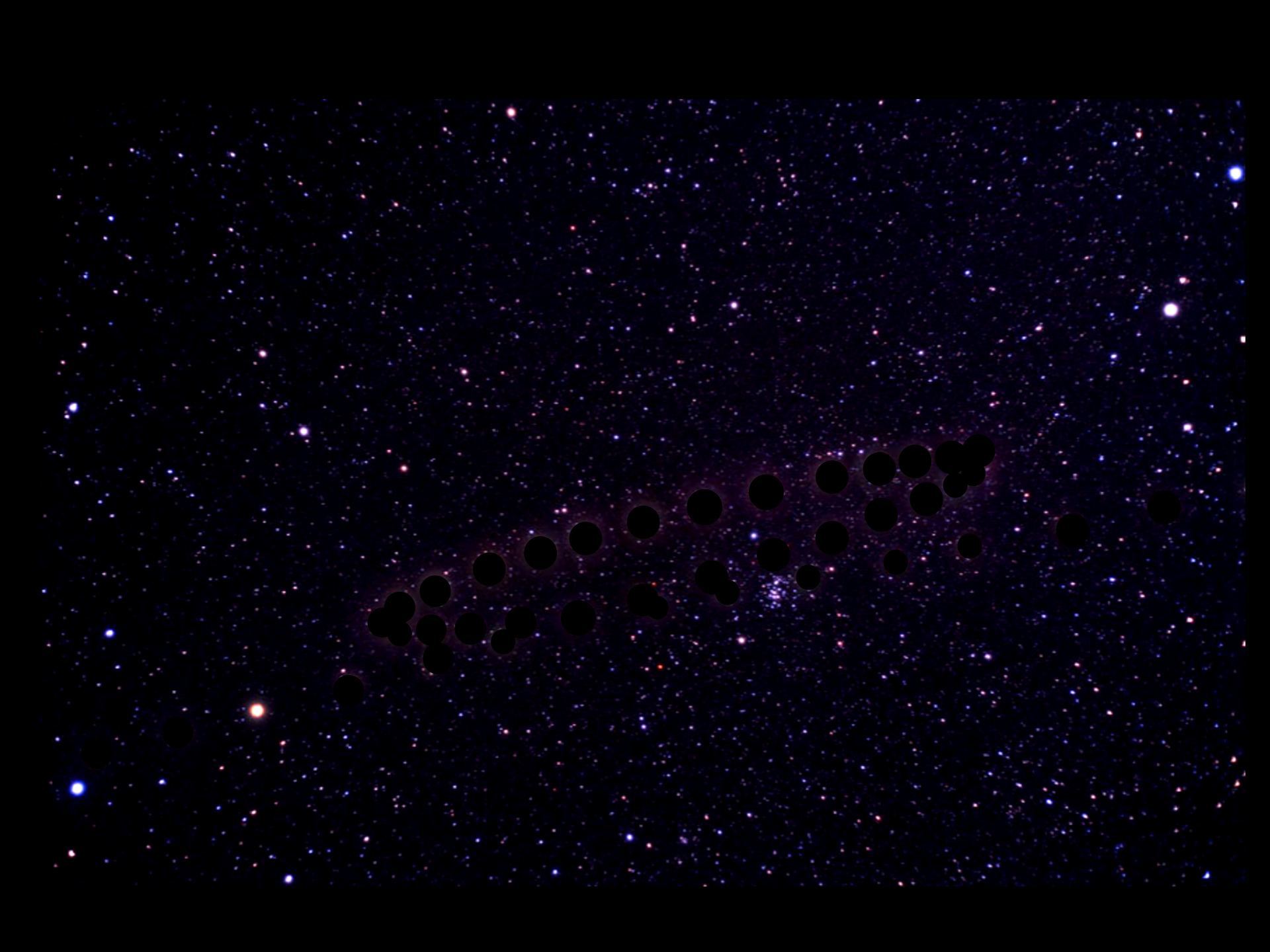


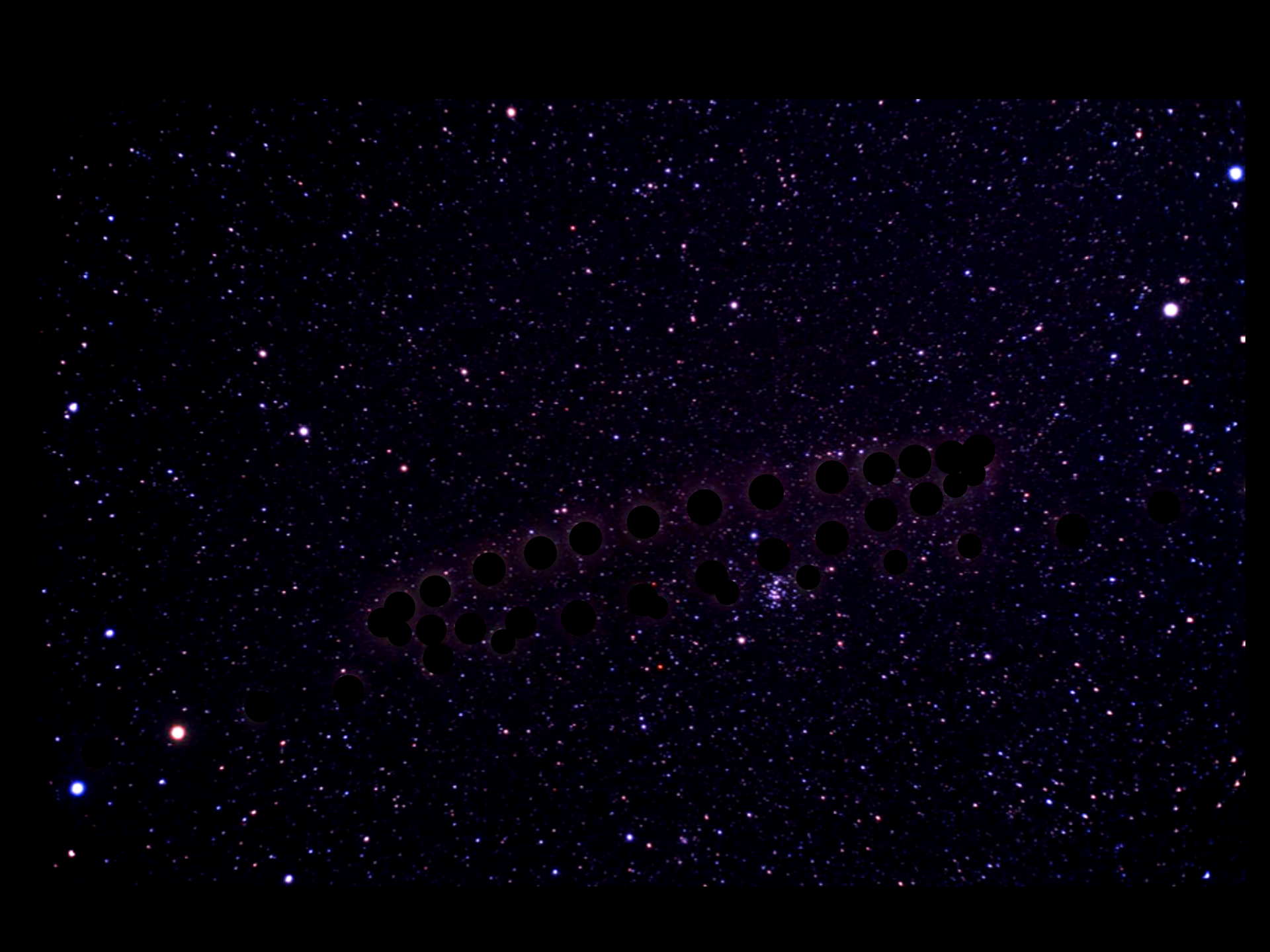


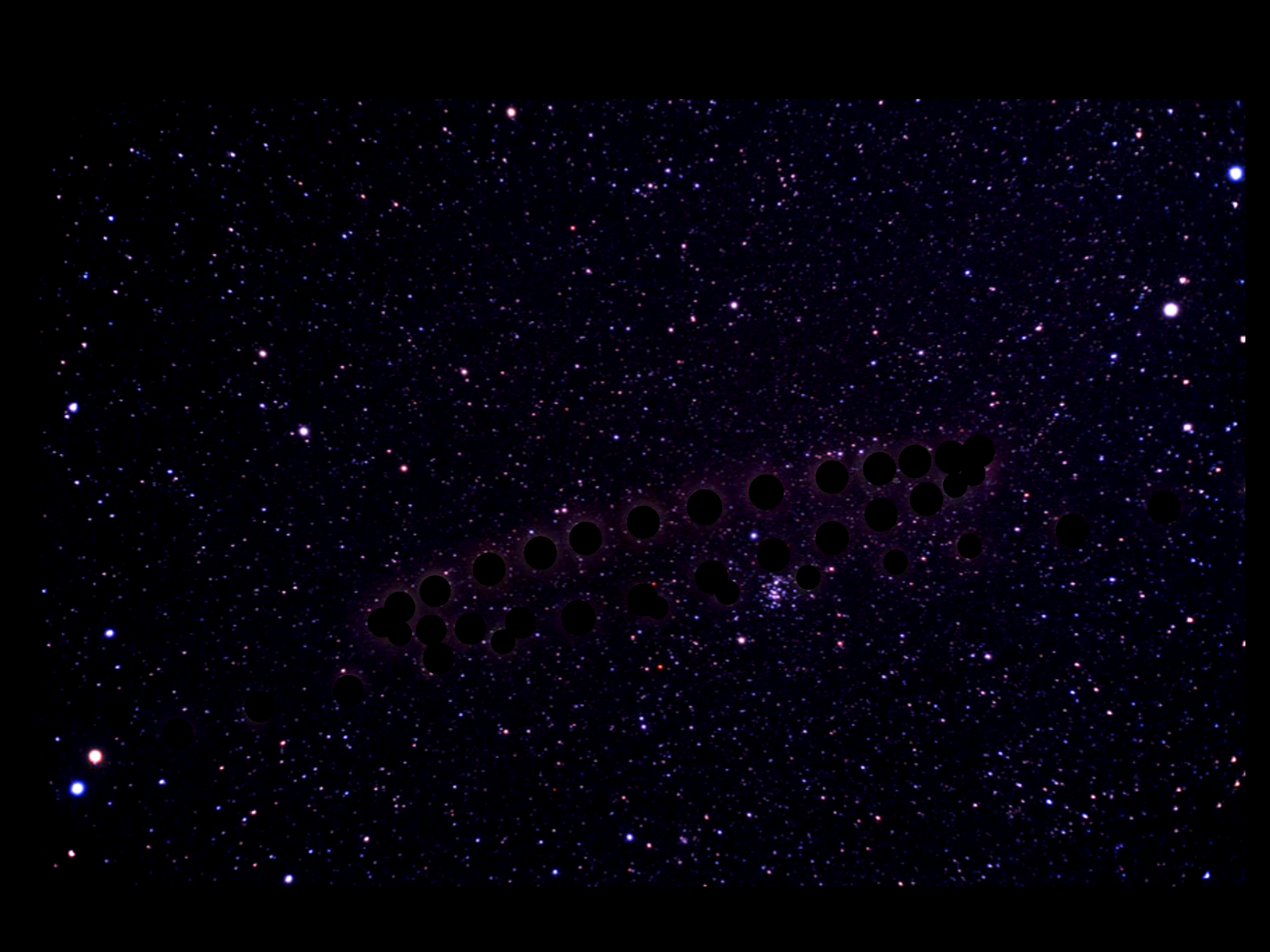


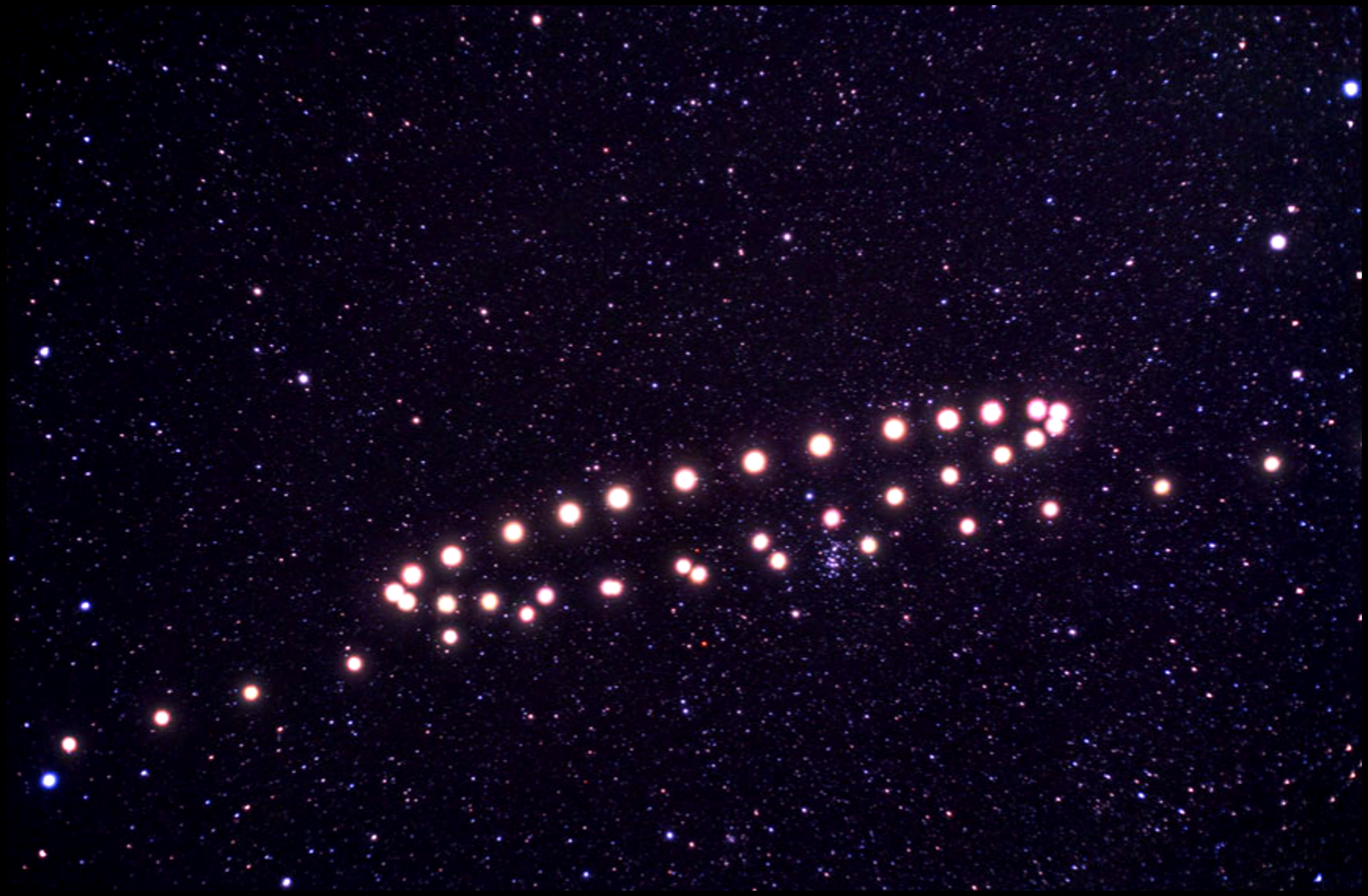




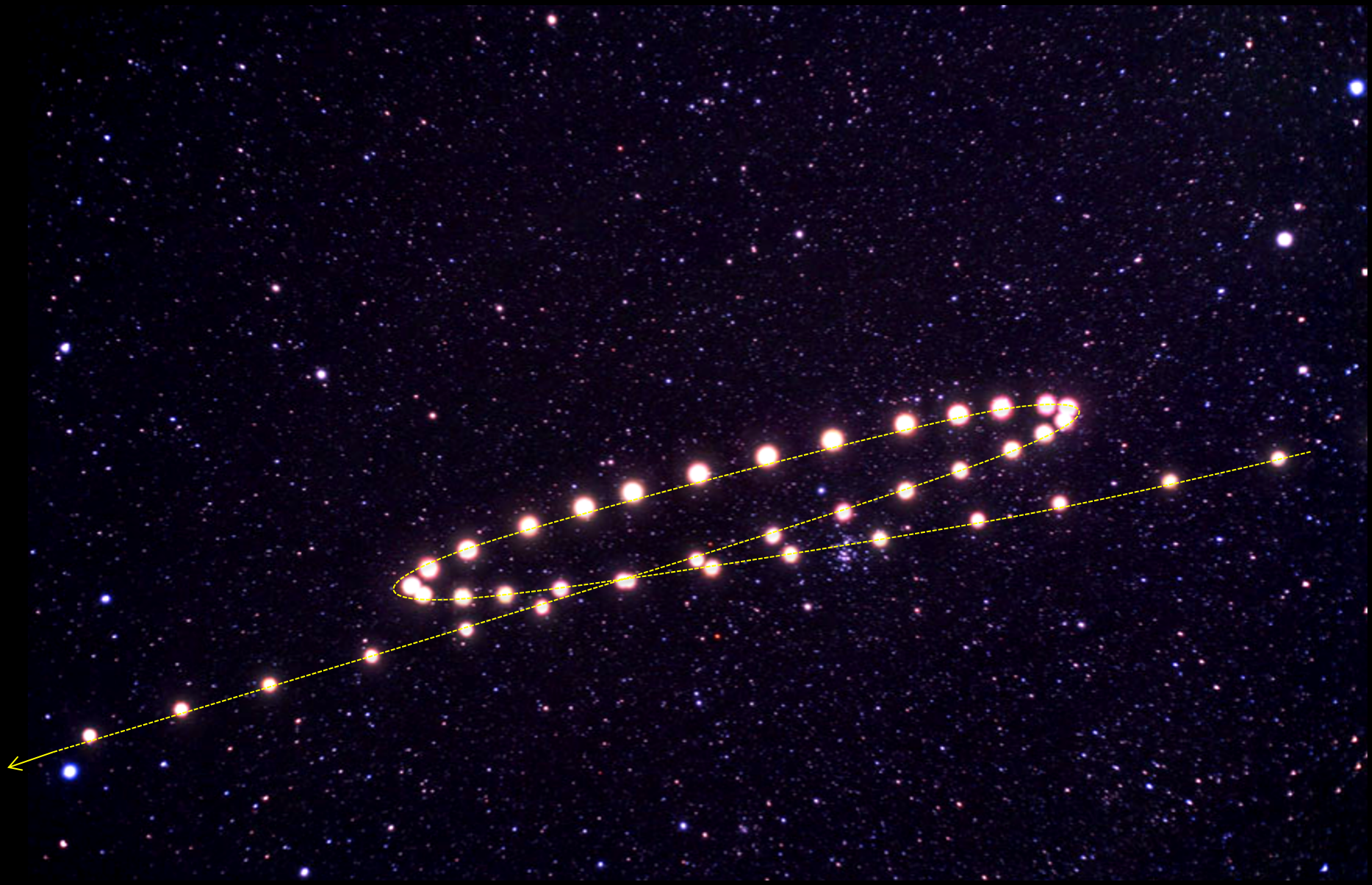








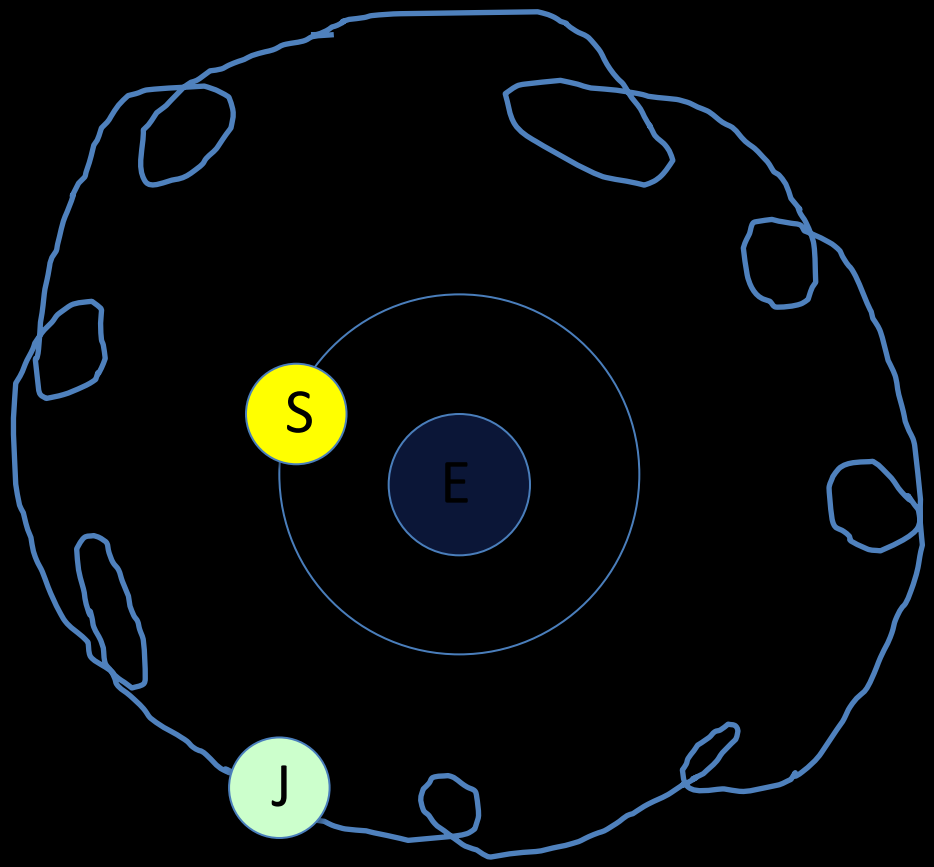
Time-lapse photo



retrograde motion



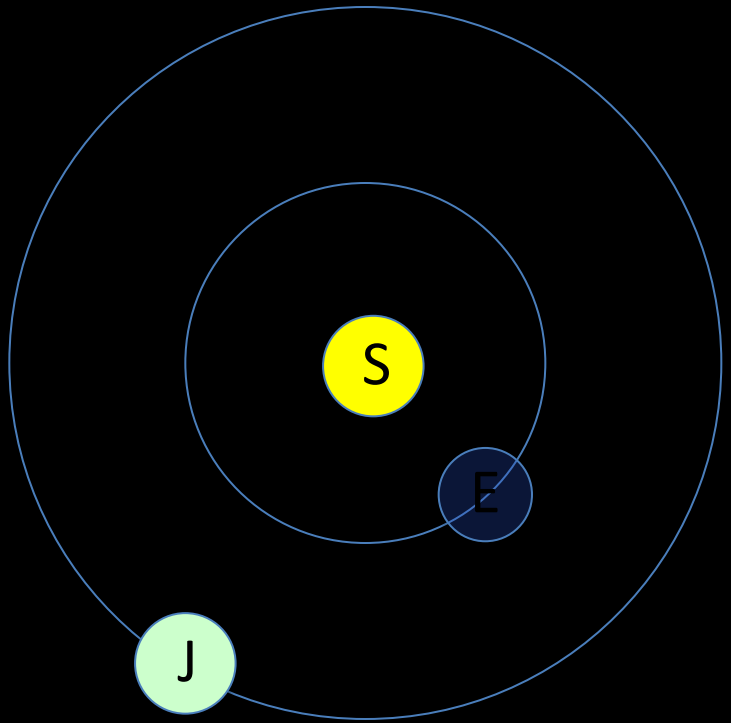
Geocentric Universe



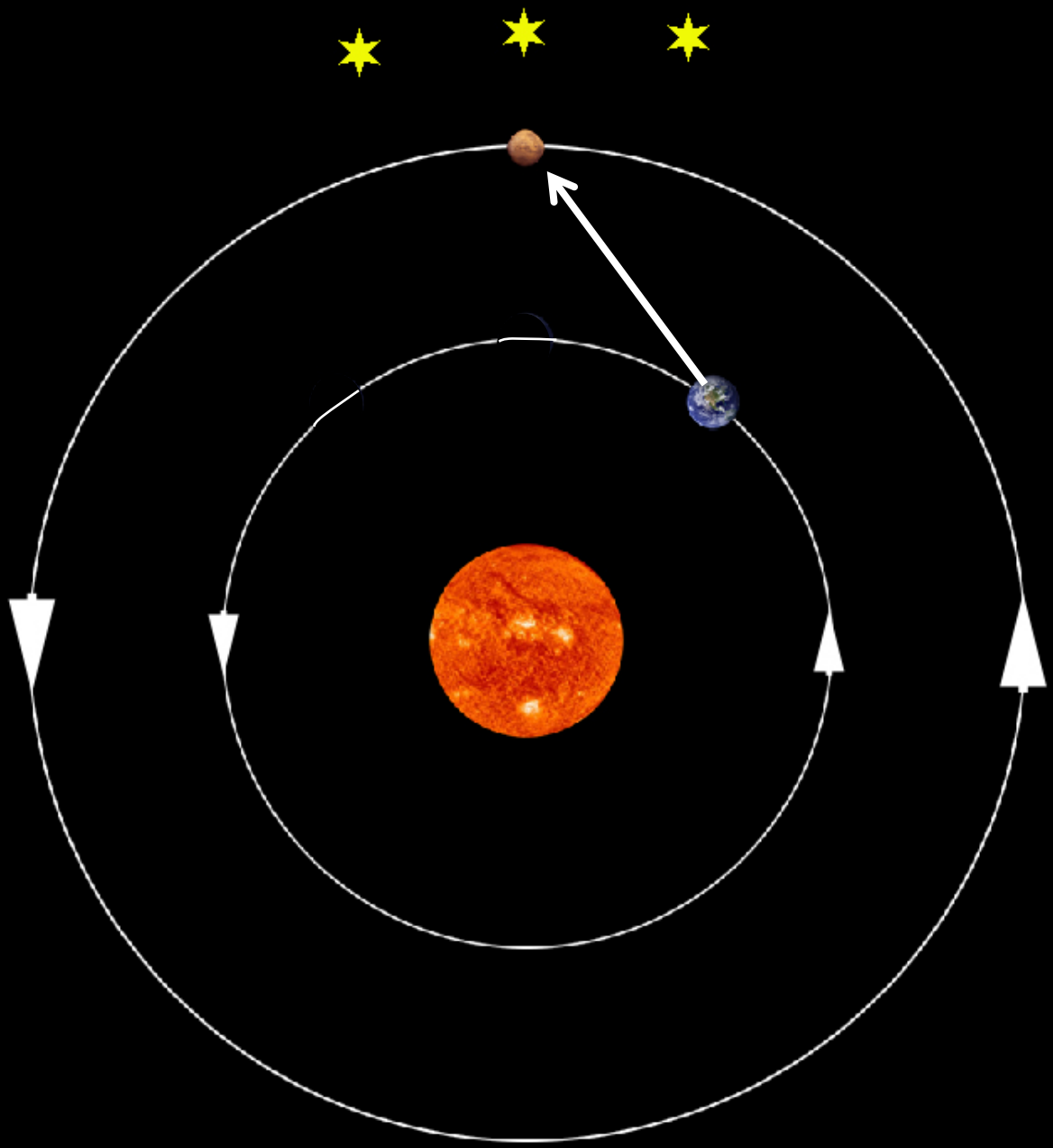
Heliocentric Universe

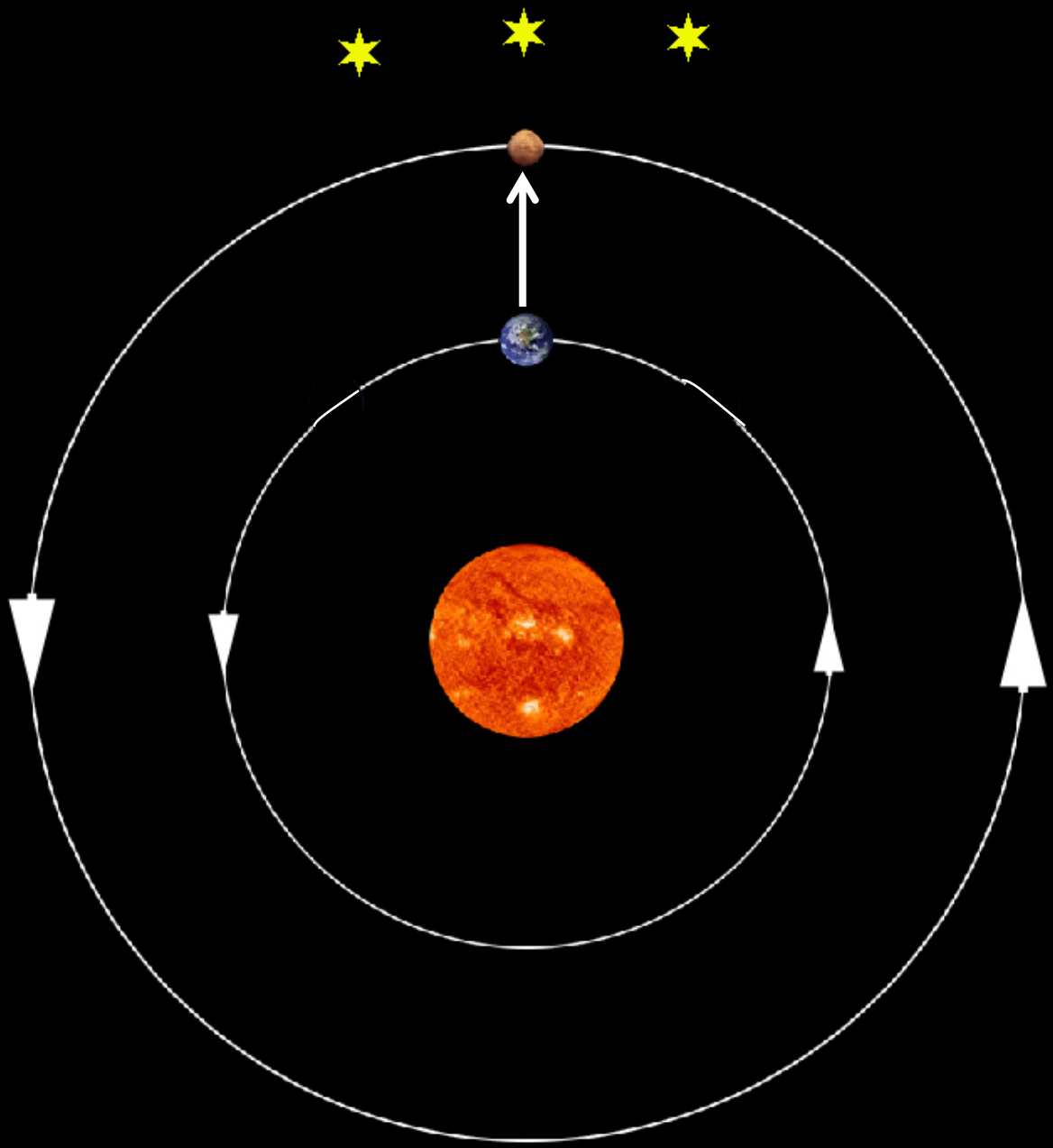


Heliocentric Universe

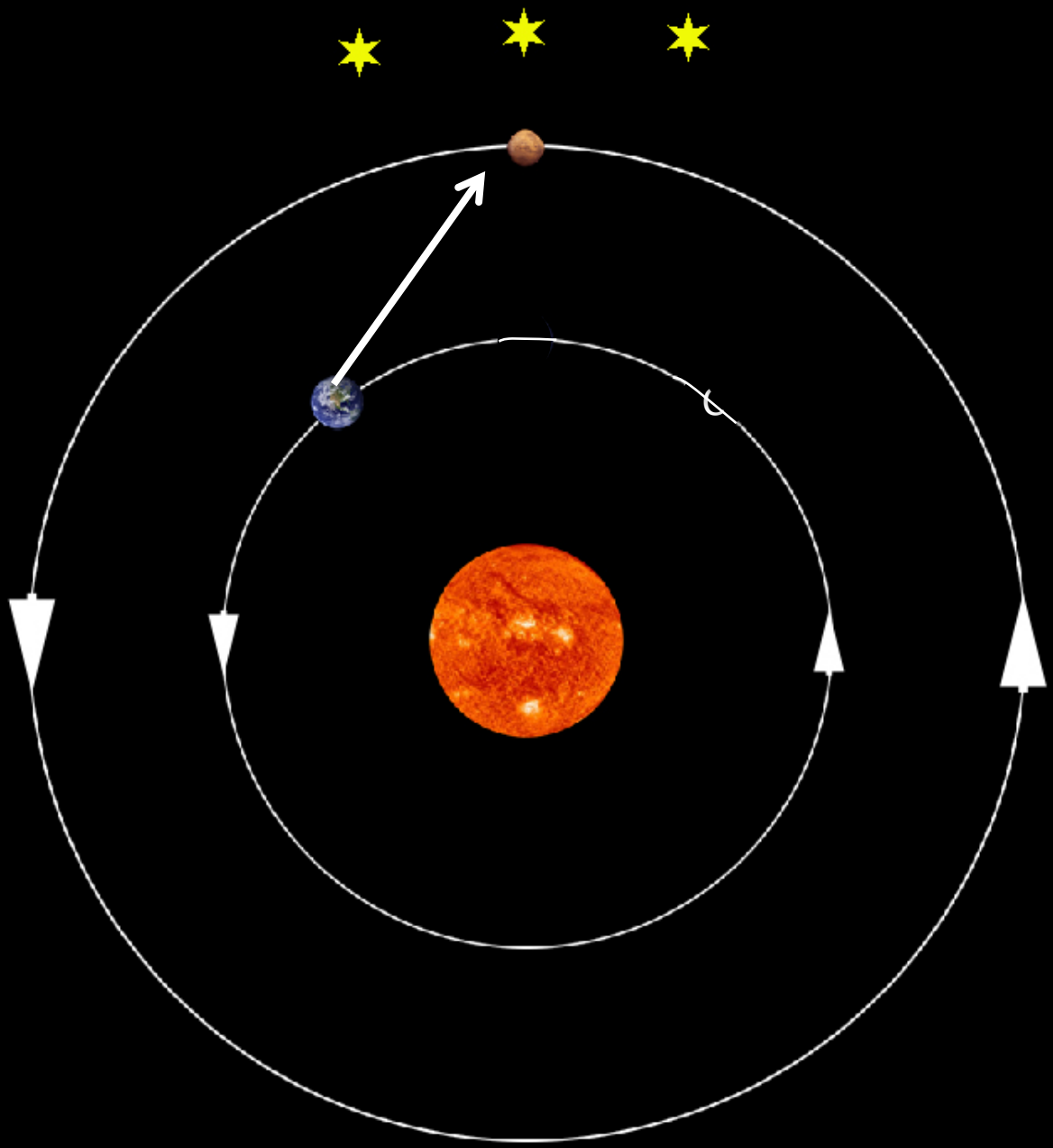


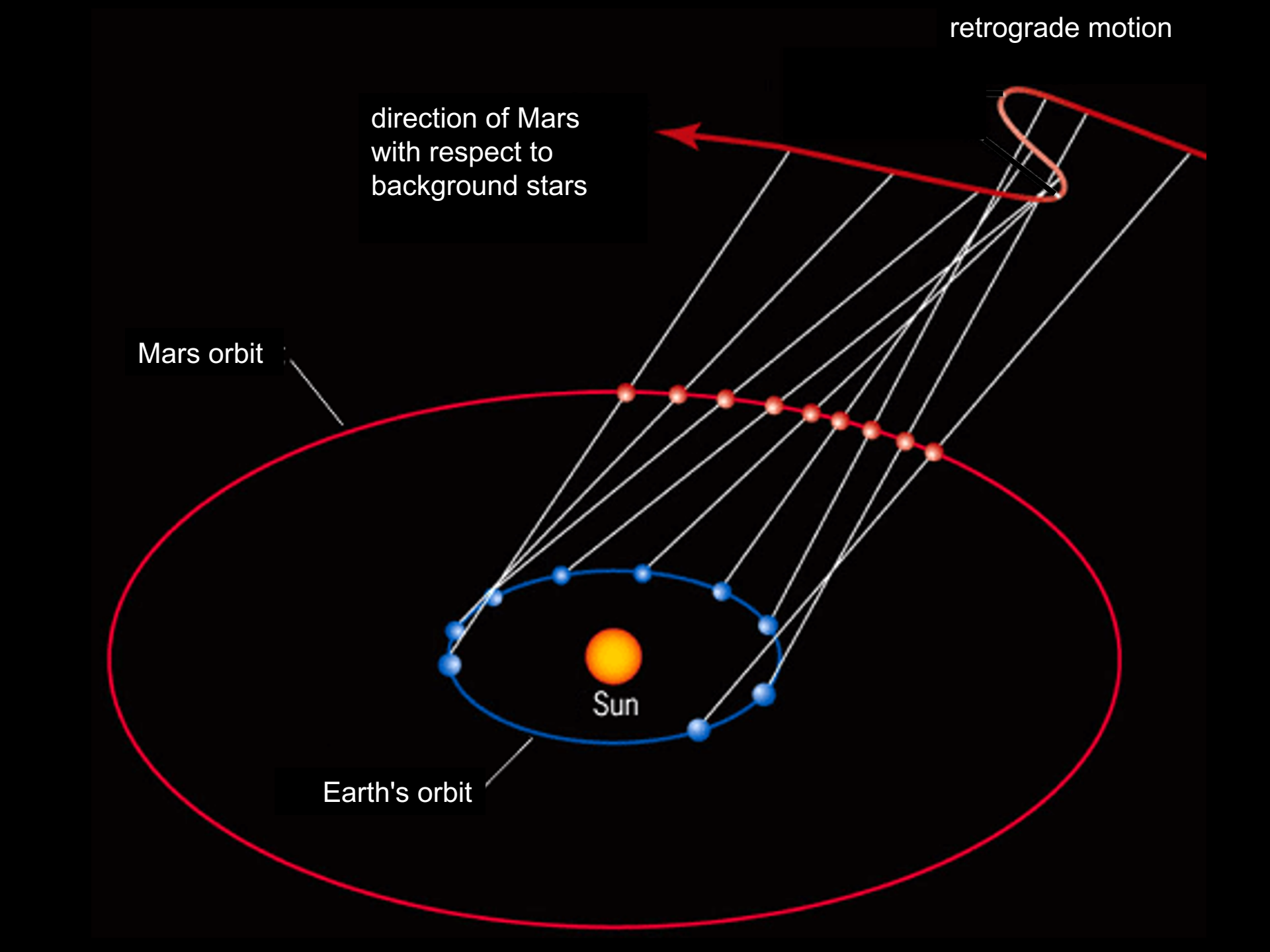
Planets move around sun

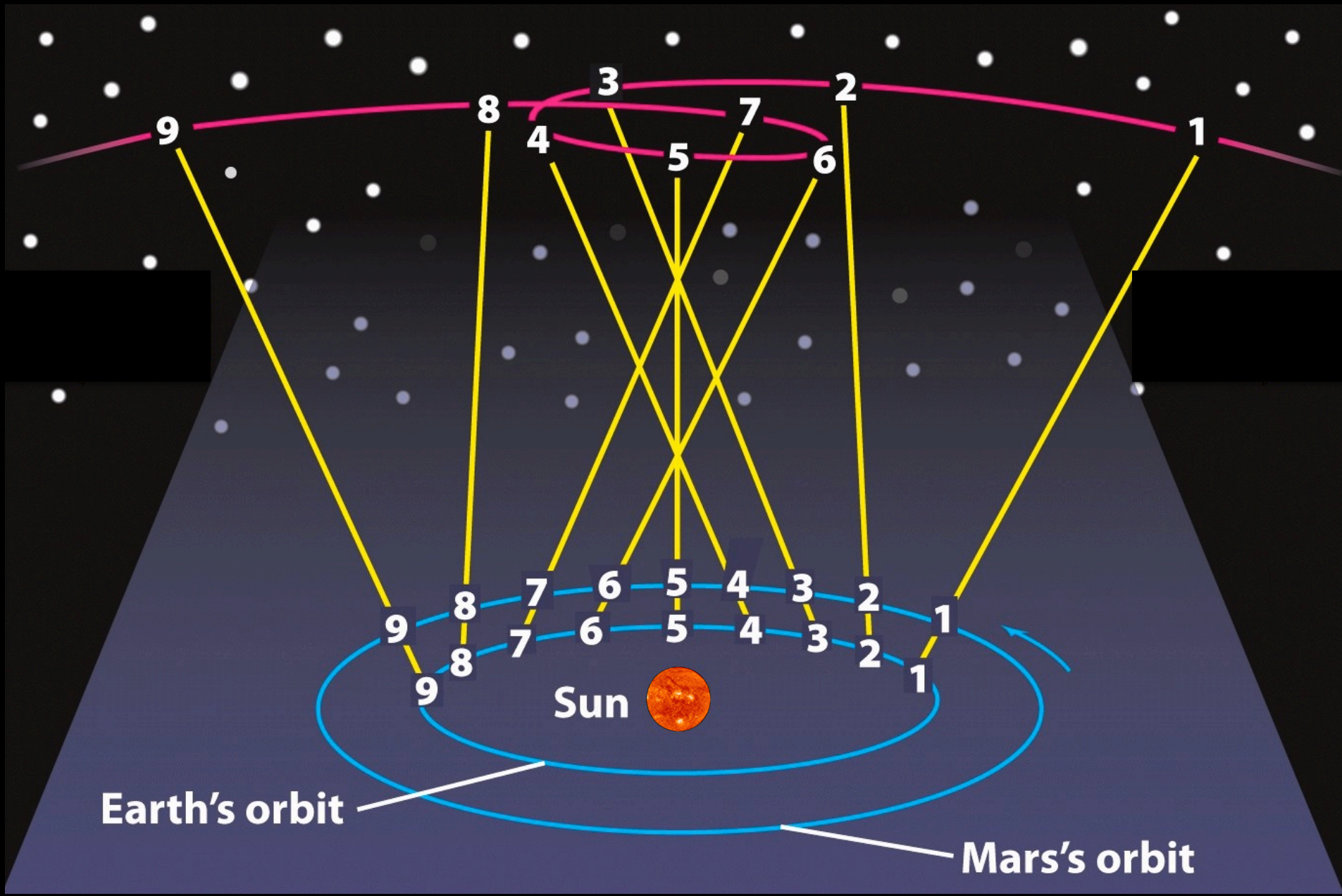

Bob Deegan 2010



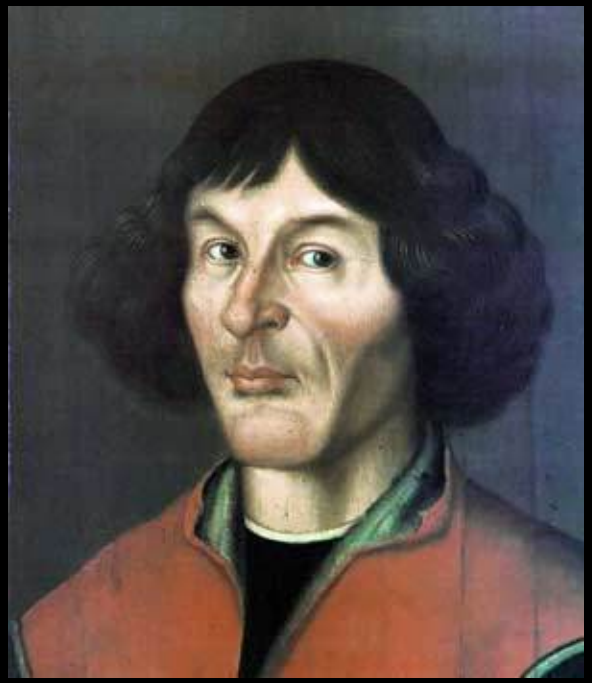
Bob Deegan 2010


Bob Deegan 2010

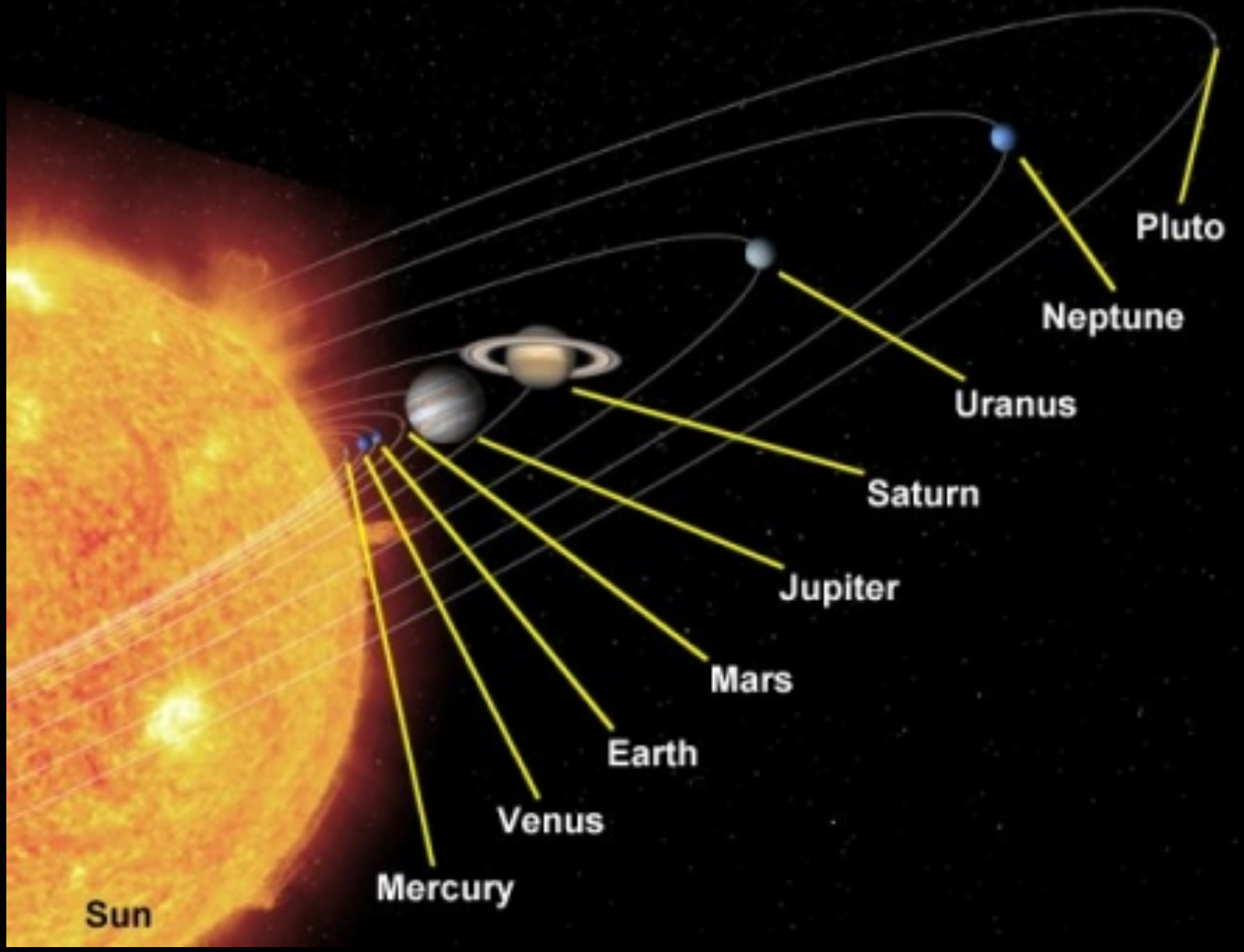

retrograde motion
direction of Mars
with respect to
background stars
Mars orbit
Sun
Earth's orbit

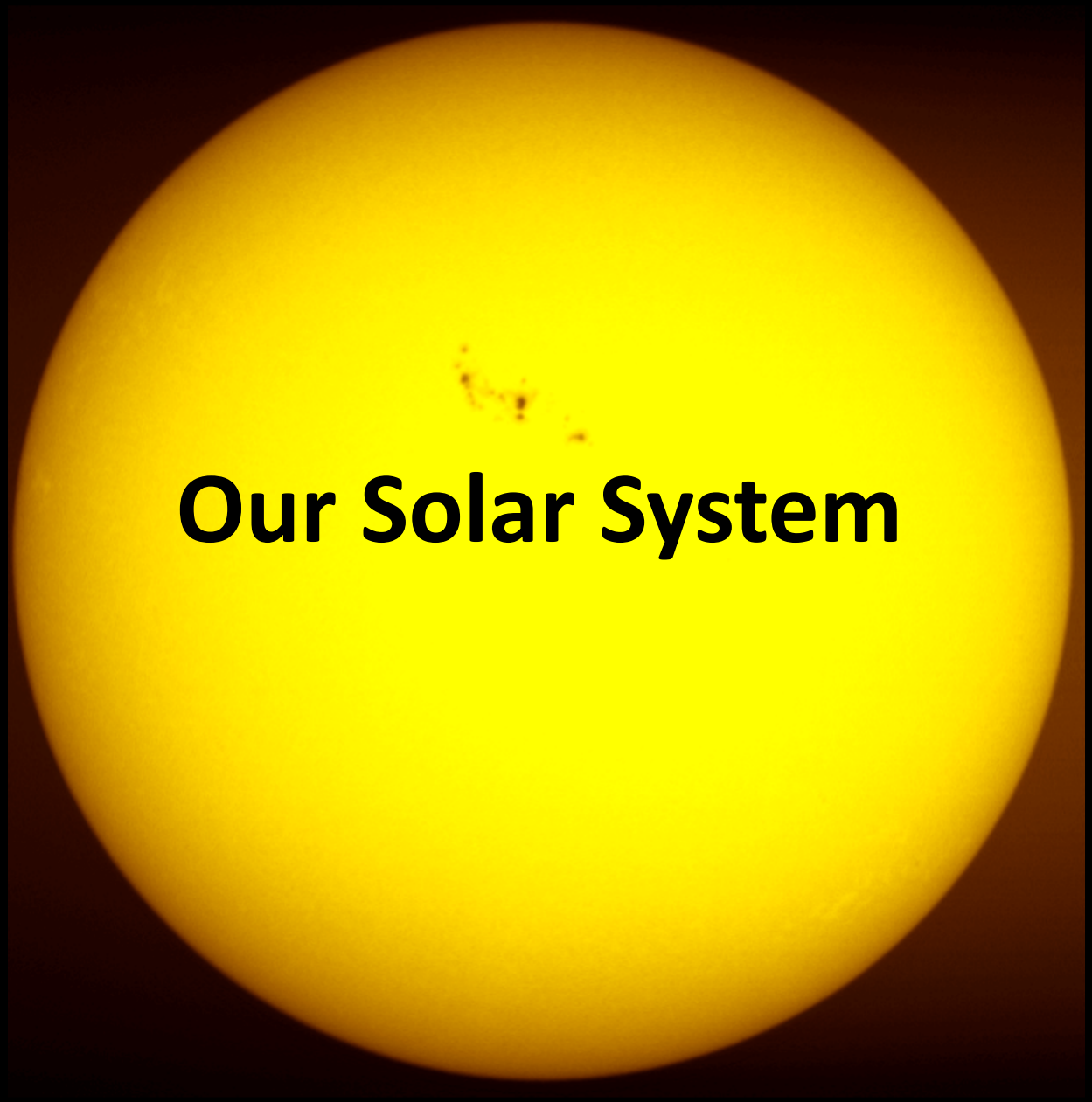

3
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Sun
Earth's orbit
Mars's orbit

Heliocentric Universe

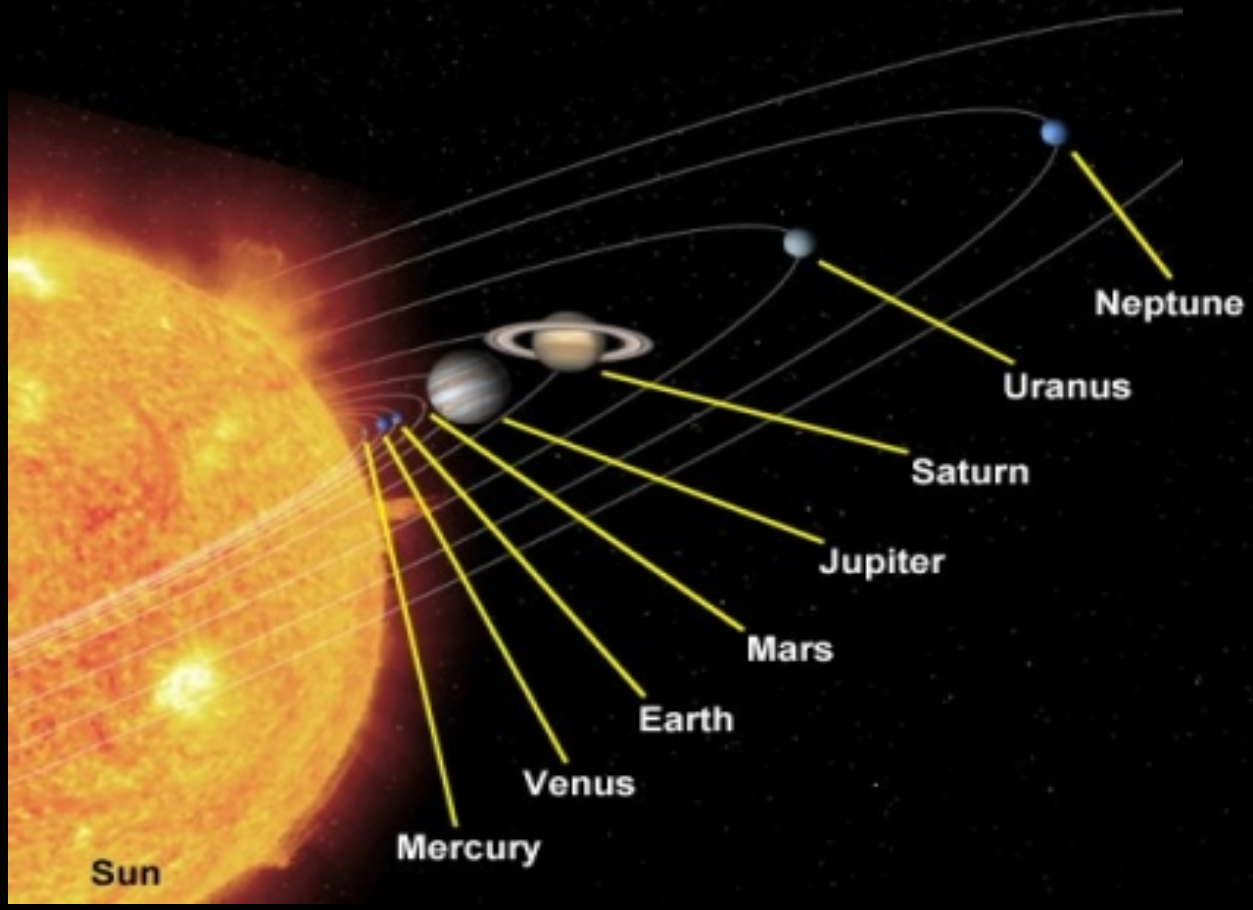


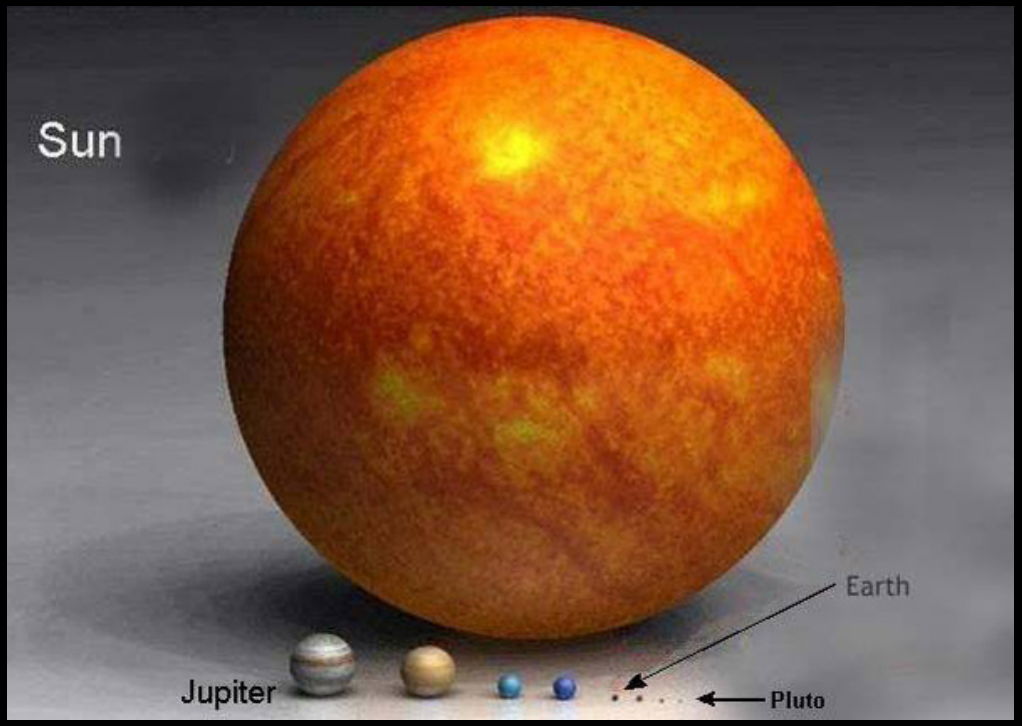
Mathematical basis

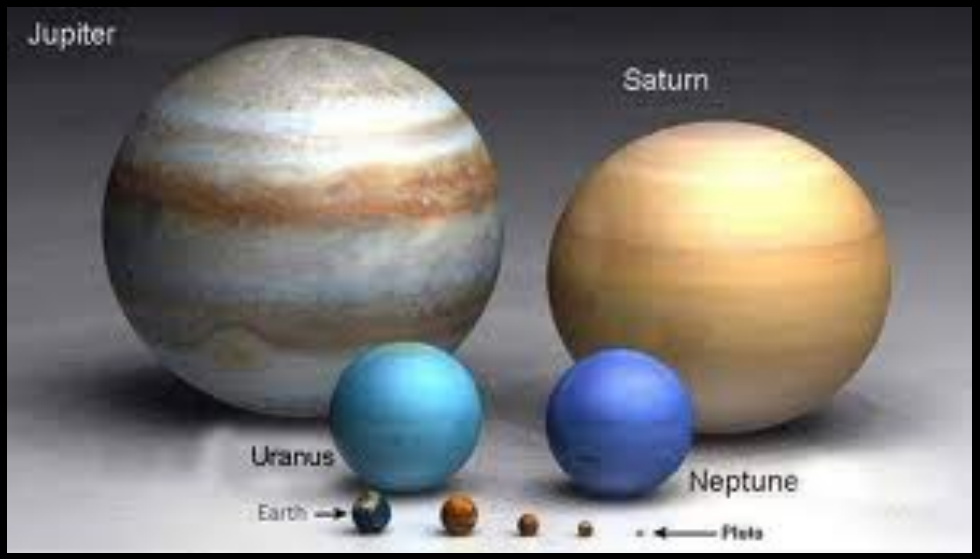

Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
Earth
Venus
Mercury
Sun

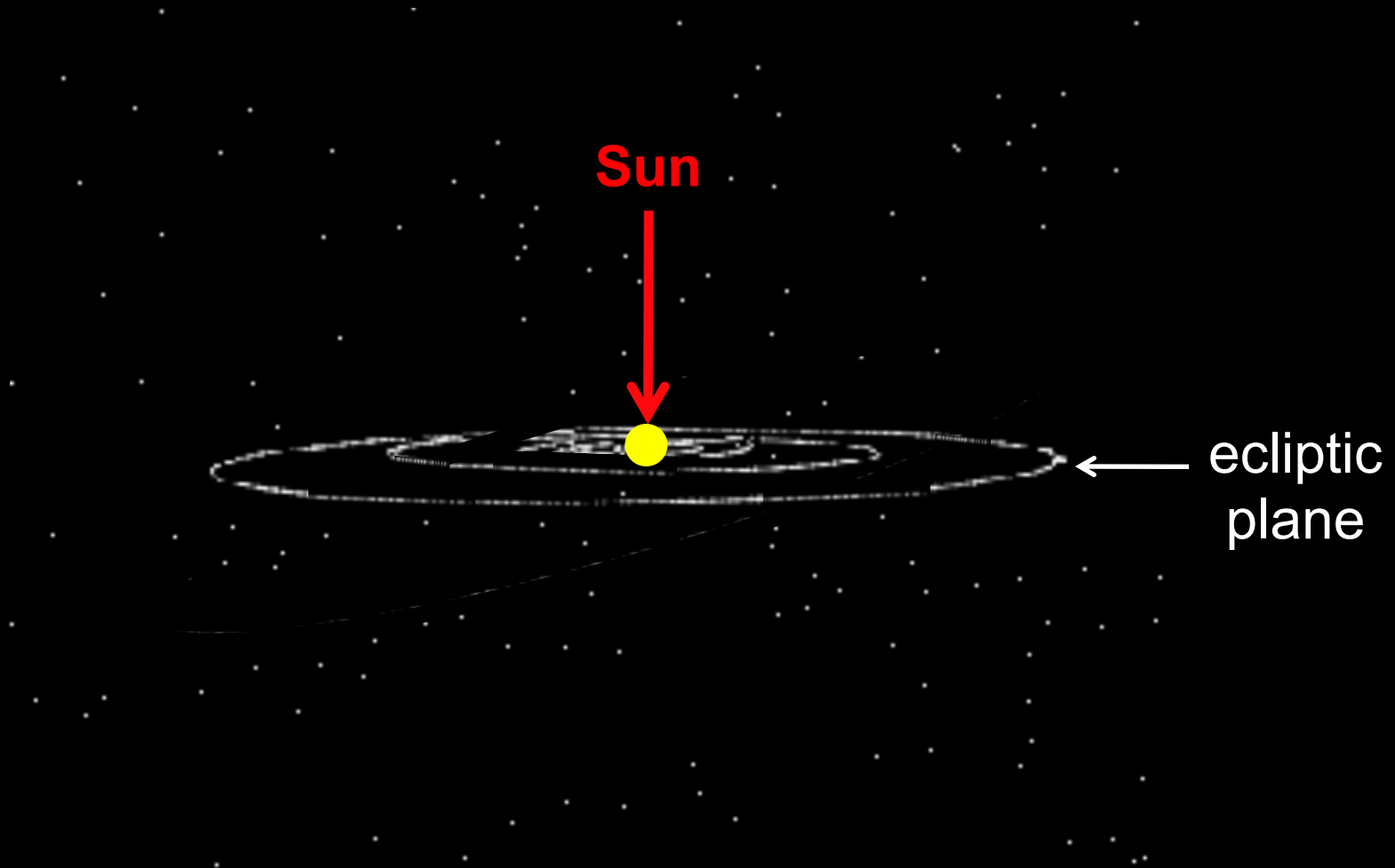

Our Solar System

Planets orbit the Sun in a plane known as the **ECLIPTIC PLANE**




Sun
Earth
Jupiter
Pluto


Jupiter
Saturn
Uranus
Neptune
Earth
Pluto

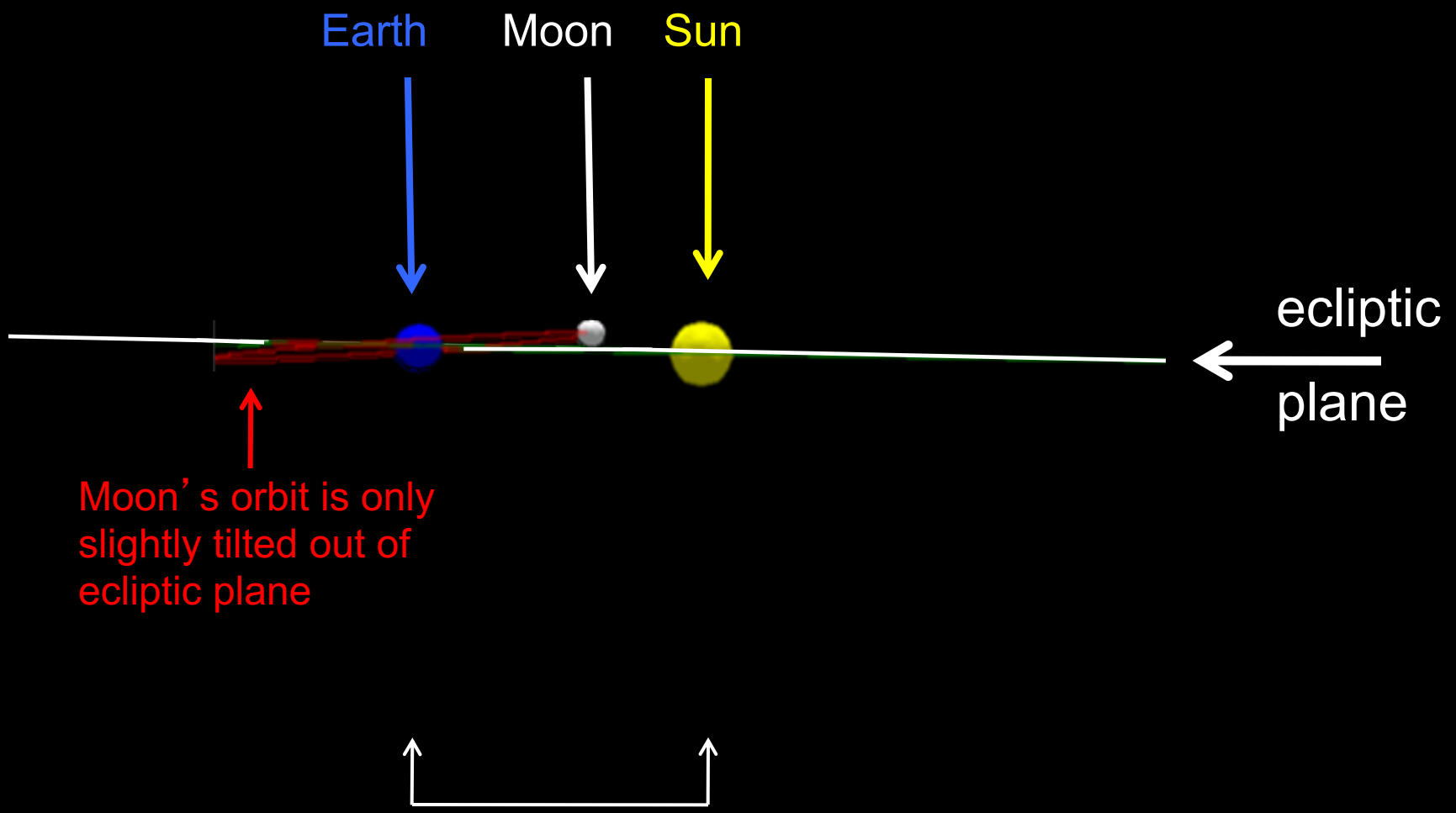


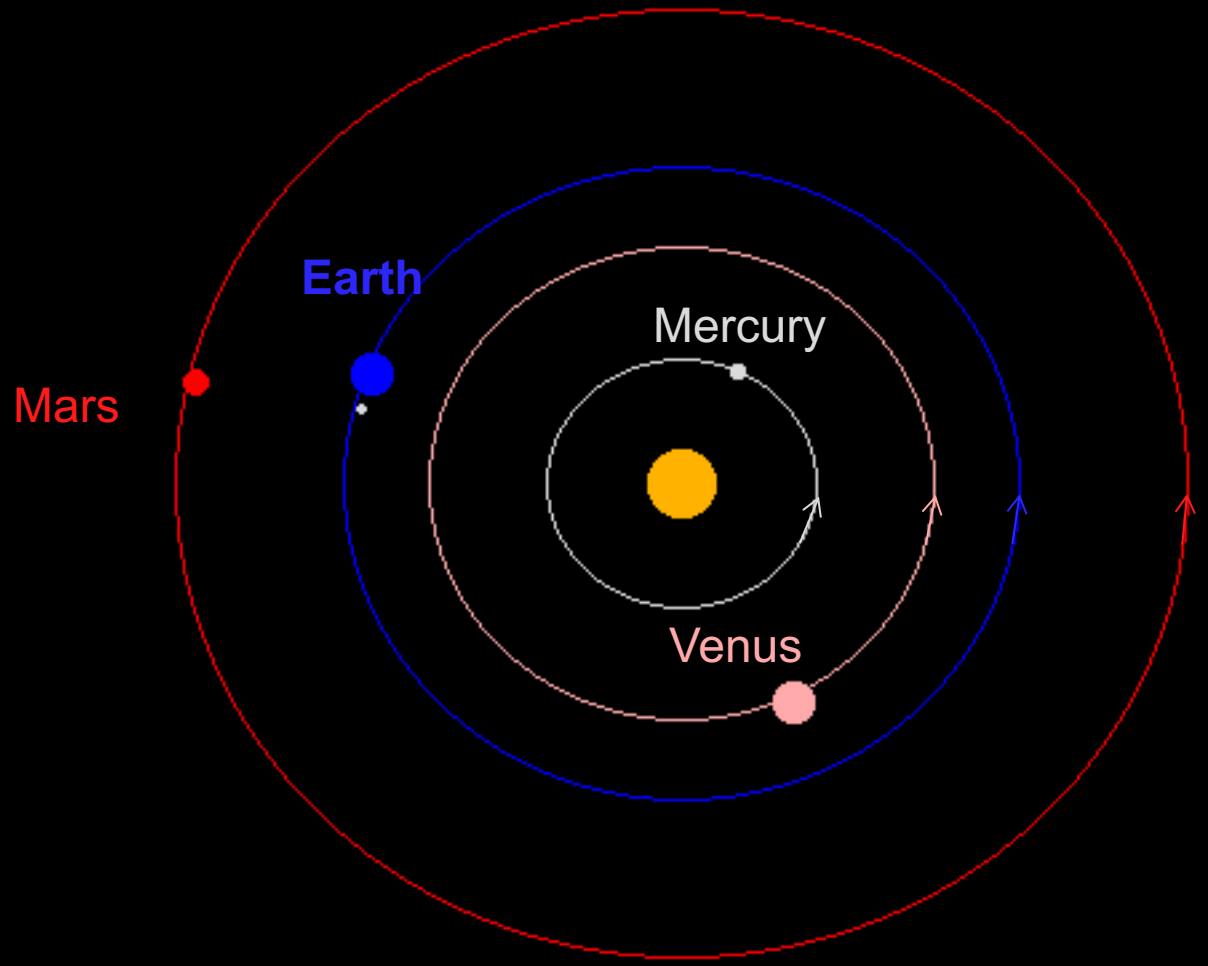
Path of planets around the Sun edge-on view



Jupiter

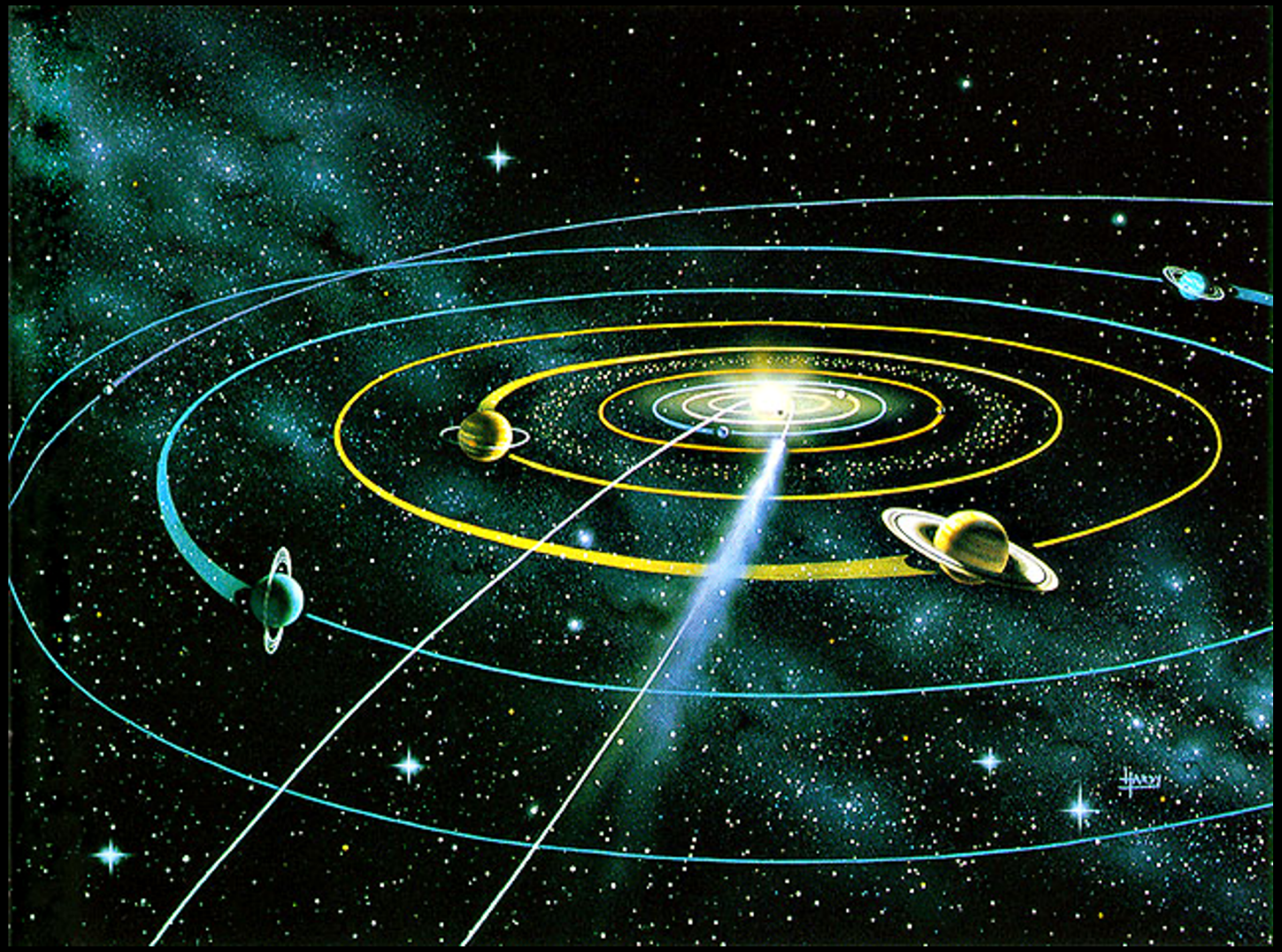
Jupiter and its moon orbit Jupiter in a flat plane, too. There is a reason the Solar System and Jupiter's moon system orbits are flat — we'll talk about it soon!


Earth
Moon
Sun
ecliptic
plane
Moon's orbit is only slightly tilted out of ecliptic plane
Earth – Sun Distance = 1 Astronomical Unit (AU)



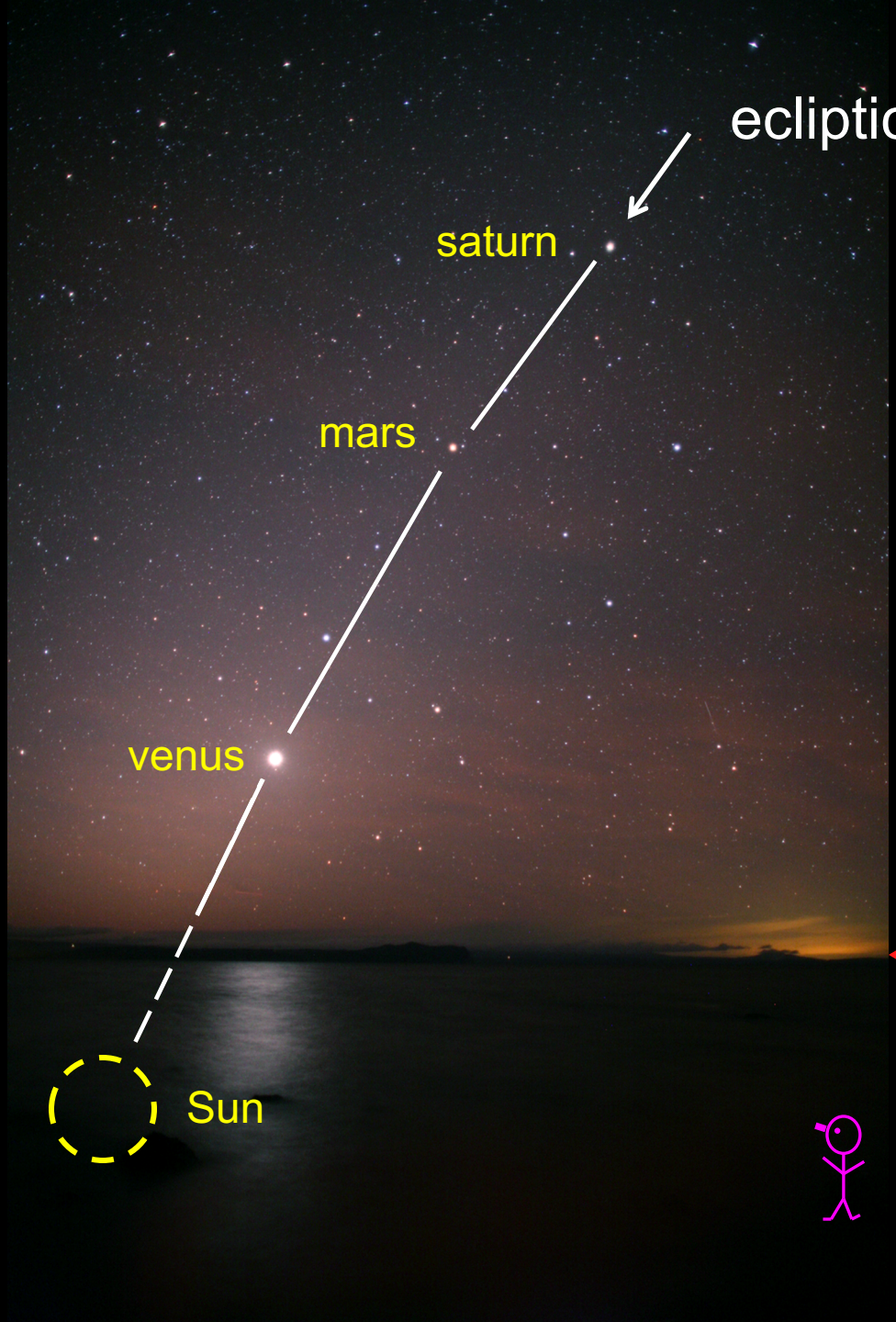
Looking down onto (north) inner Solar System —
all planets orbit Sun counterclockwise

(not to scale)

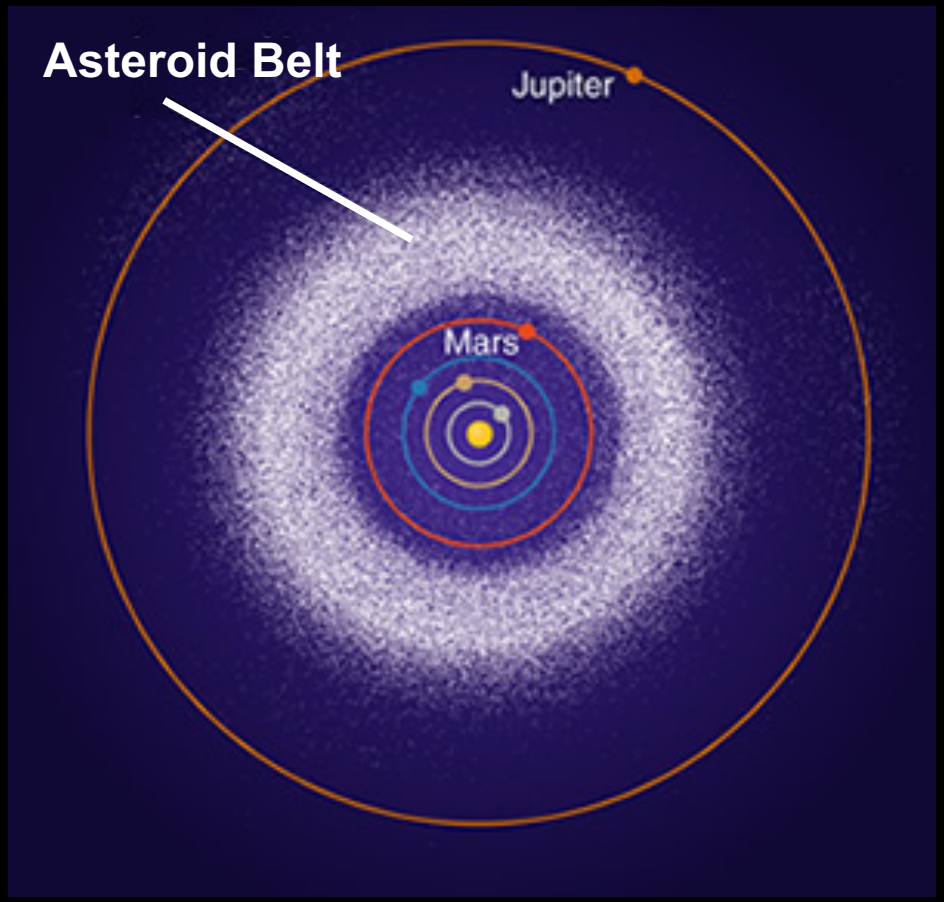


How does being in the ecliptic affect where we see the planets in the sky from the ground, on Earth?

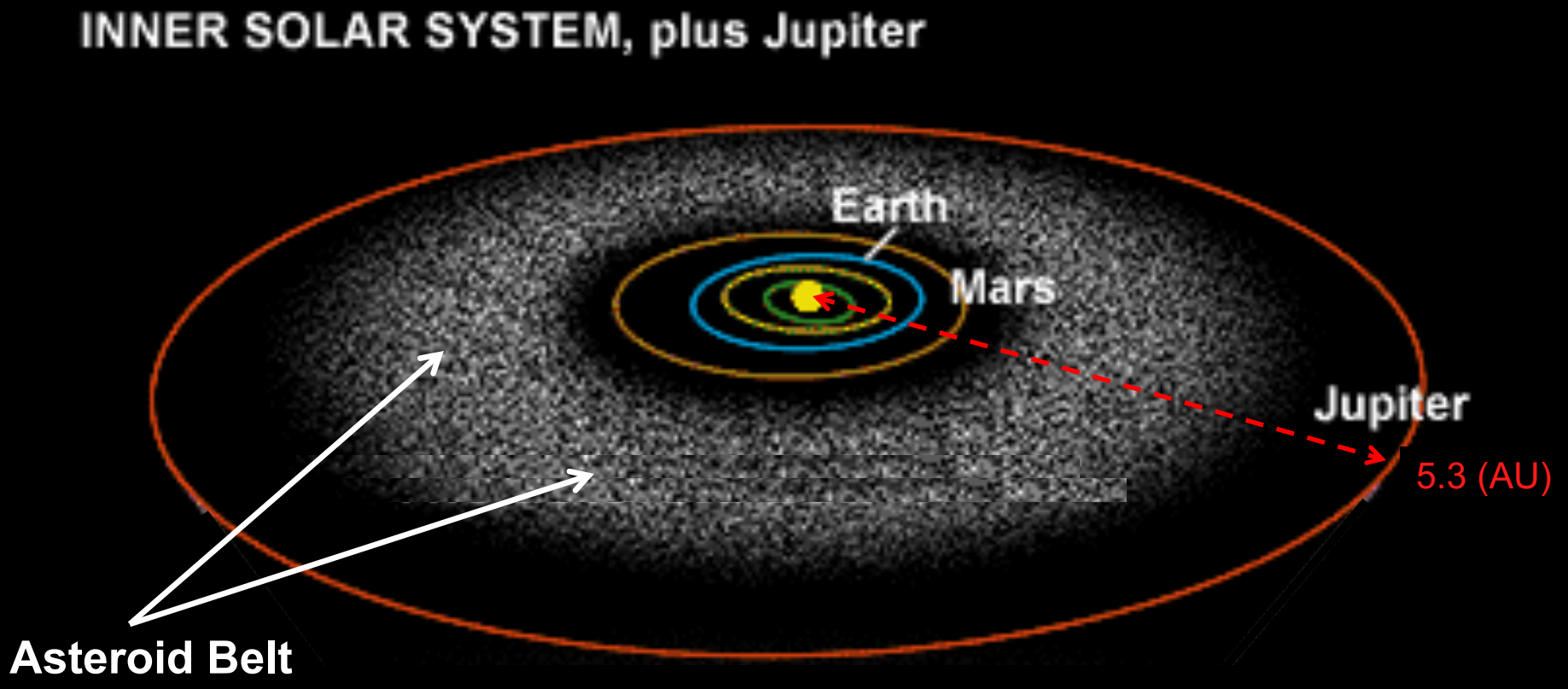

horizon



Sun, planets look as if they’ re in a gentle arc — the ecliptic



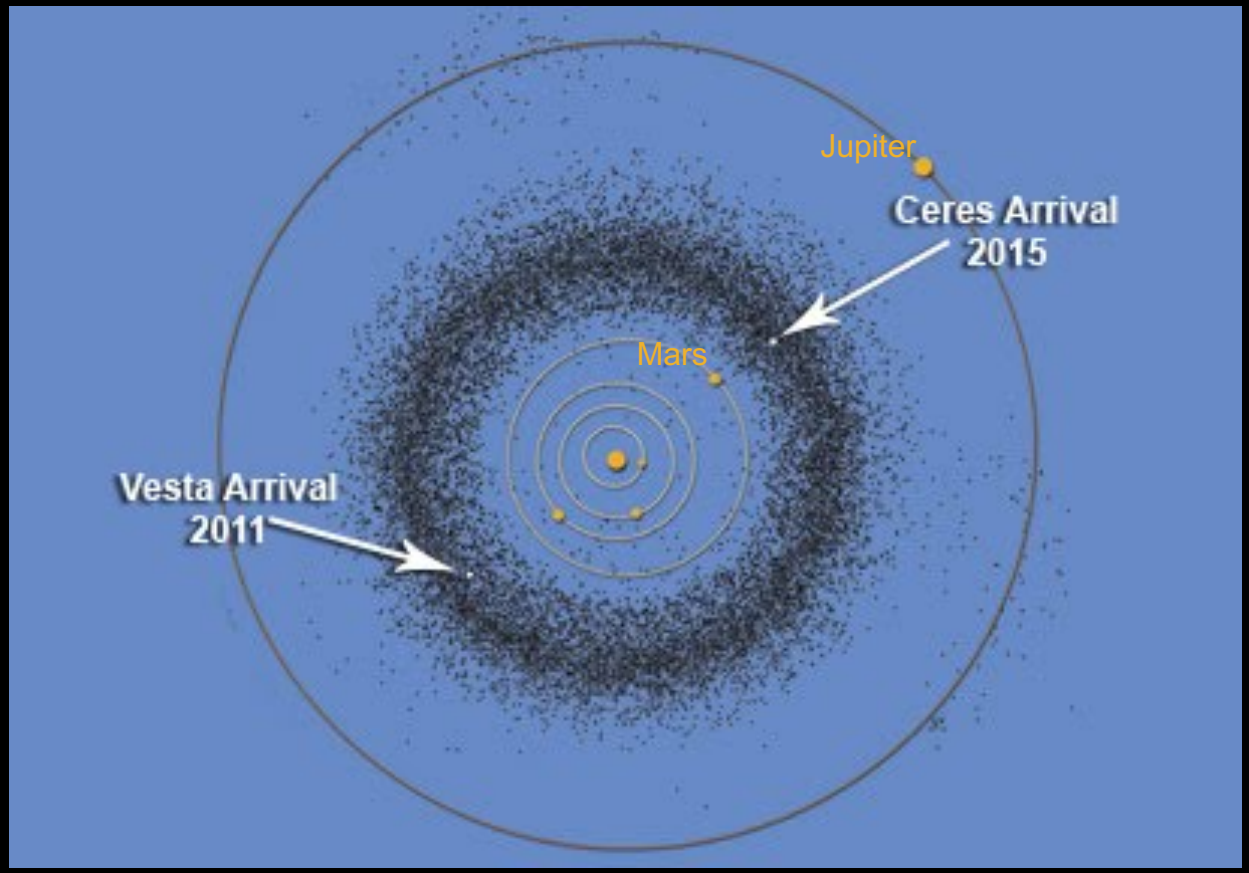
there are more than just planets and Sun in the Solar System
in the ecliptic plane — the **ASTEROID BELT**



Thousands of asteroids (rocks) — rubble from failed planets

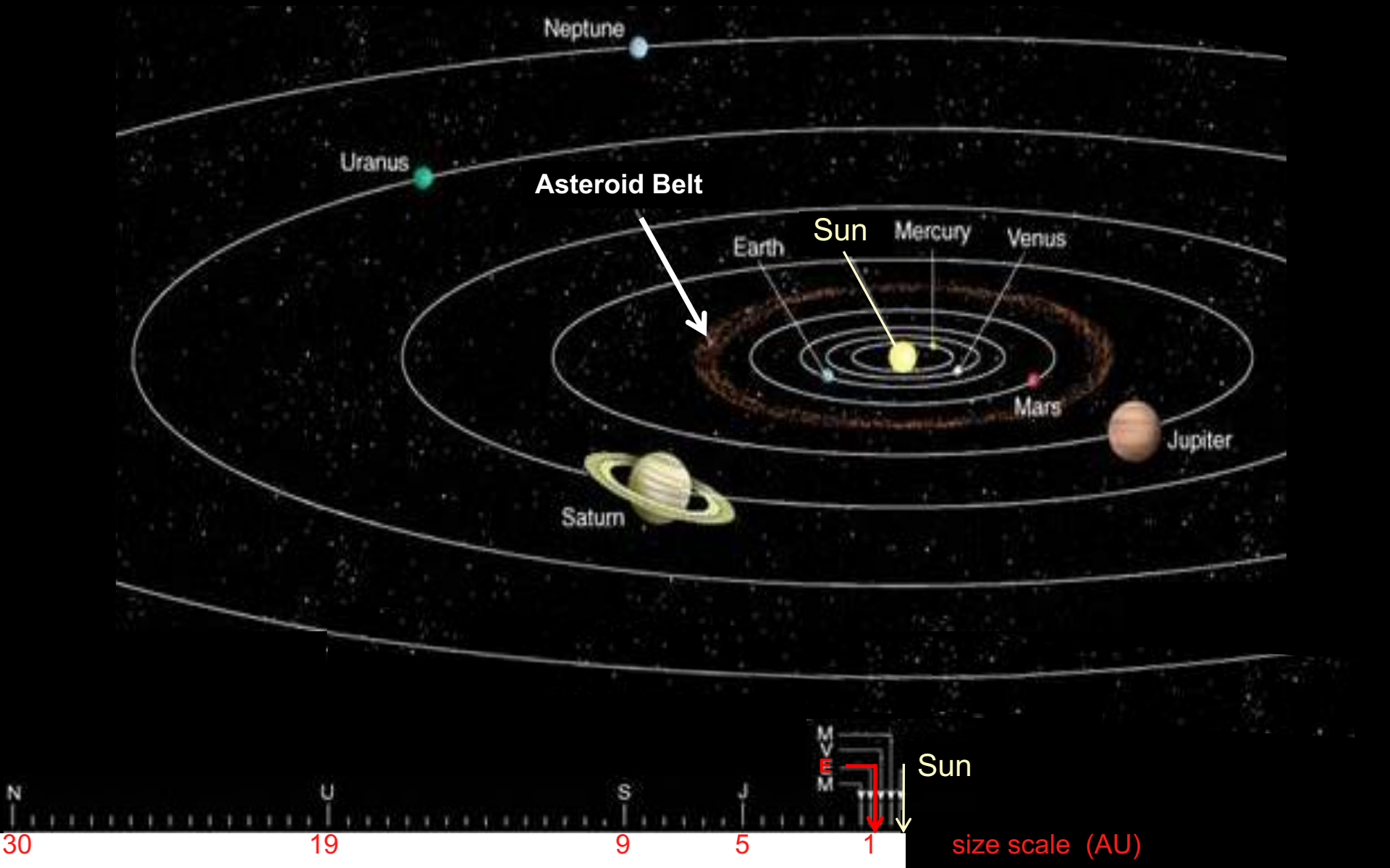
Asteroids that wander to inner Solar System pose great danger to Earth

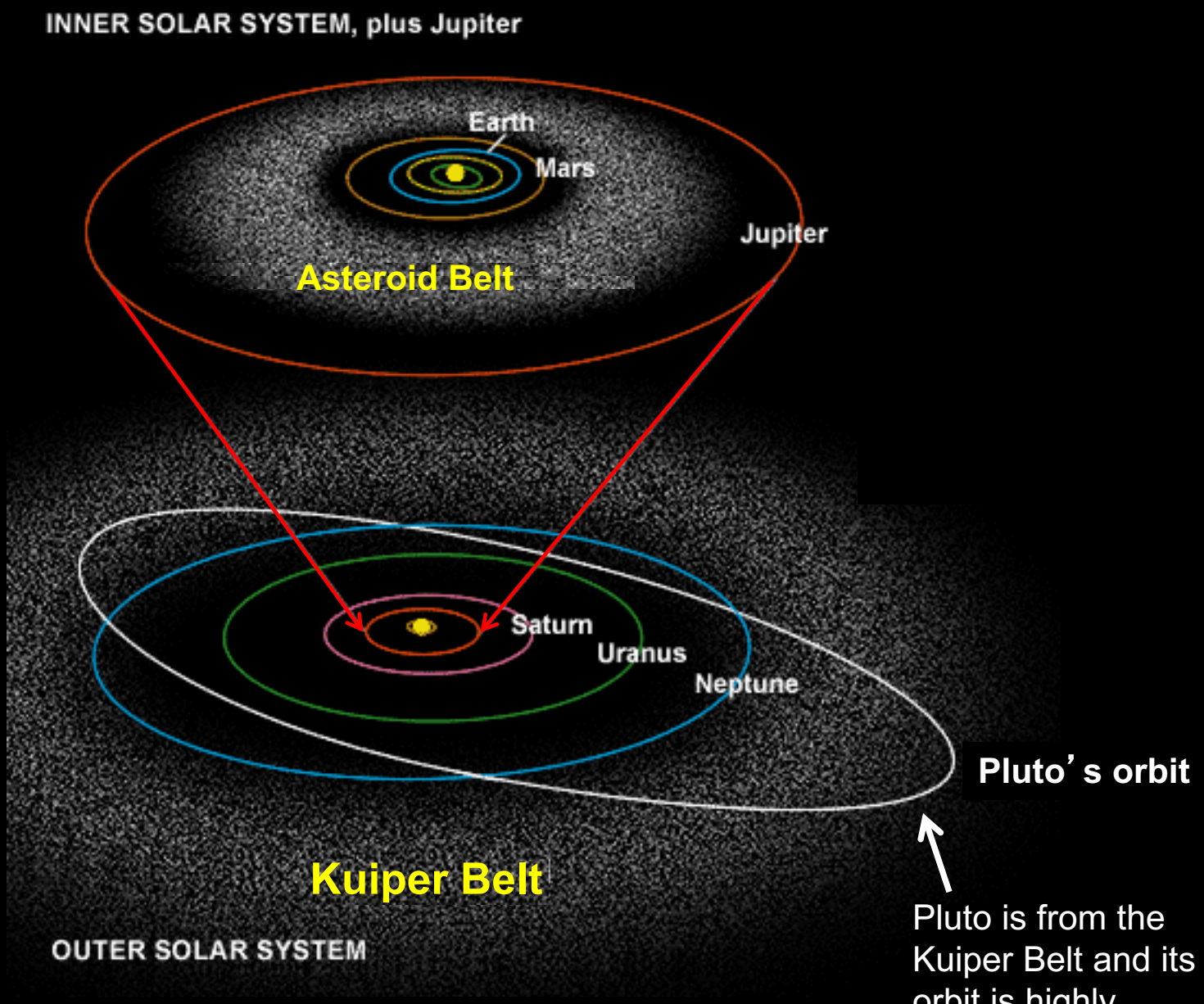
NASA missions arrival dates



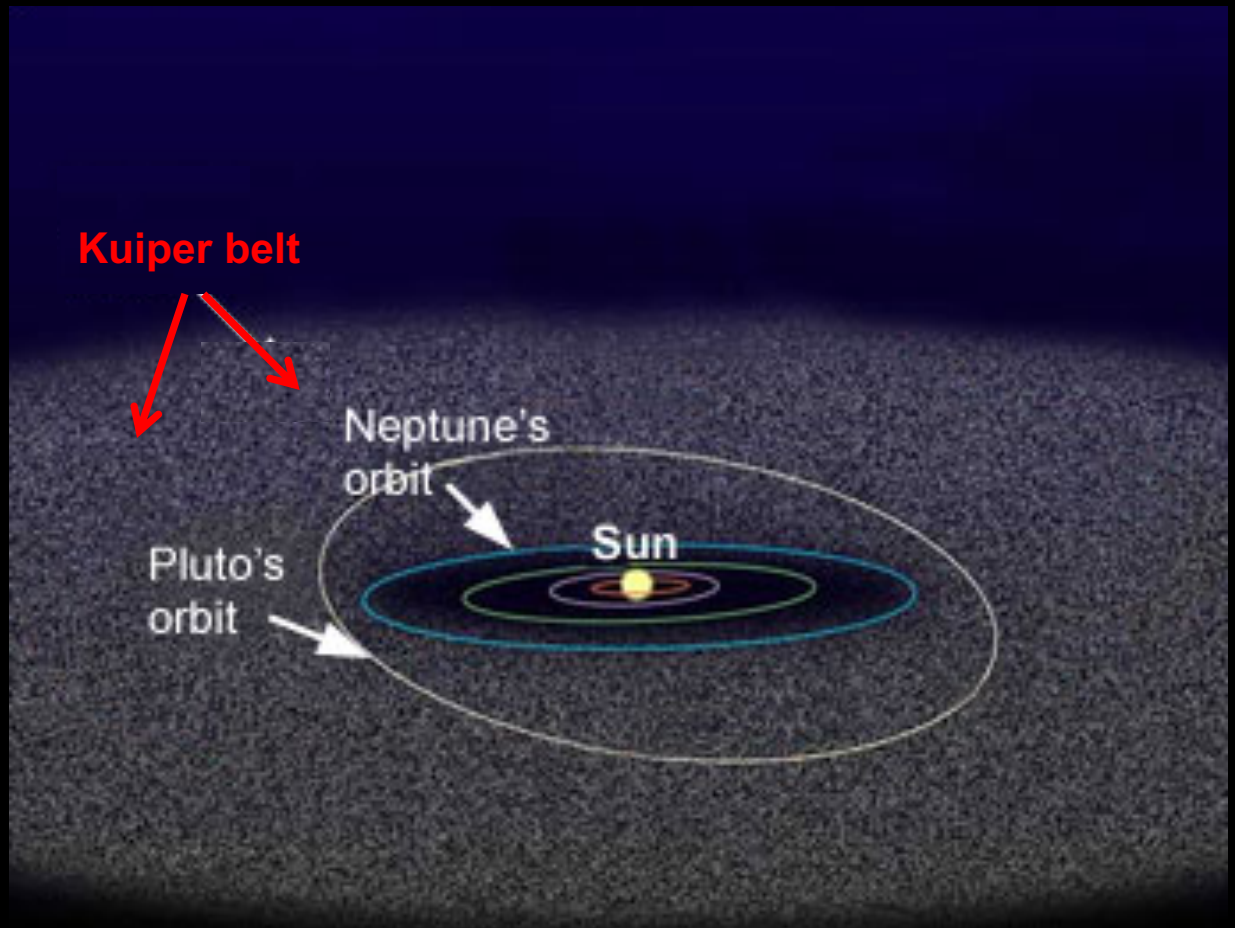
Ceres (900 km) and Vesta (400 km) —

others asteroids from < 1 m to 100 km


Neptune
Uranus
Asteroid Belt
Earth
Sun
Mercury
Venus
Mars
Jupiter
Saturn
M
V
E
M
Sun
N
U
S
J
30
19
9
5
1
size scale (AU)



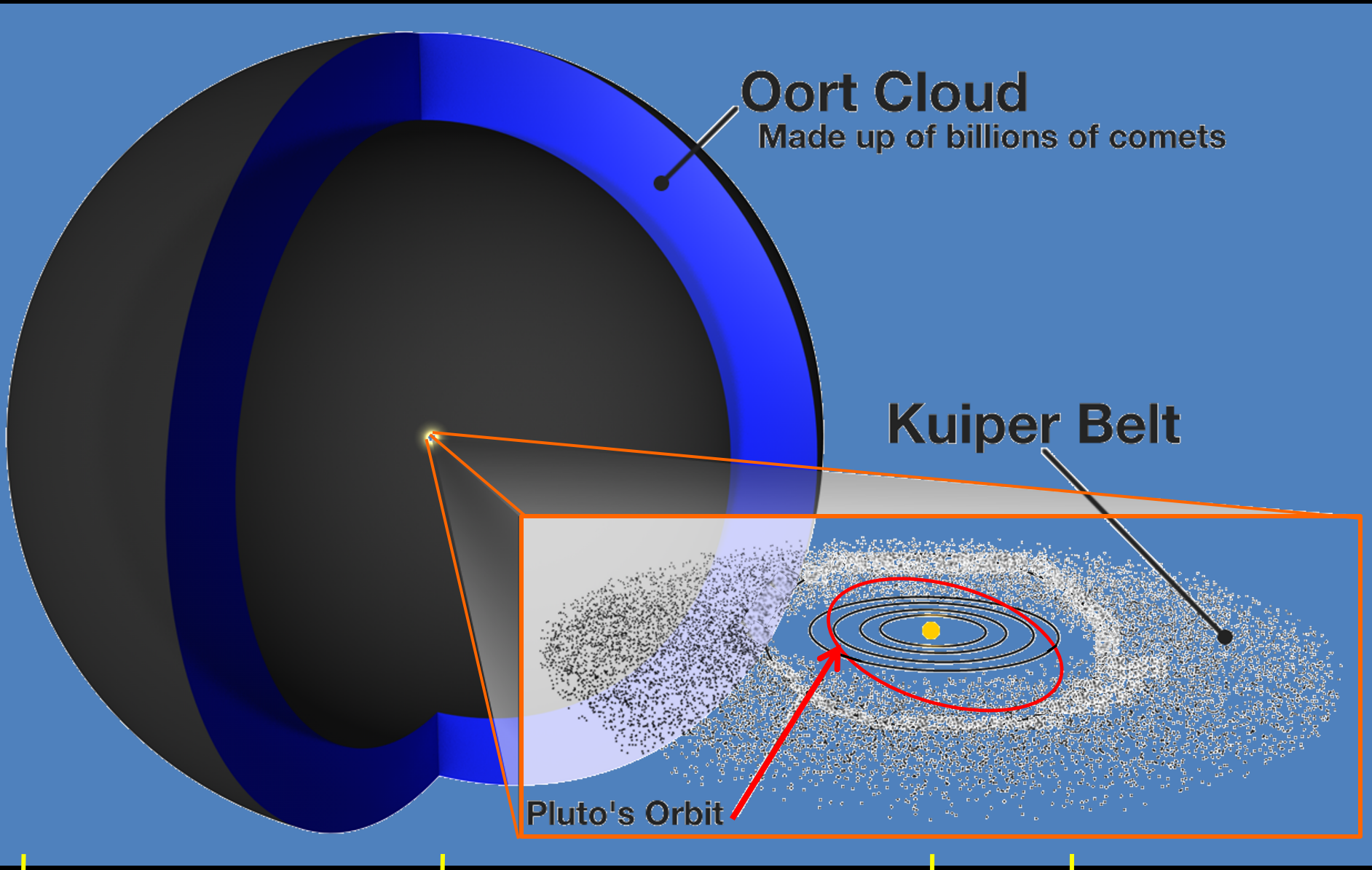
Pluto is from the Kuiper Belt and its orbit is highly inclined to the ecliptic plane

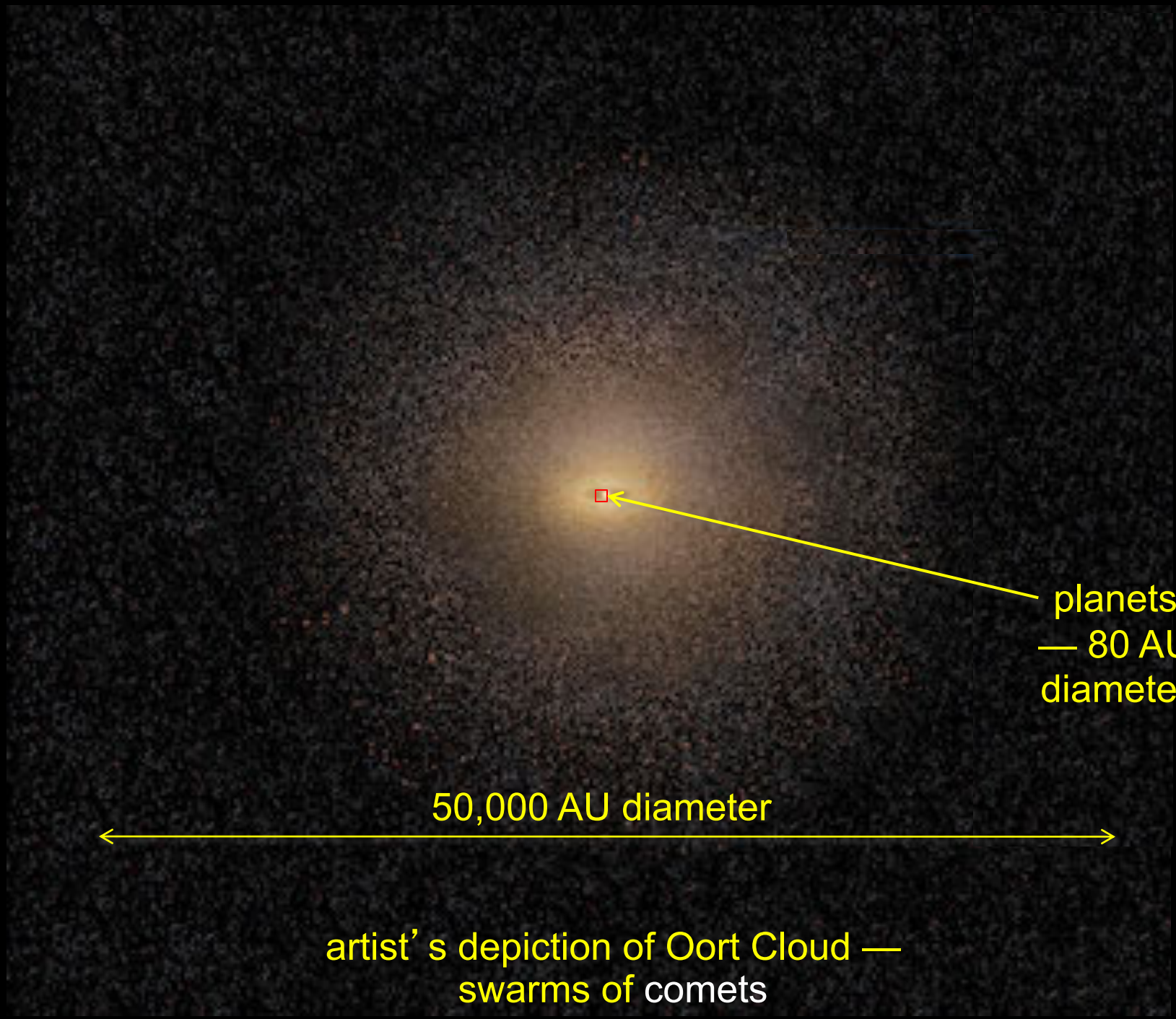


Beyond Neptune's orbit — **Kuiper belt** — asteroids and COMETS

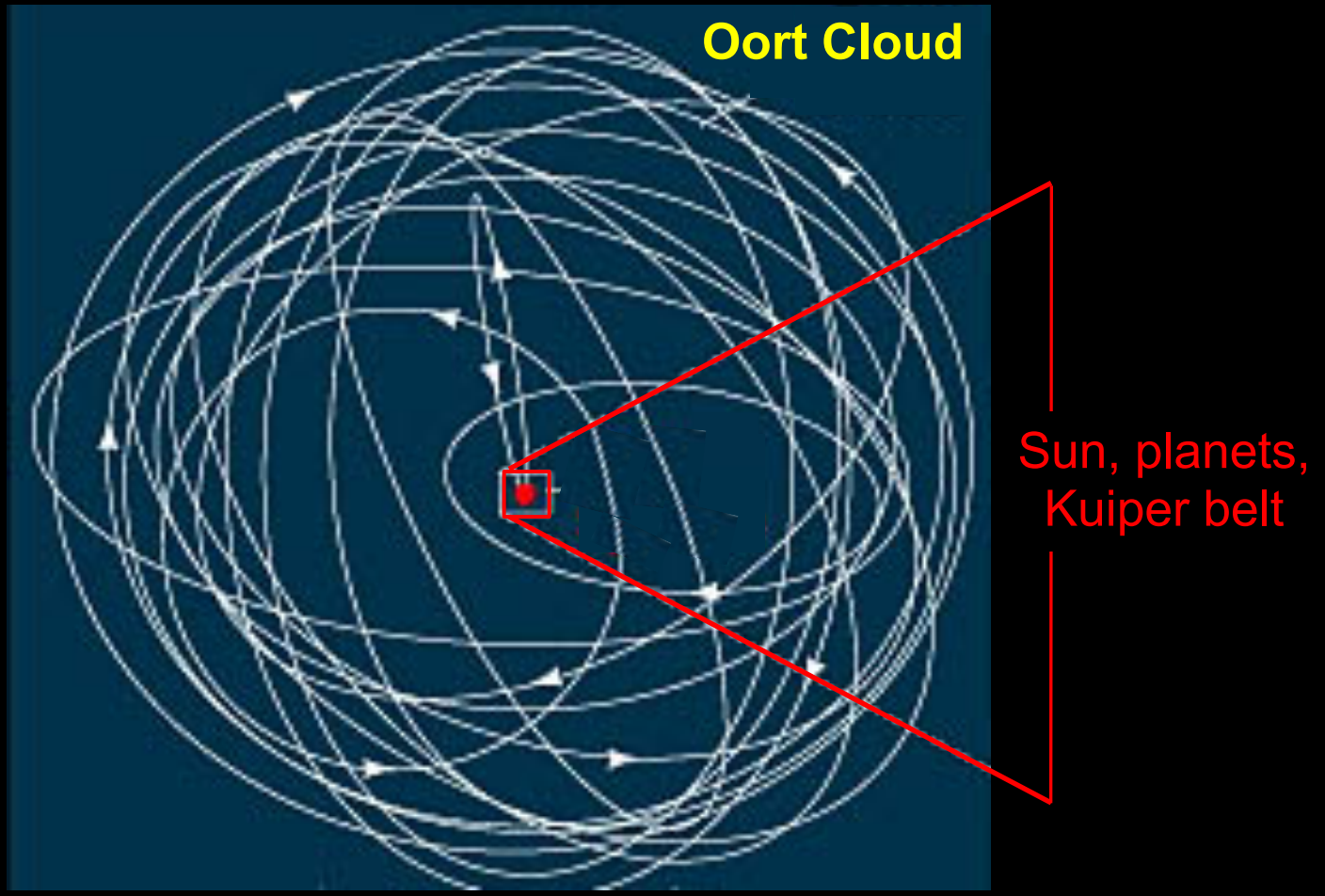
But that is still not the edge of the Solar System….

This is the whole Solar System:





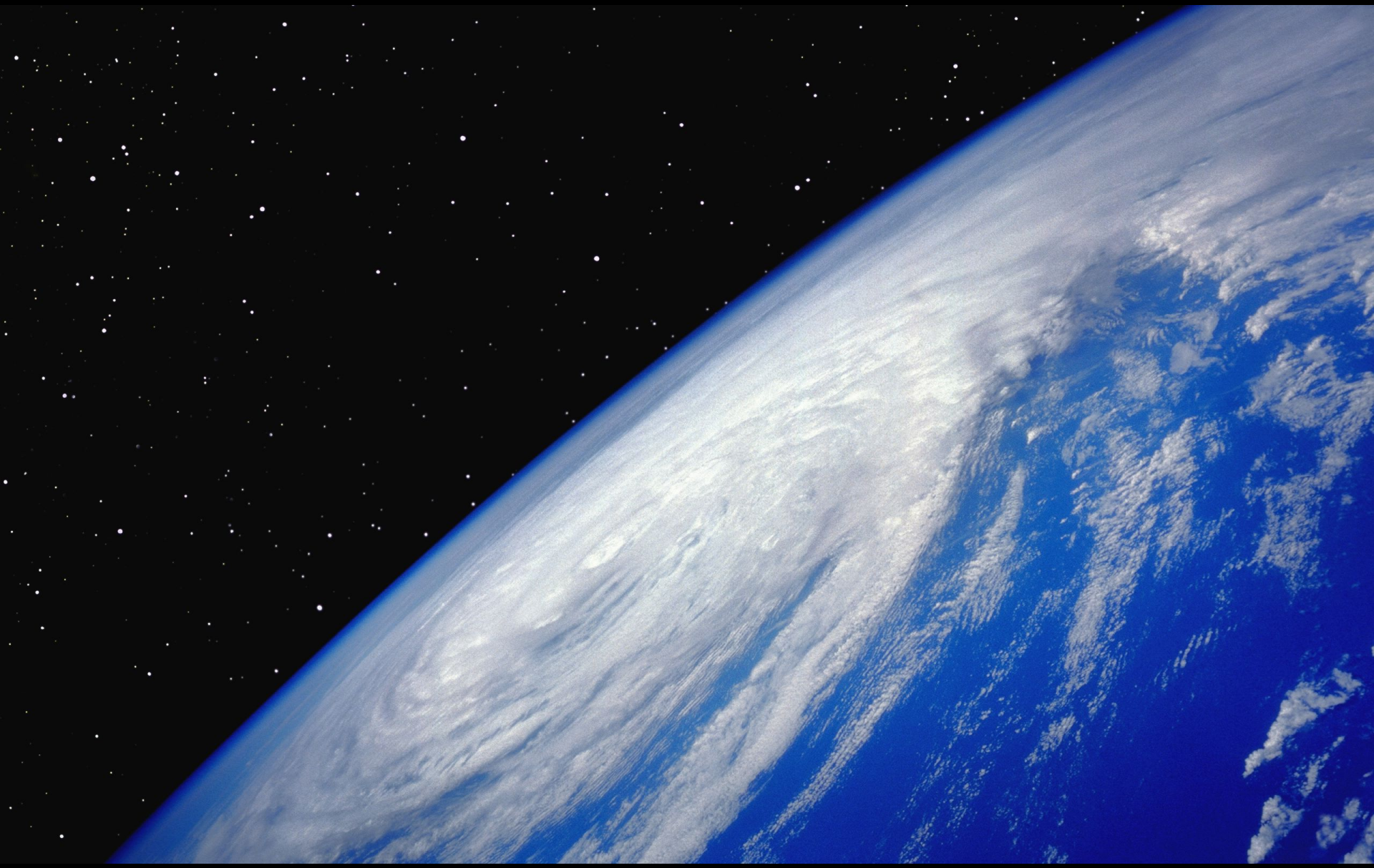
artist's depiction of Oort Cloud —
swarms of comets

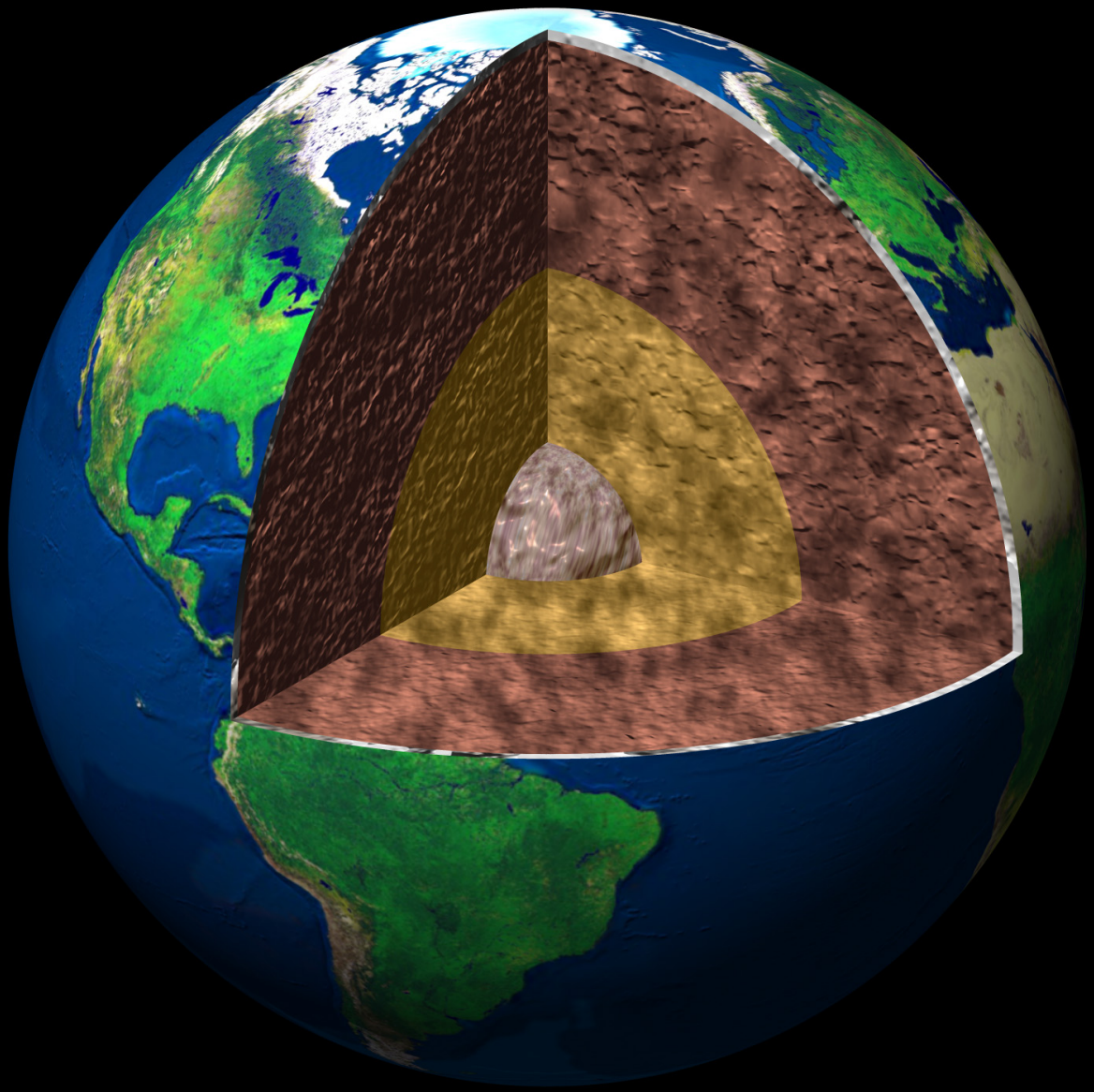


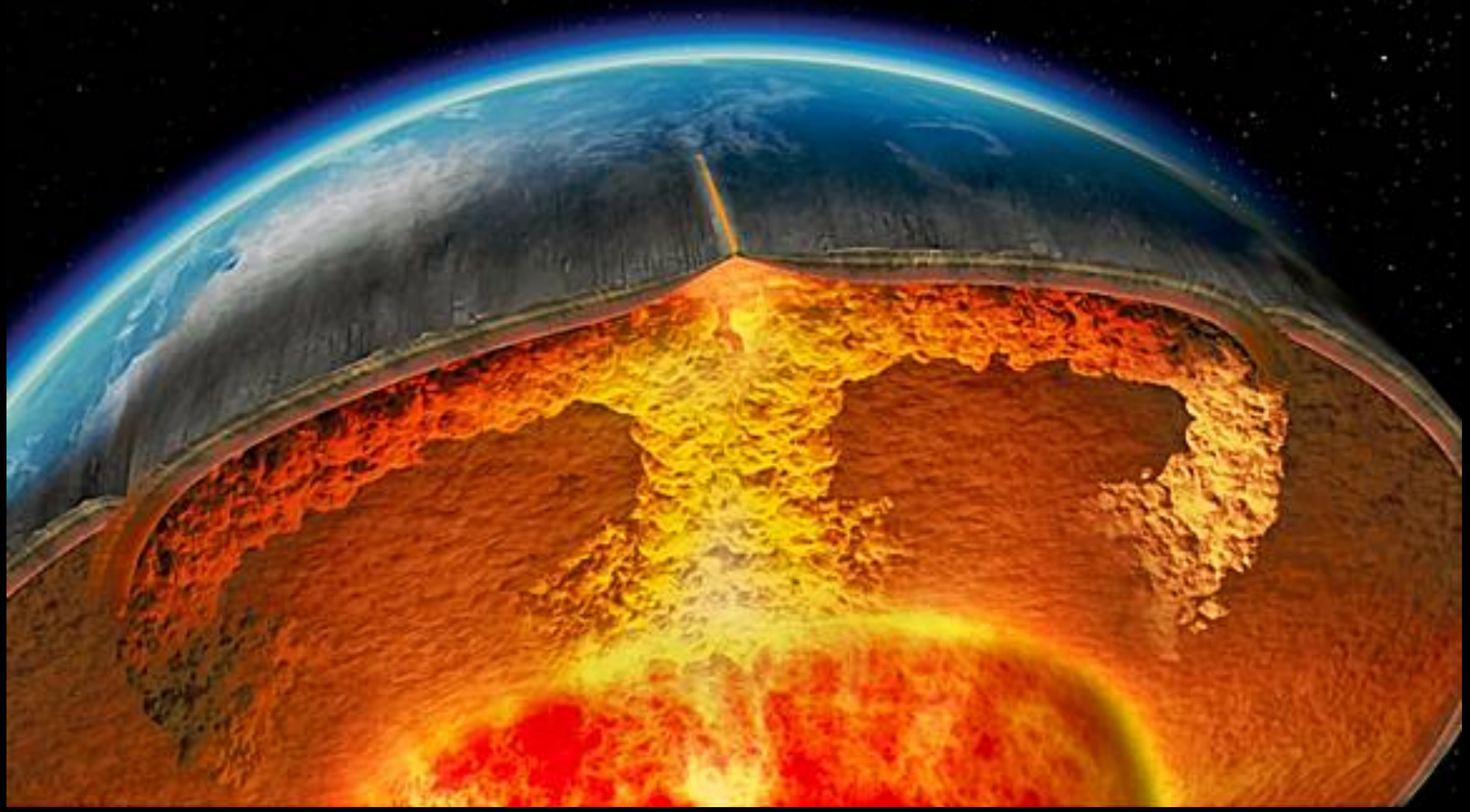
orbits of comets in Oort Cloud are like
bees swarming around a hive

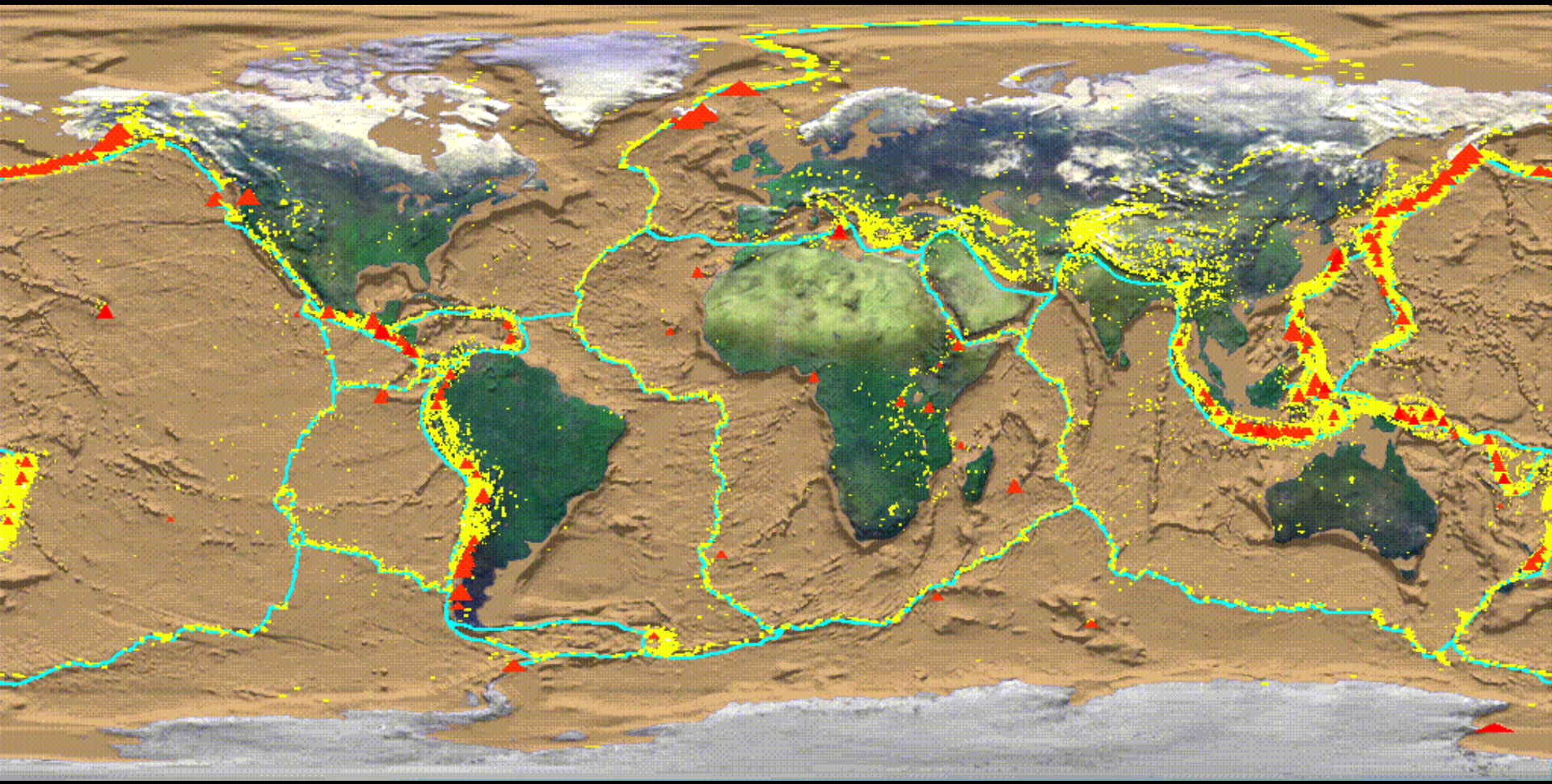




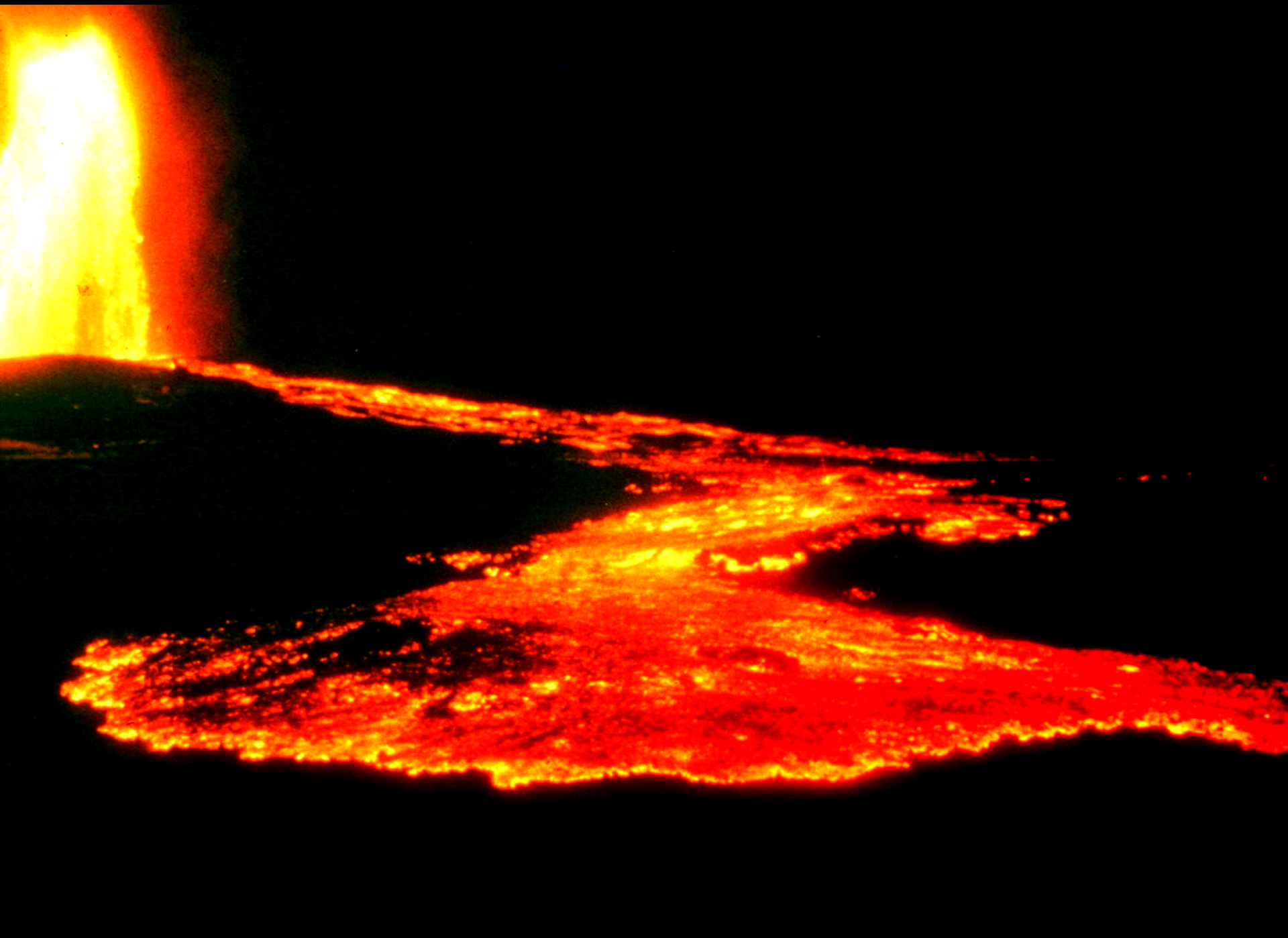


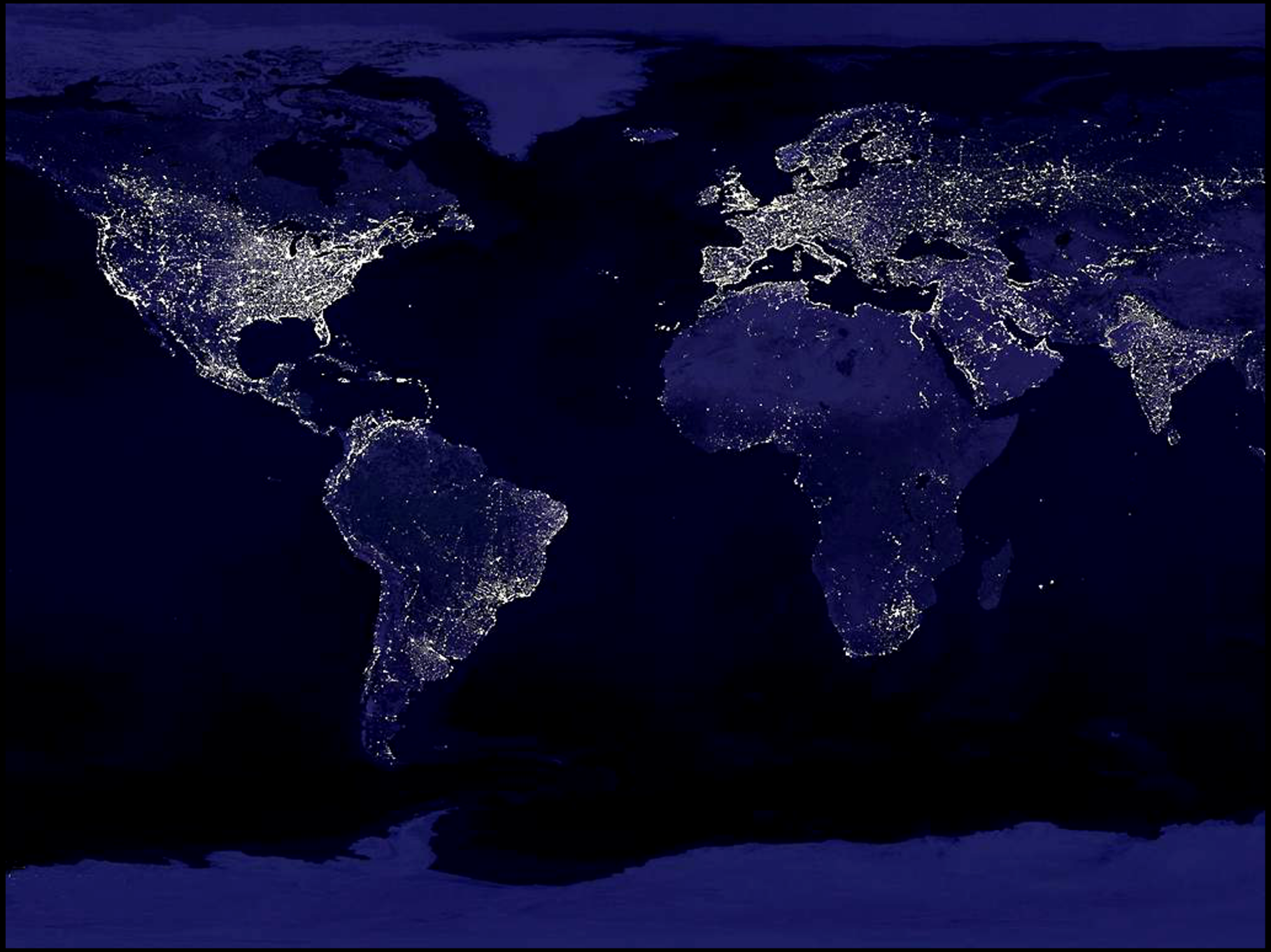


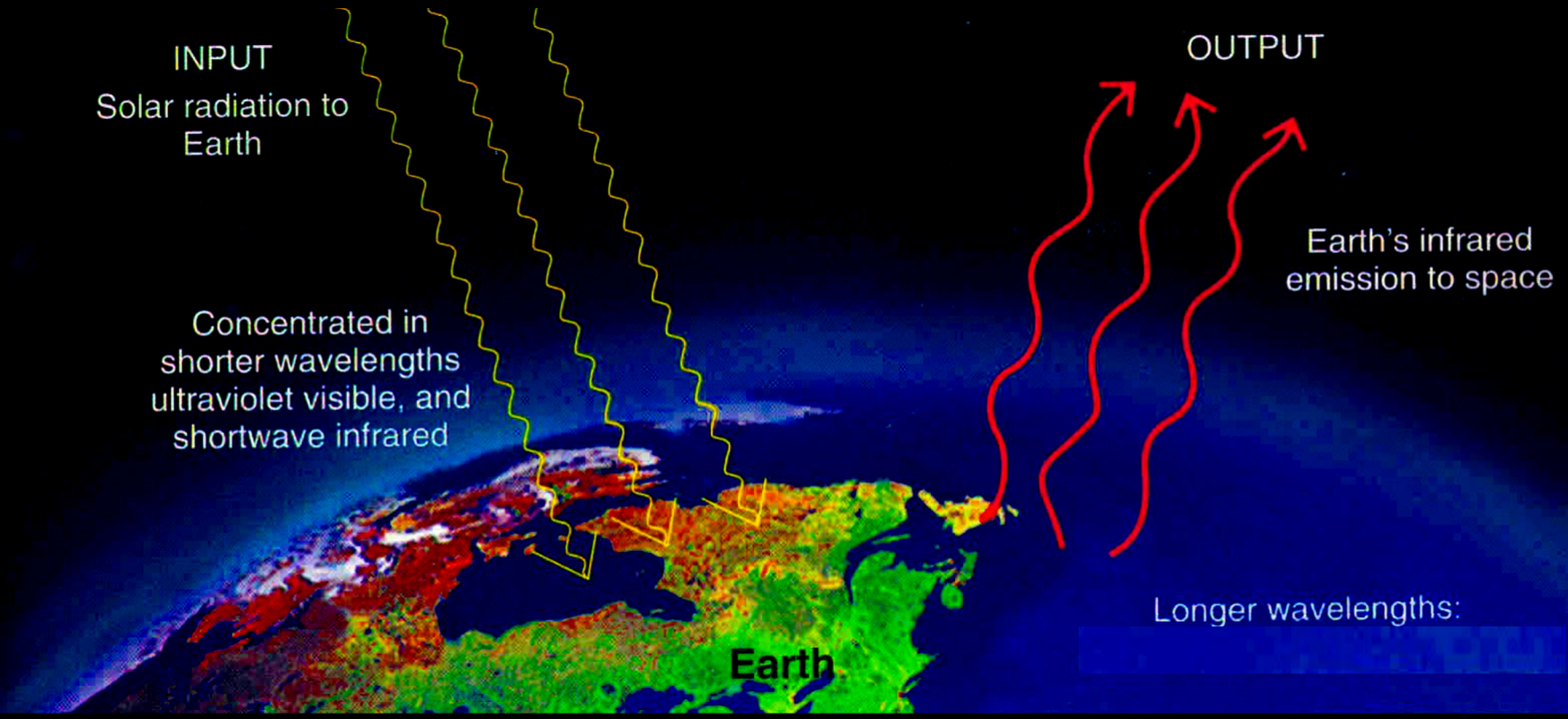


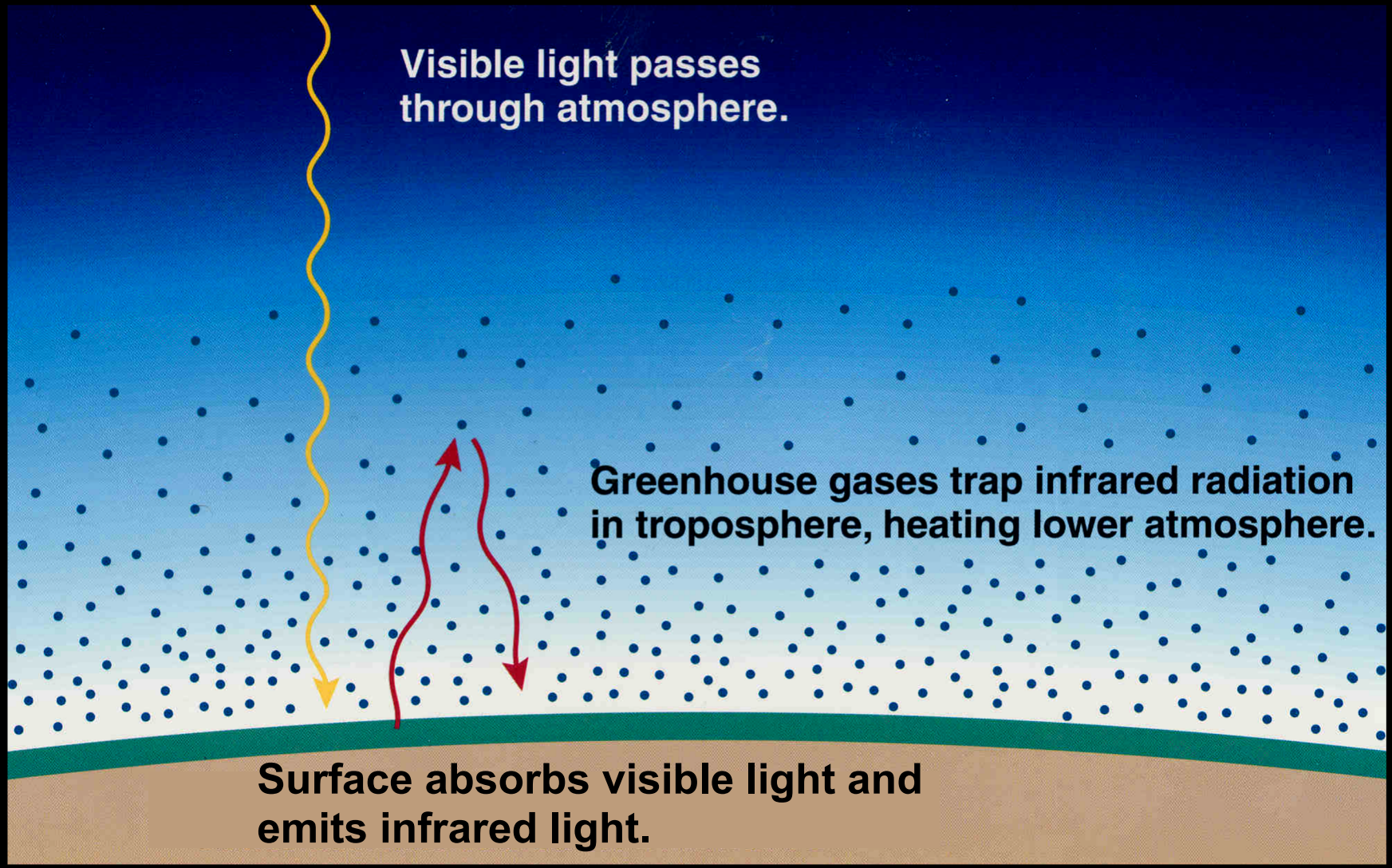


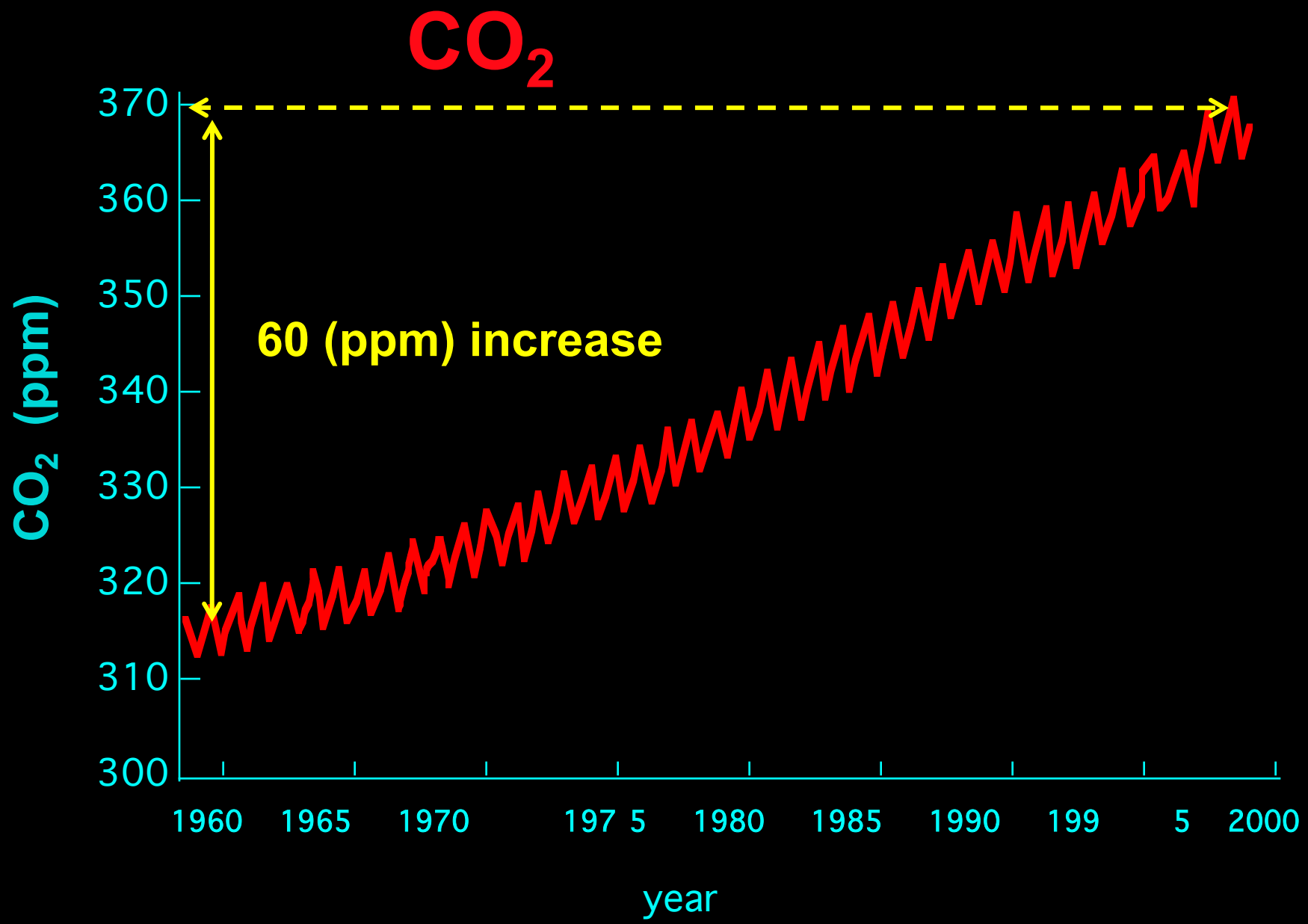


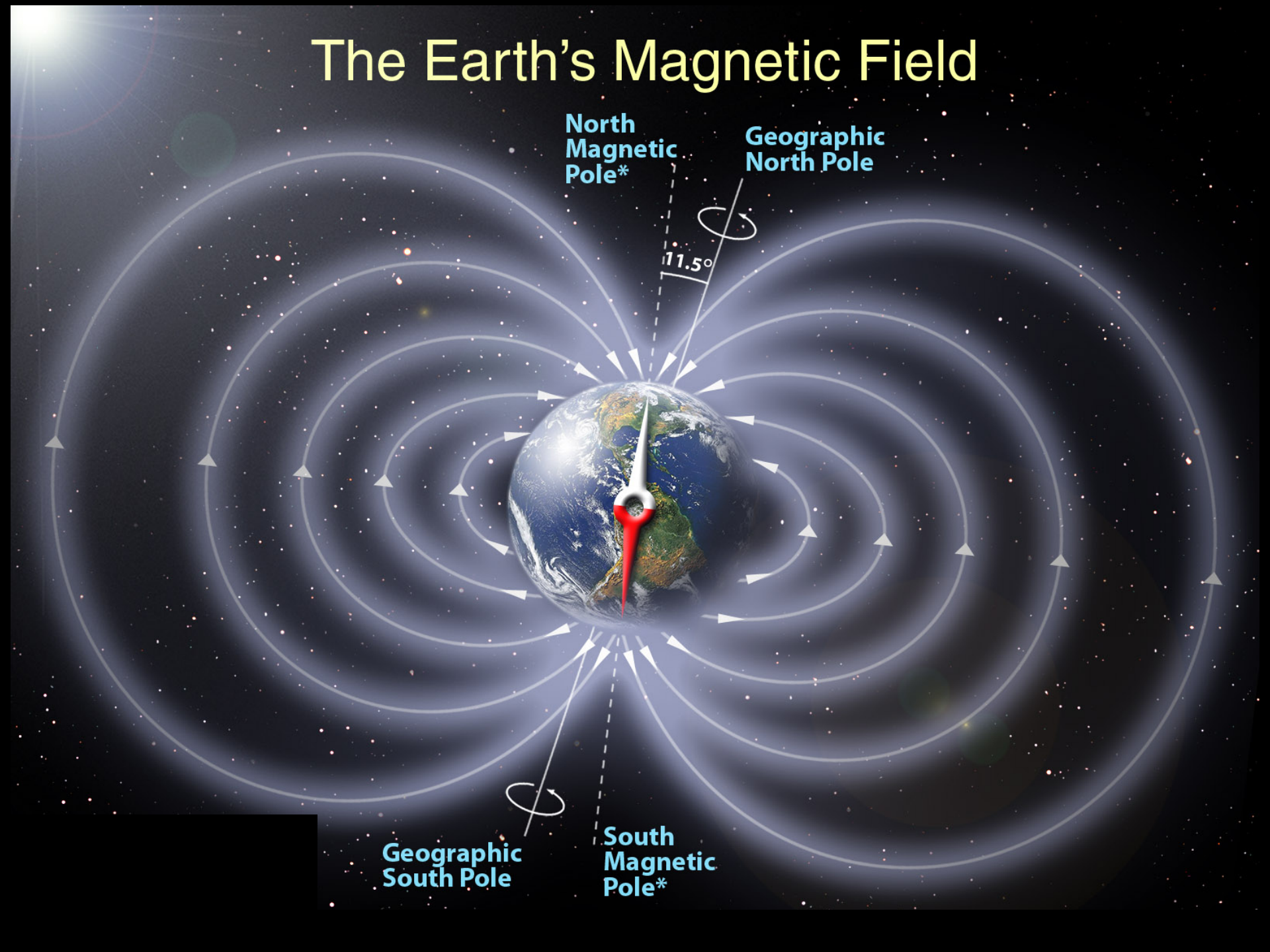


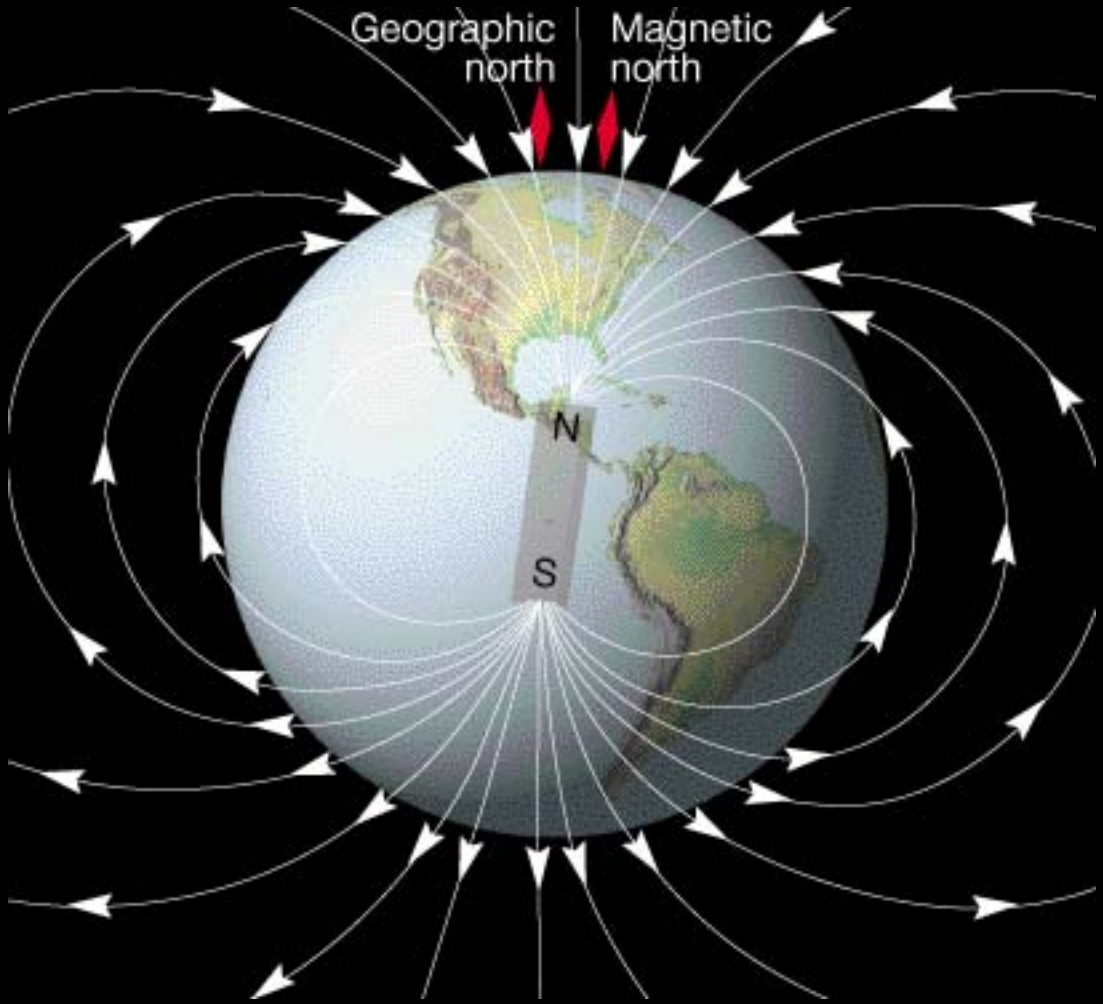


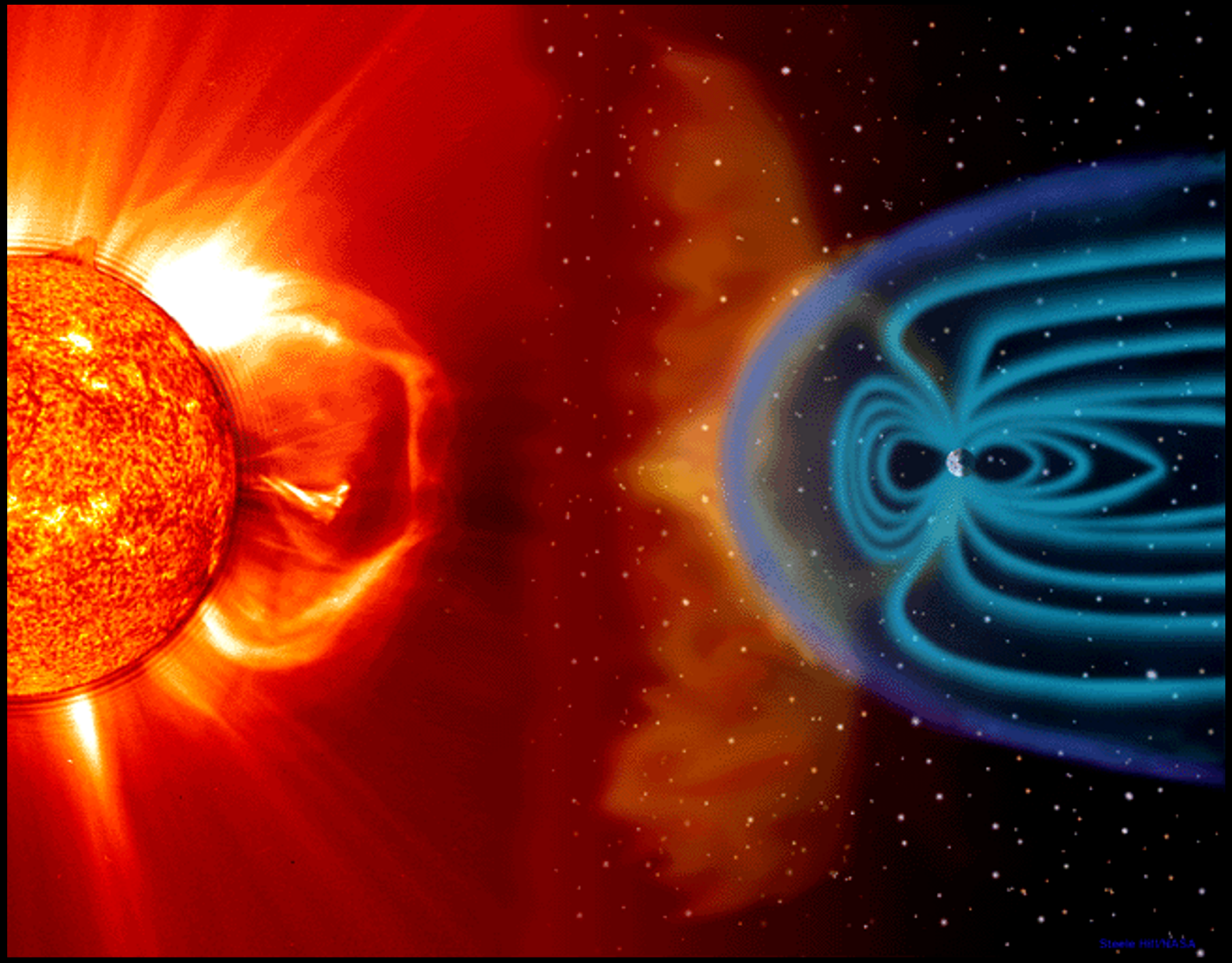

INPUT
Solar radiation to Earth
Concentrated in shorter wavelengths ultraviolet visible, and shortwave infrared
OUTPUT
Earth's infrared emission to space
Longer wavelengths:
Earth


Visible light passes through atmosphere.
Greenhouse gases trap infrared radiation in troposphere, heating lower atmosphere.
Surface absorbs visible light and emits infrared light.


CO2
370
360
350
340
330
320
310
300
CO2 (ppm)
60 (ppm) increase
1960
1965
1970
197 5
1980
1985
1990
199
5
2000
year


The Earth's Magnetic Field
North Magnetic Pole*
Geographic North Pole
11.5°
Geographic South Pole
South Magnetic Pole*


Geographic north
Magnetic north
N
S

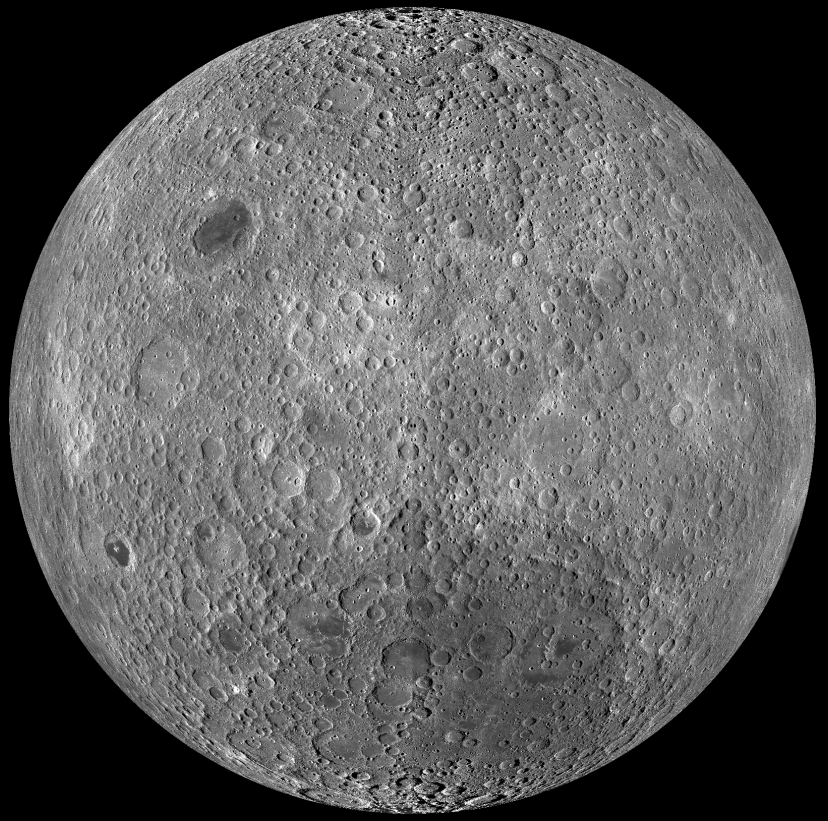

Steele Hill/NASA



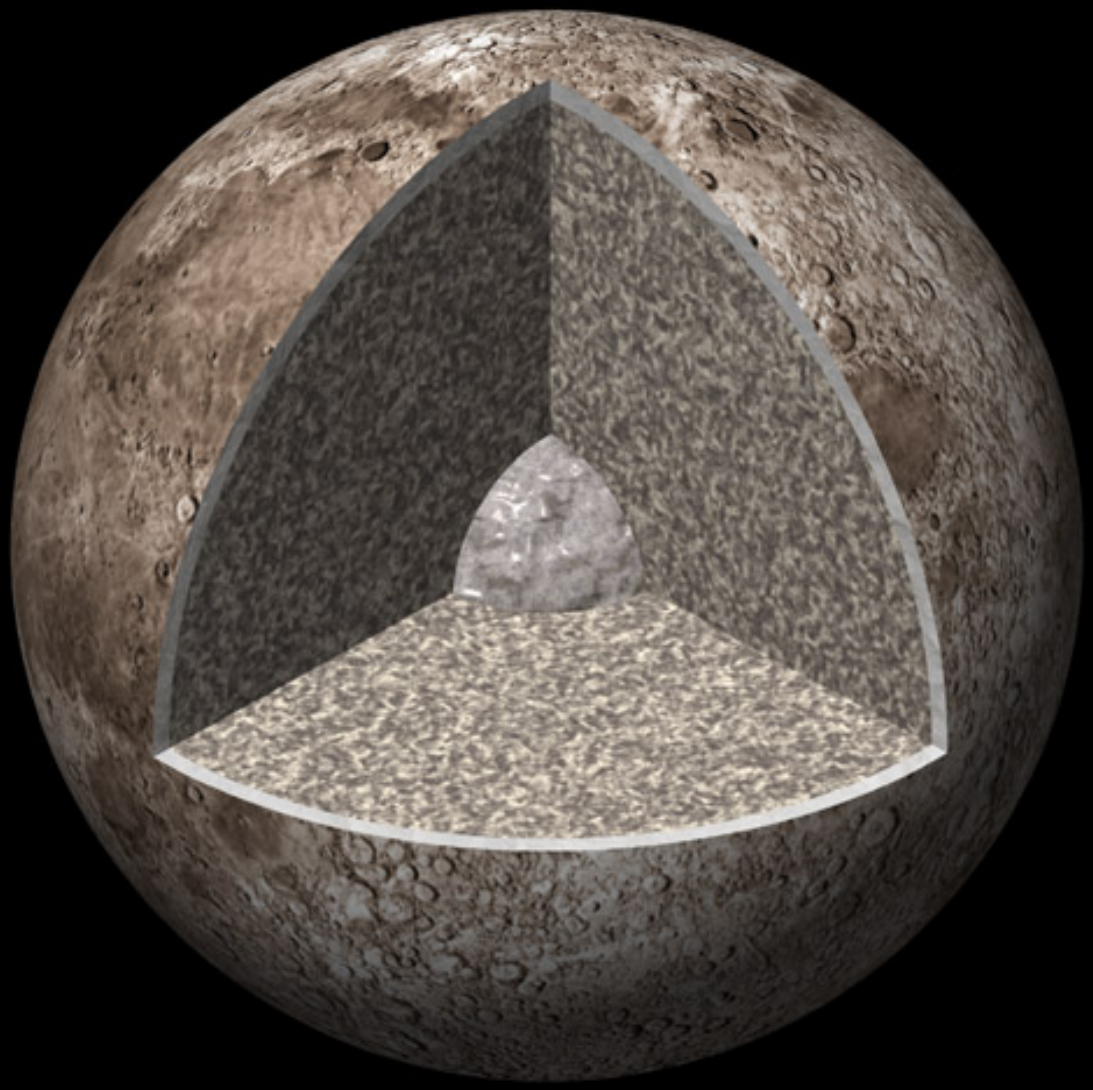




Earth's view of the Moon — only one side

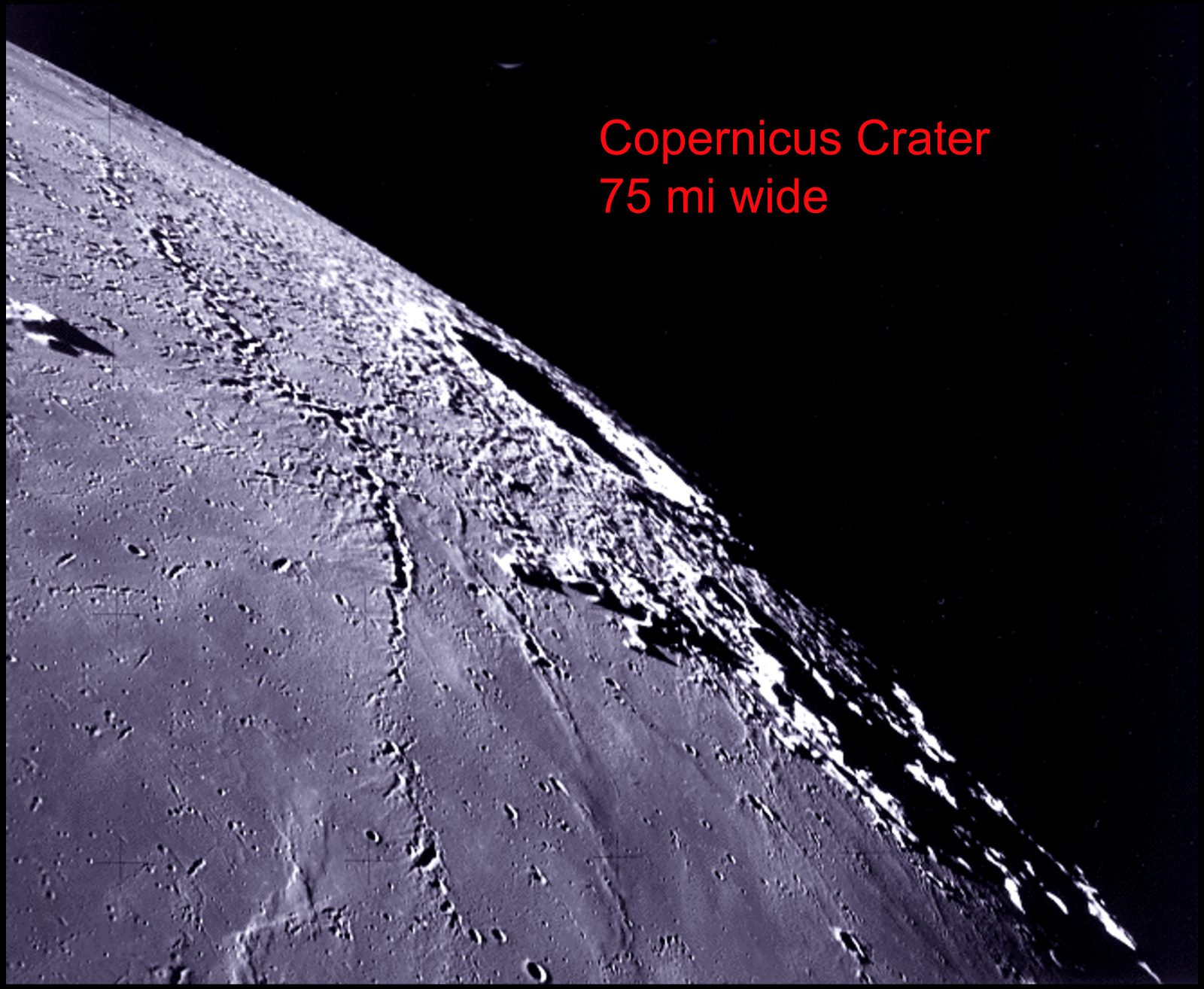


Farside of the Moon — not seen from Earth

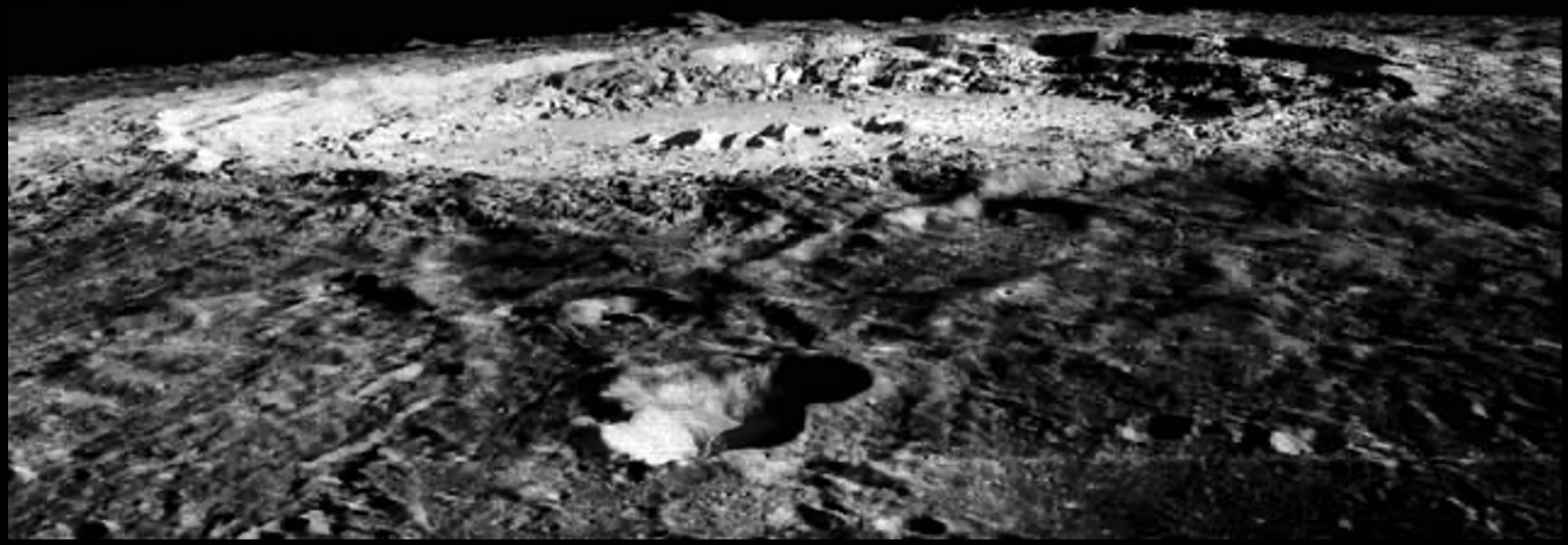


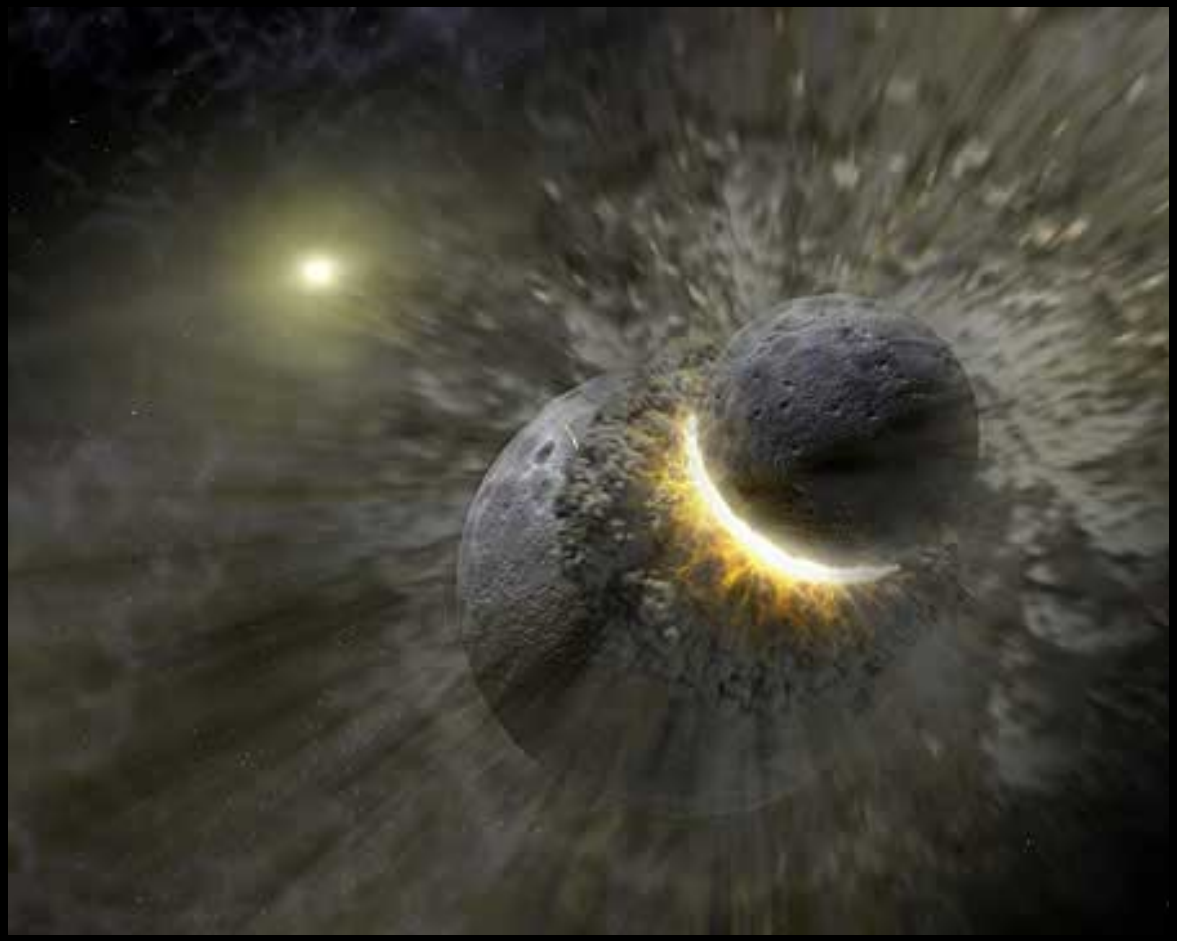





Copernicus Crater
75 mi wide

Copernicus Crater



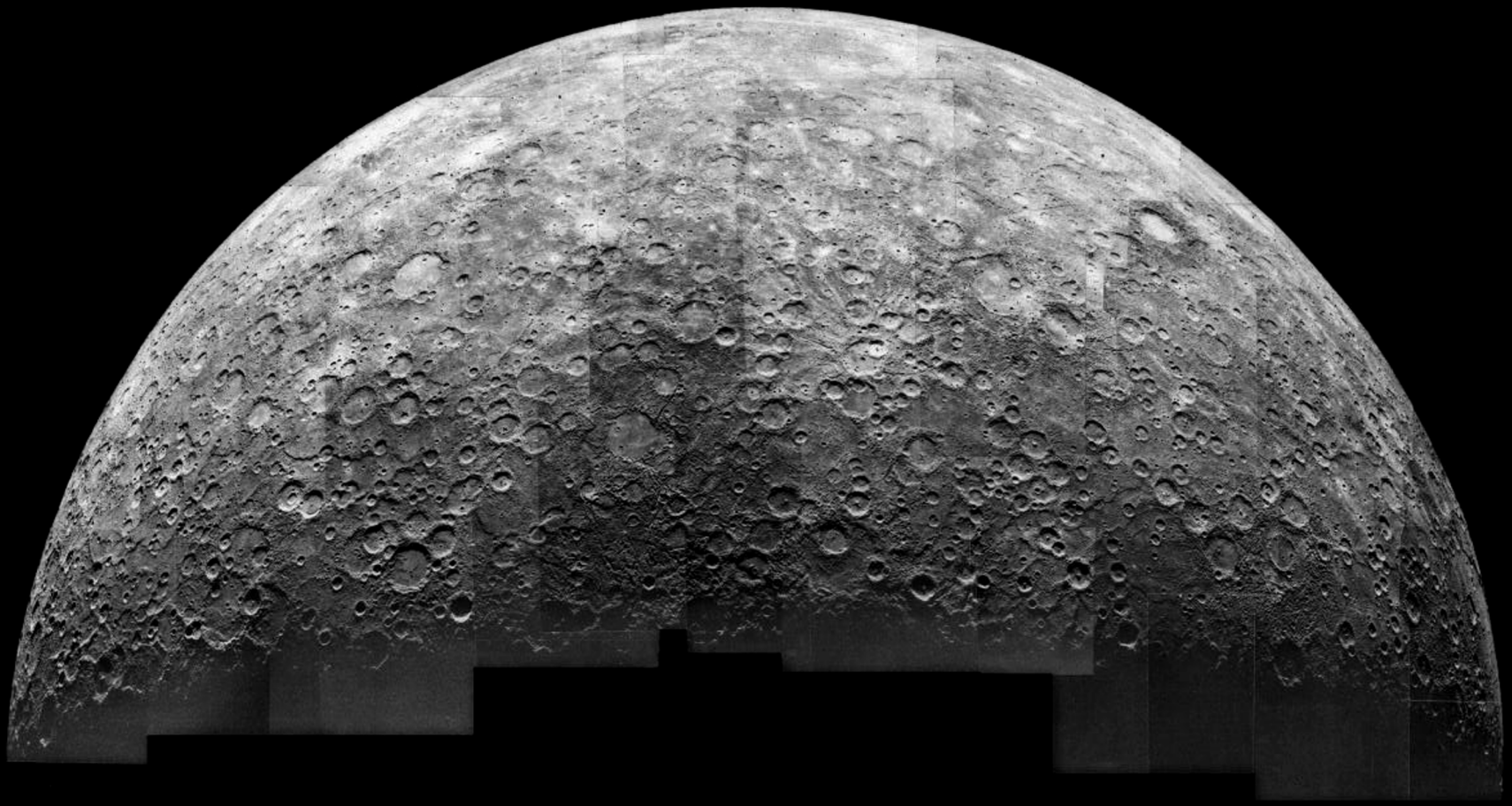


Abour 1 billion years after the
solar system started to form

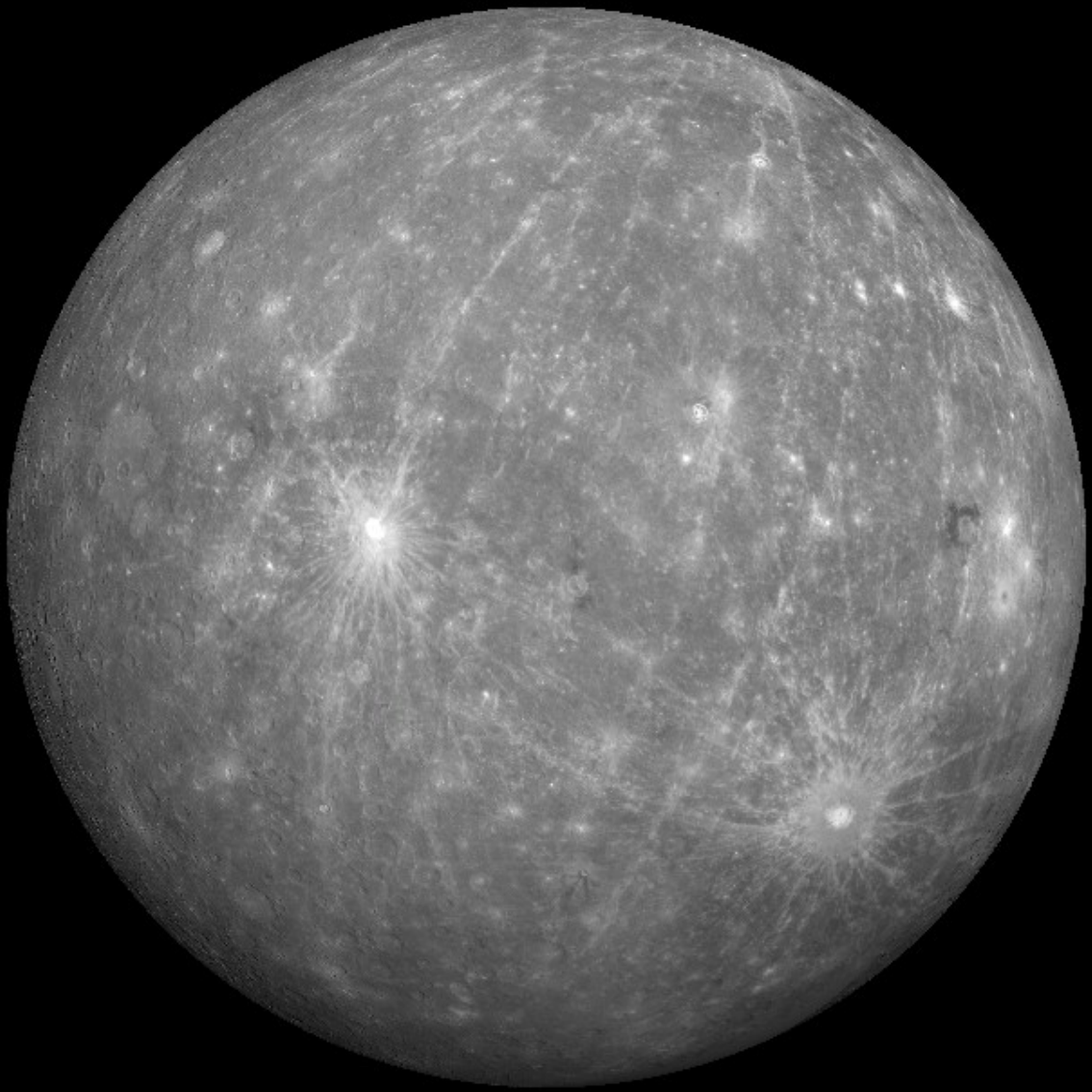
Moon's formation:

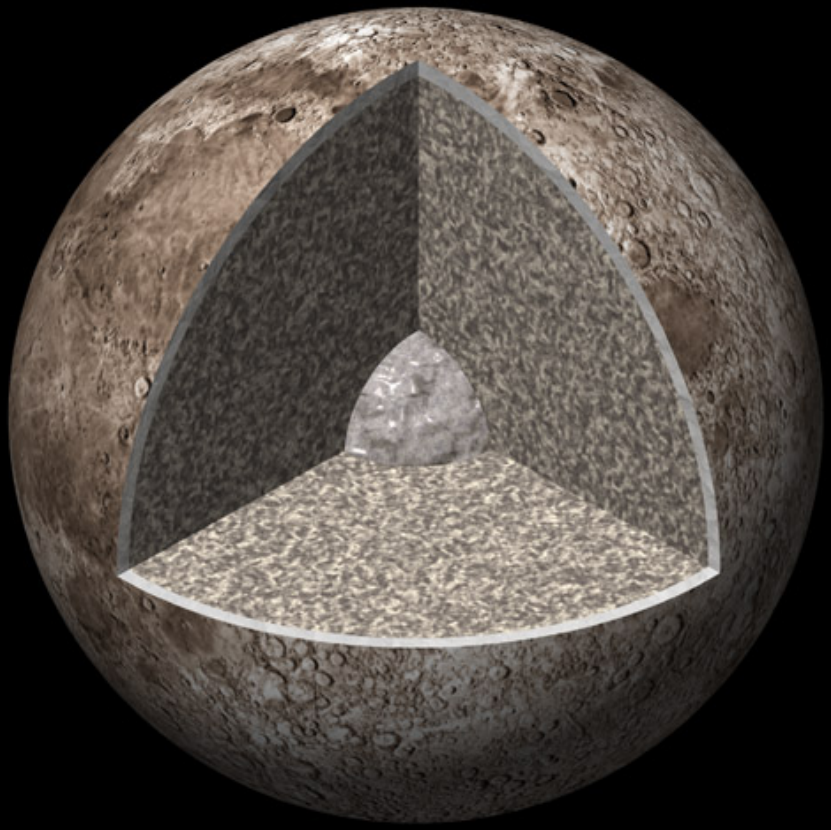
➔ caused strong tides on Earth

➔ stabilized Earth's rotational tilt

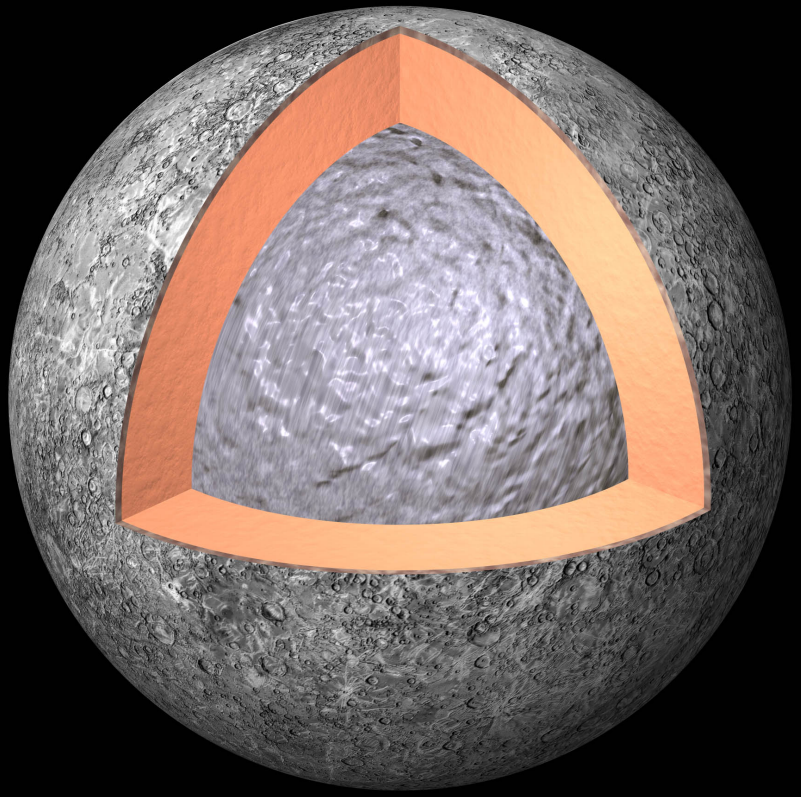


Mercury





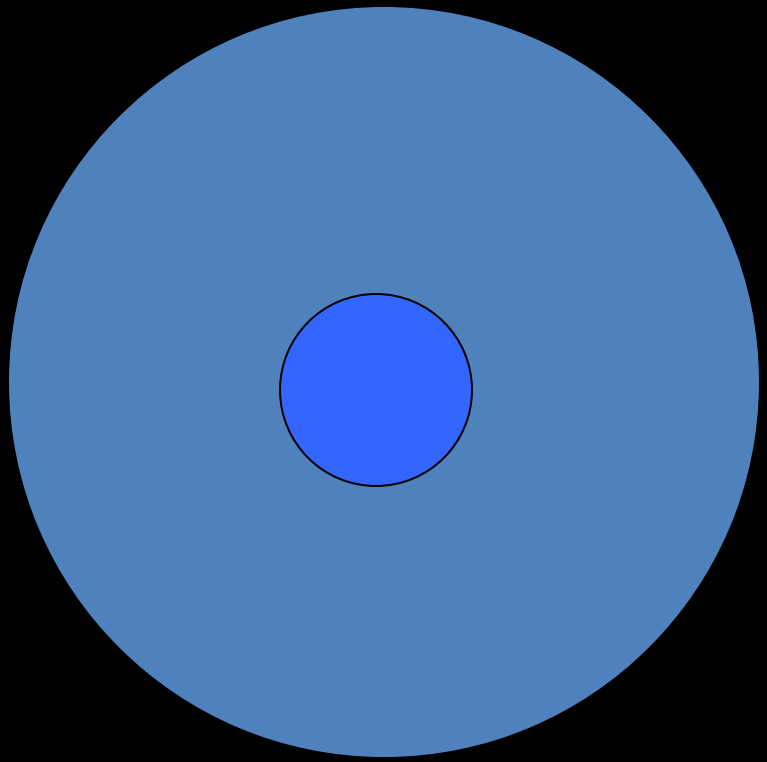
Earth’s Moon

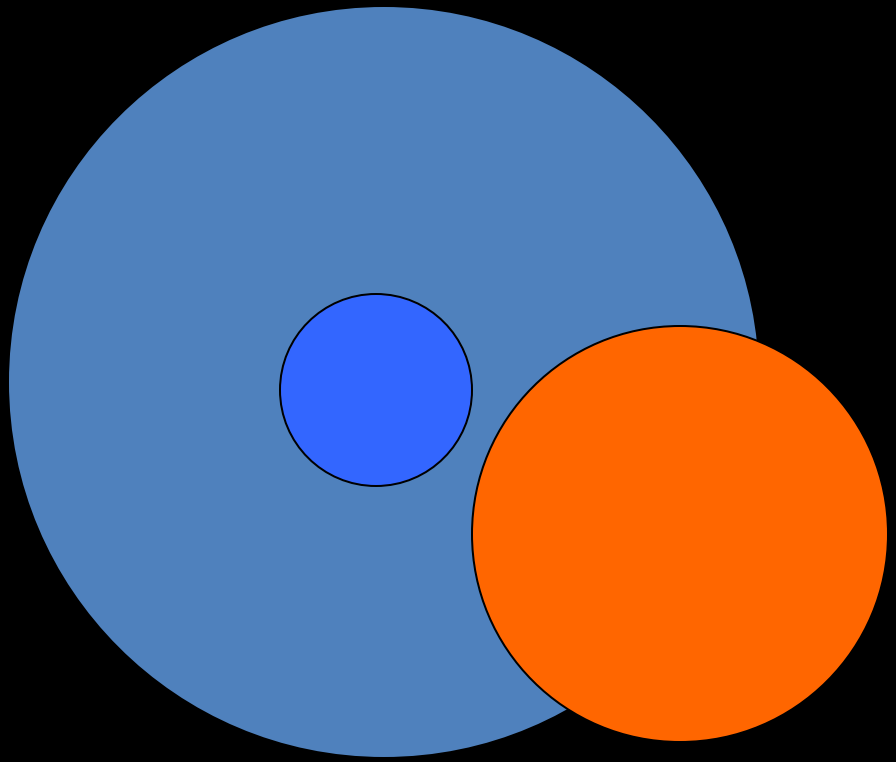


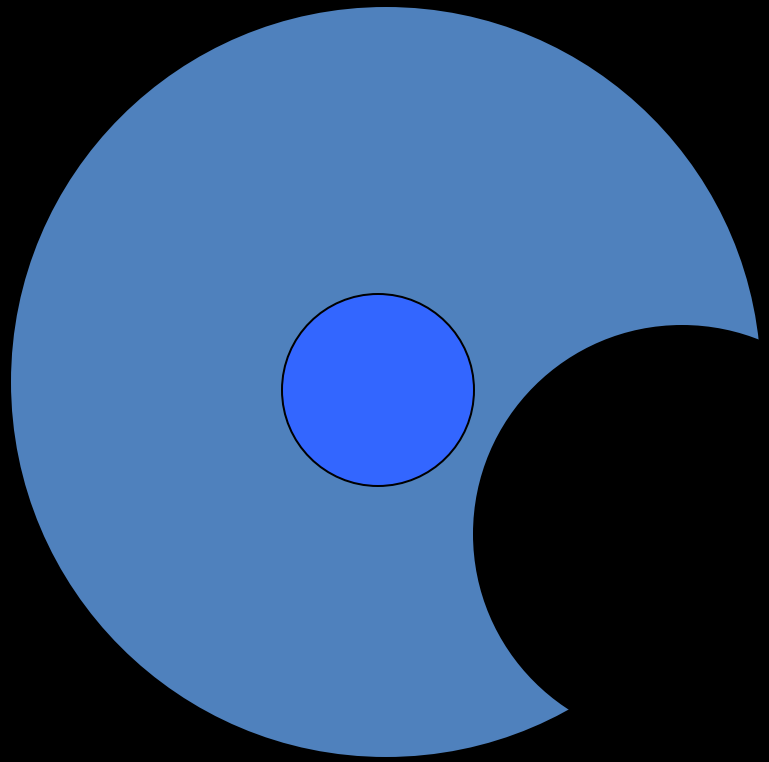
Mercury

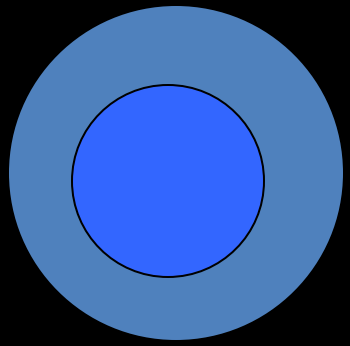

glancing blow



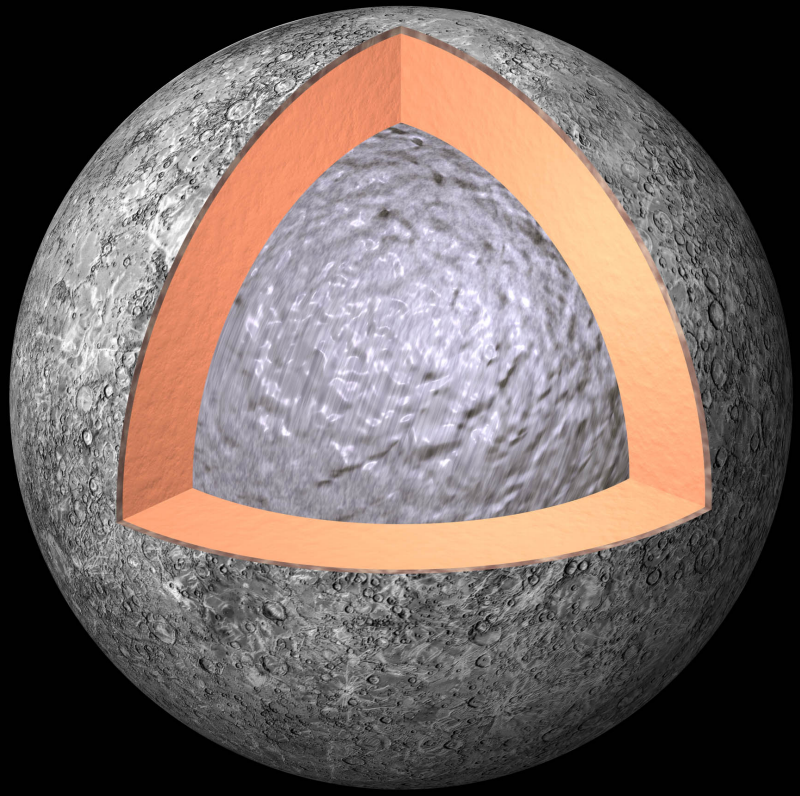




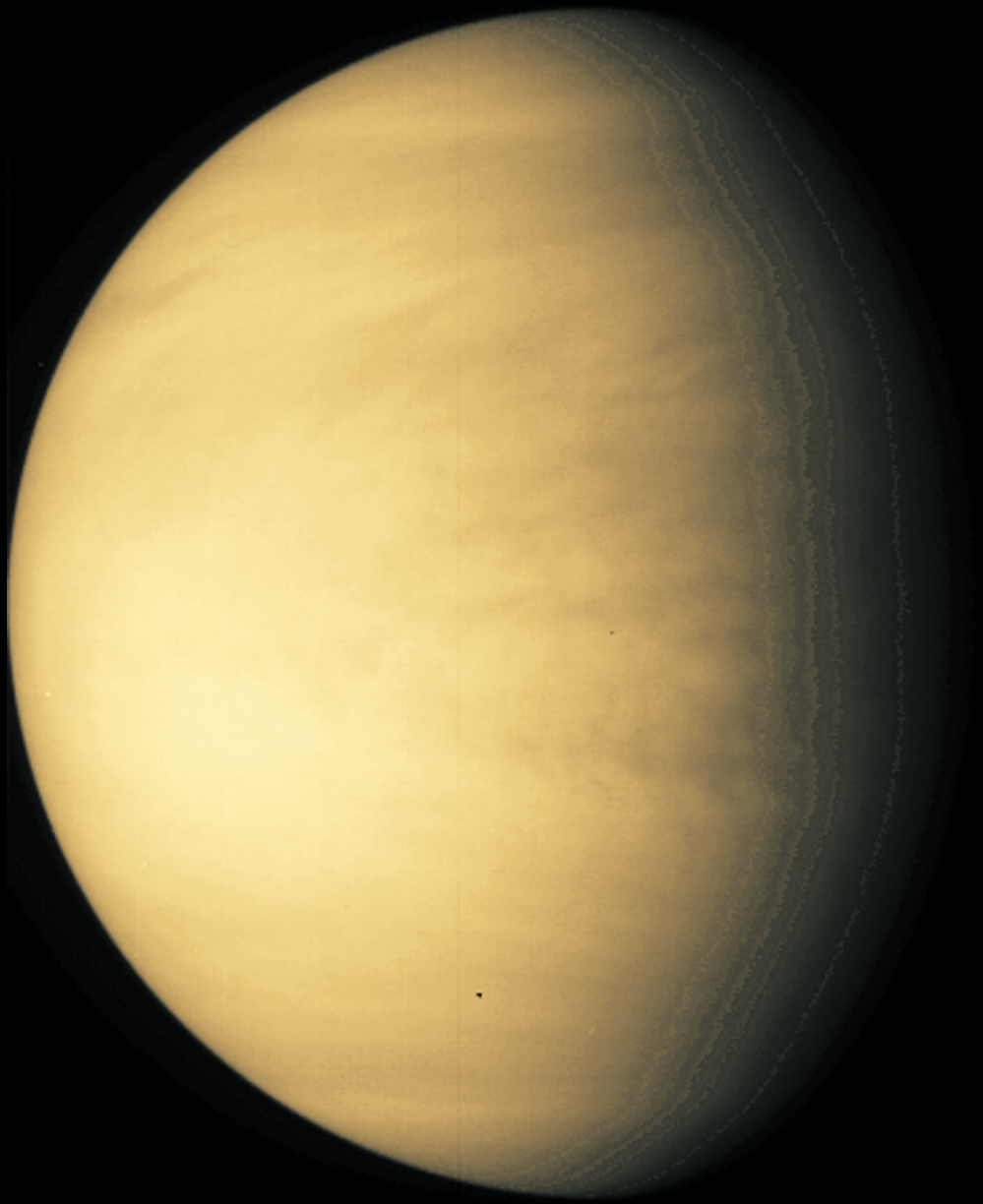




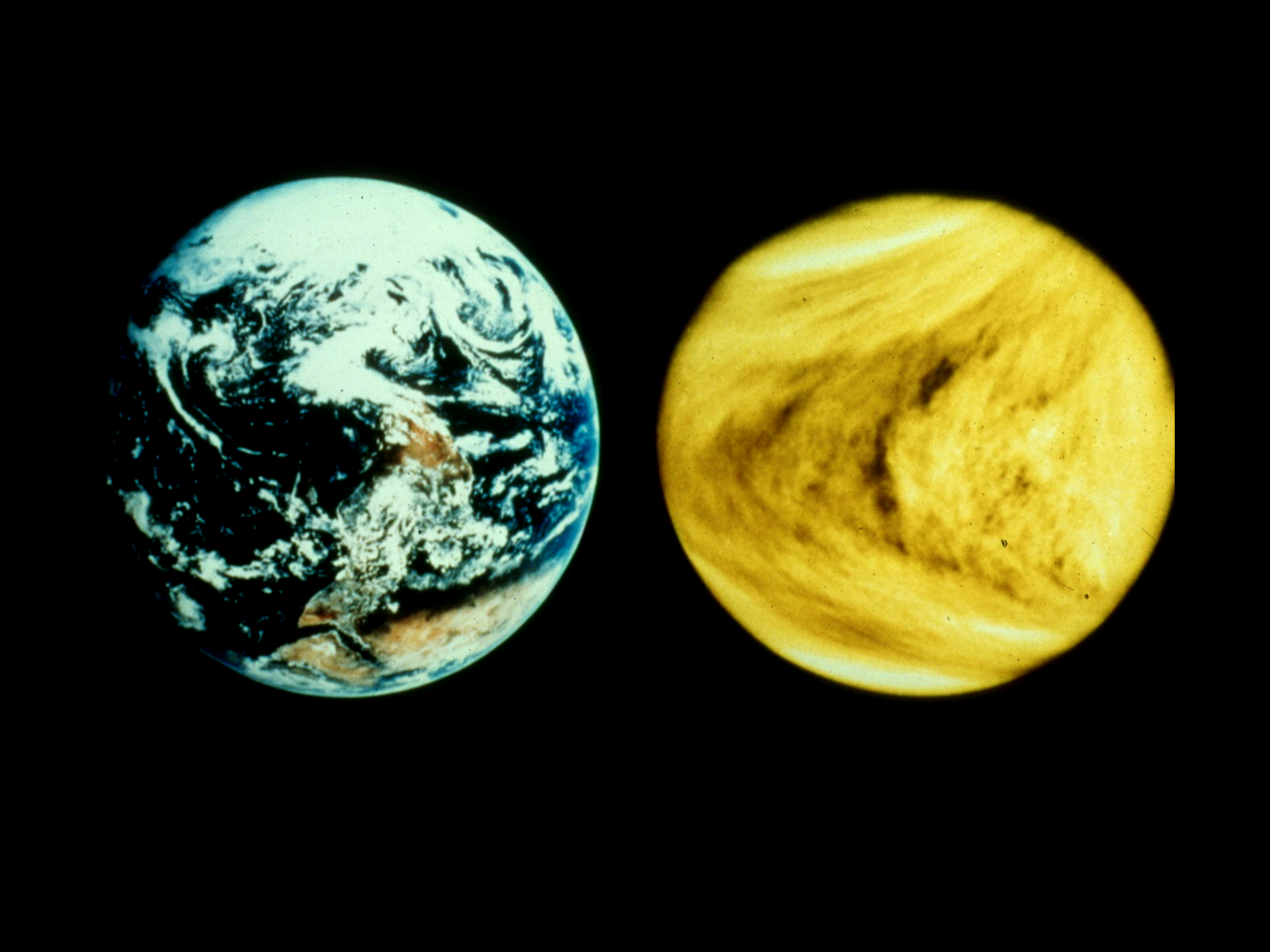
Mercury's huge core

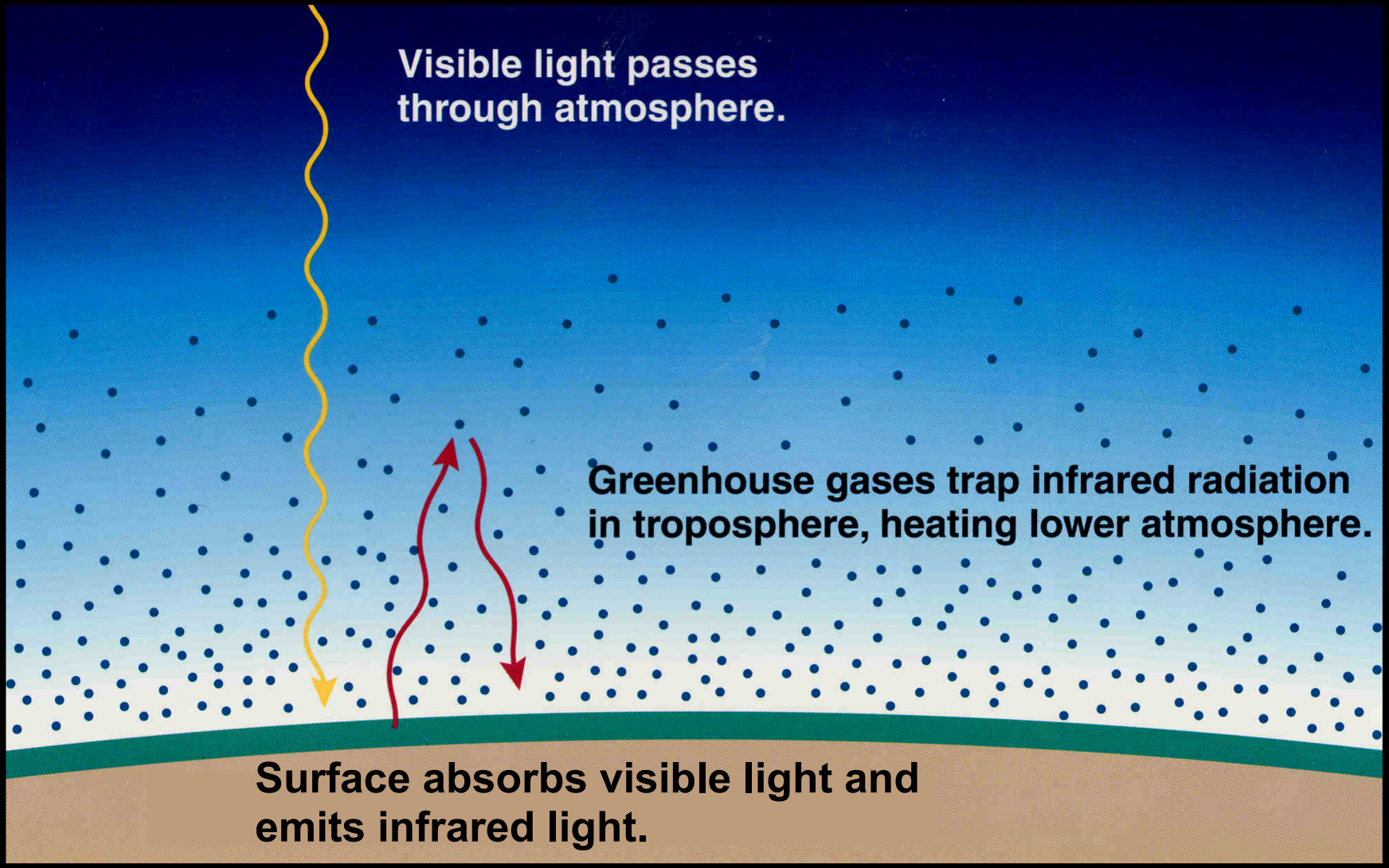


Mercury's huge core



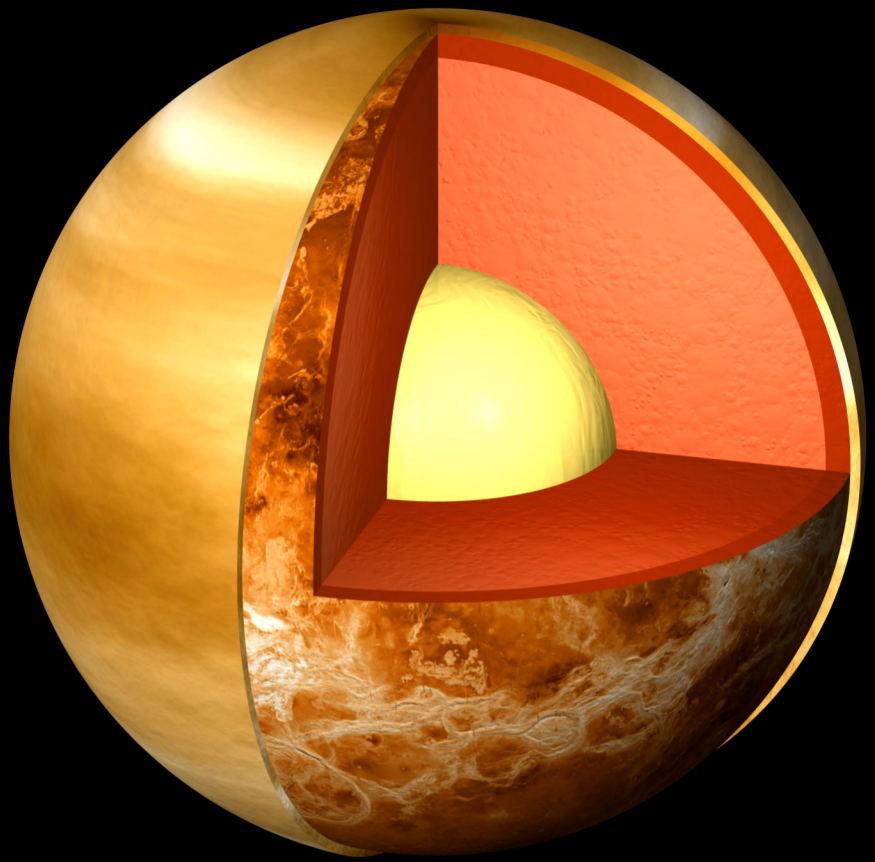
Venus




Visible light passes
through atmosphere.
Greenhouse gases trap infrared radiation
in troposphere, heating lower atmosphere.
Surface absorbs visible light and
emits infrared light.



Venus imaged by Magellan using radar





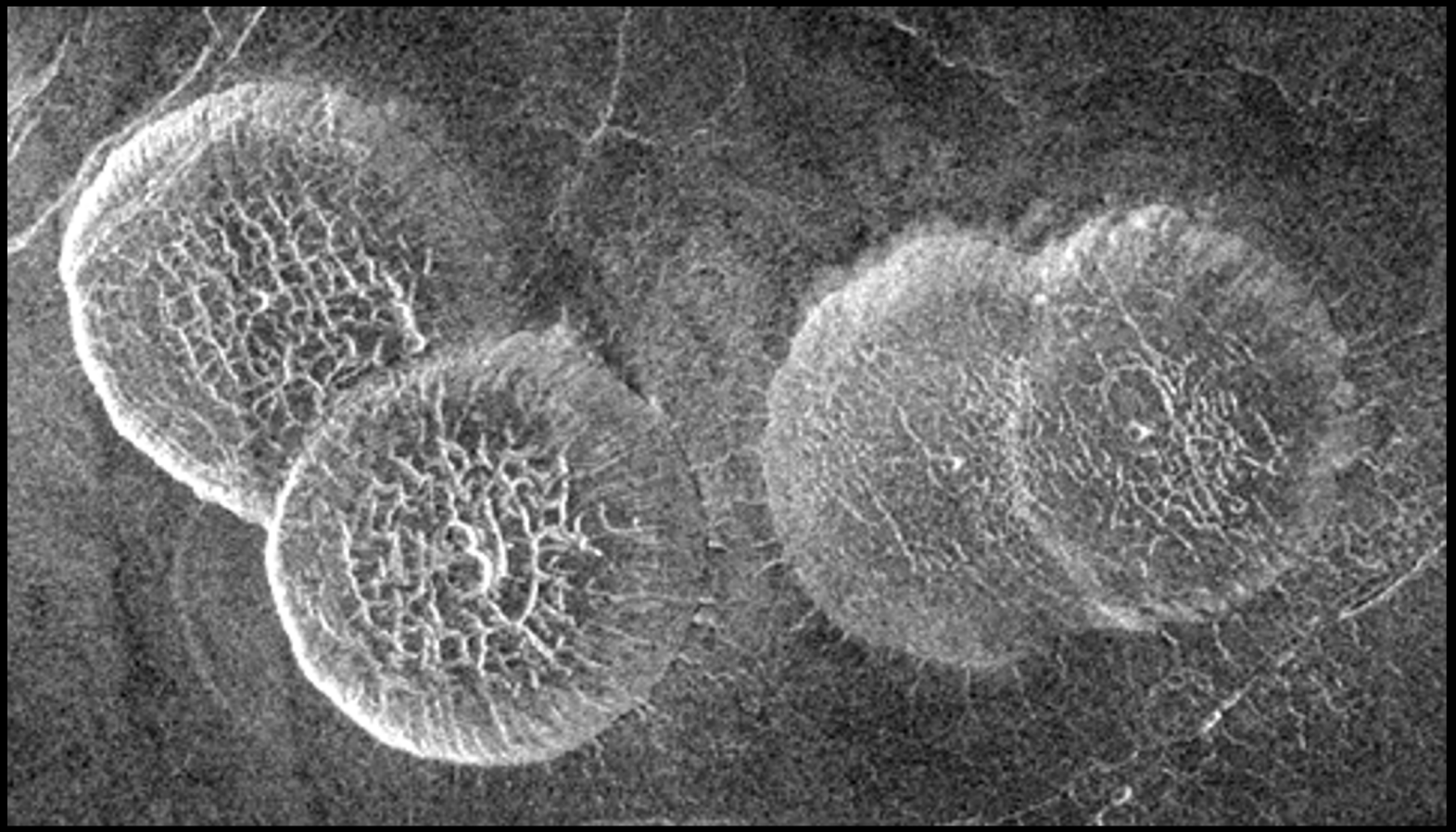
Color as seen on the surface of Venus

Venera 13

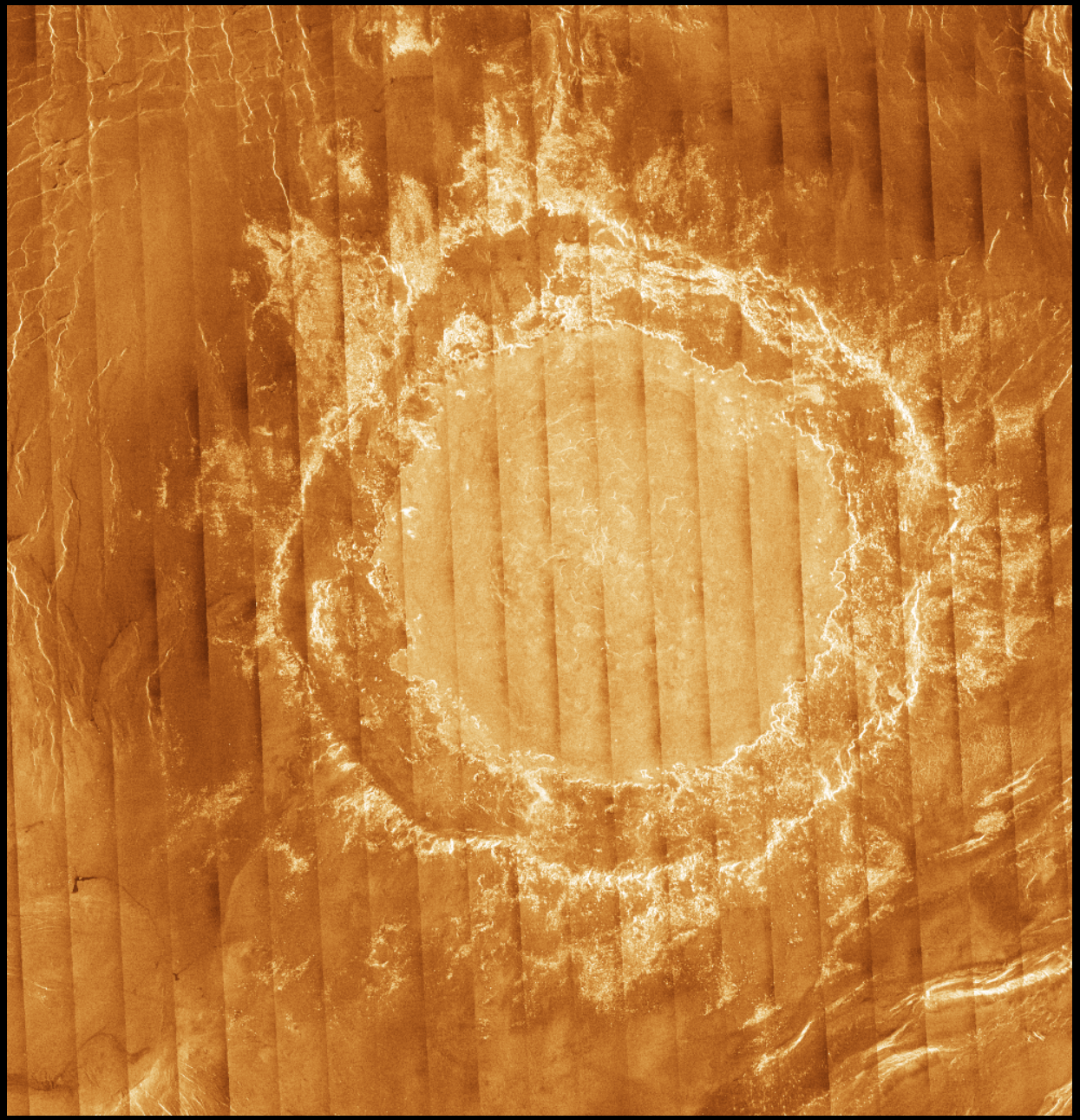
Color with atmospheric effects removed



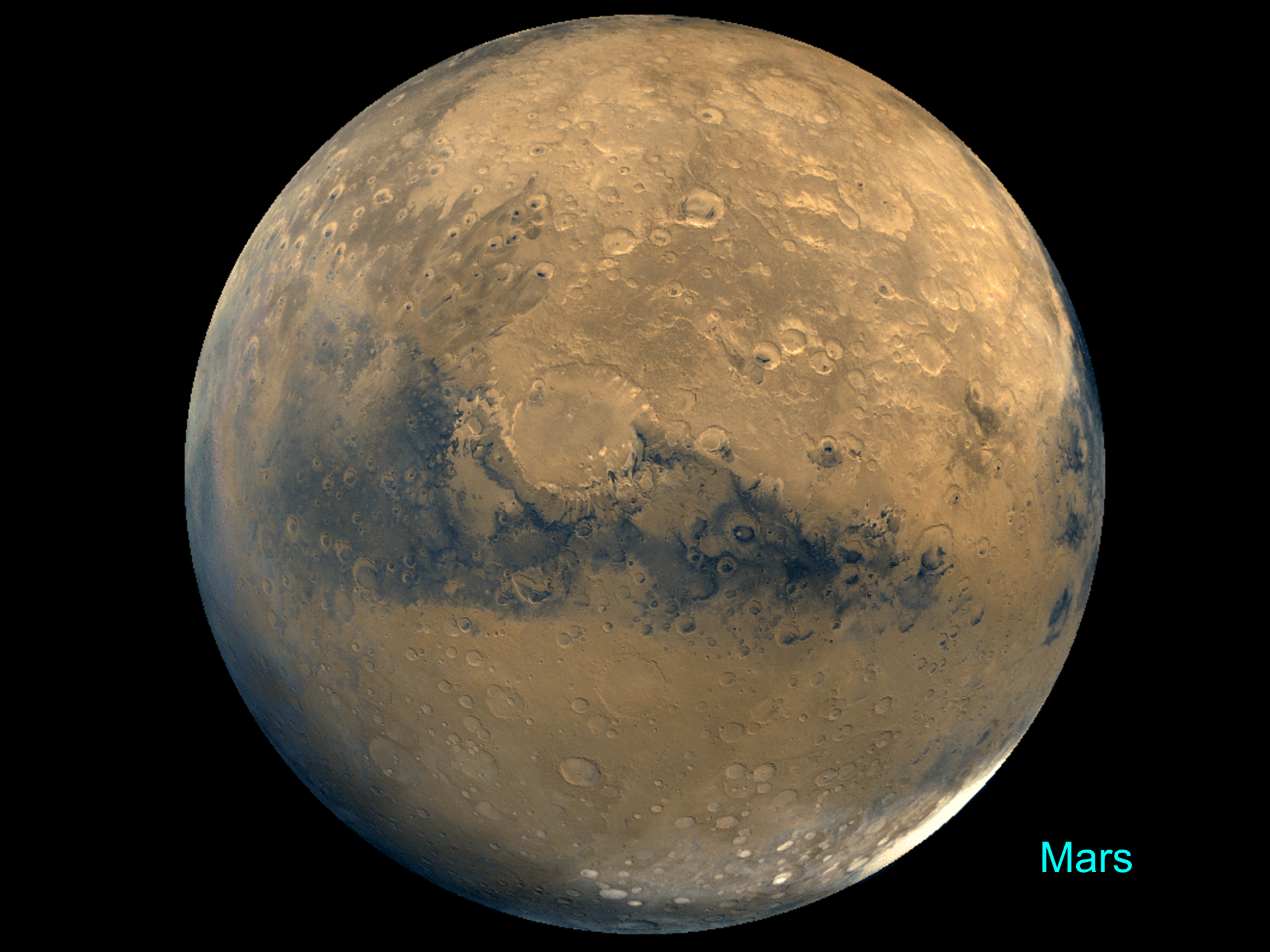
USSR Academy of Sciences / Brown University

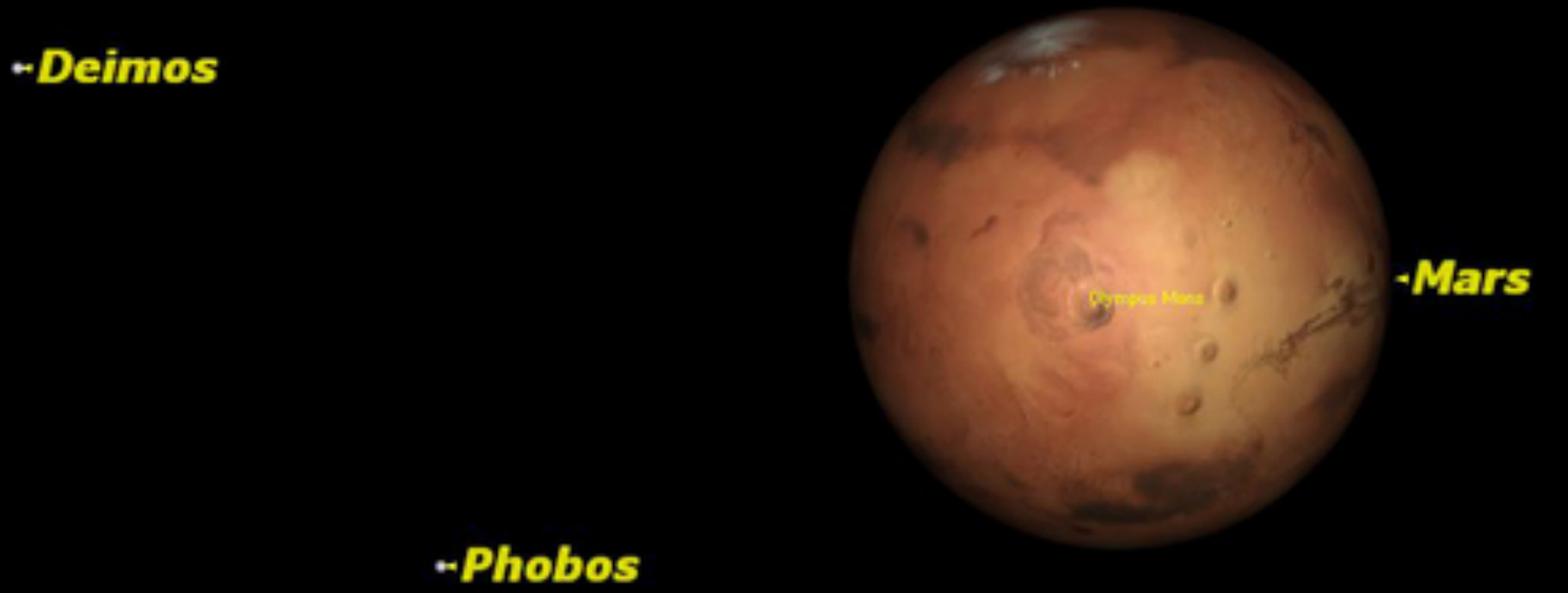


pancake volcanoes — possibly similar to shield volcanoes on Earth

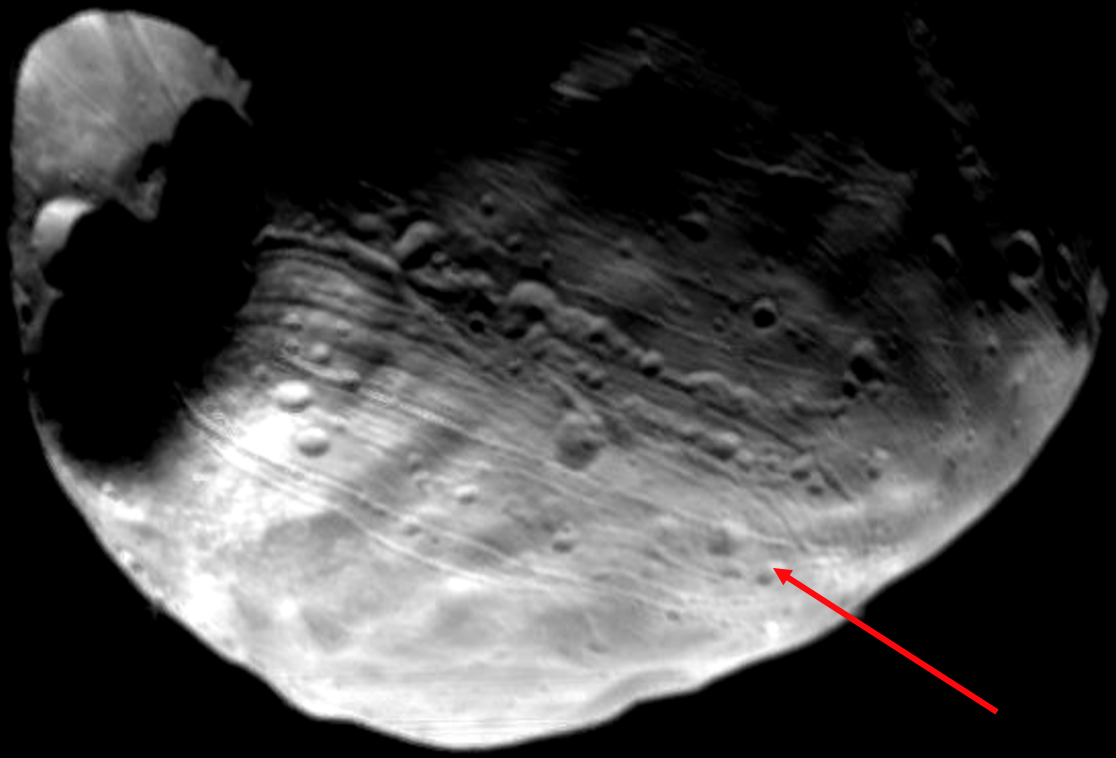


Mead
Crater


Mars



Mars system to scale

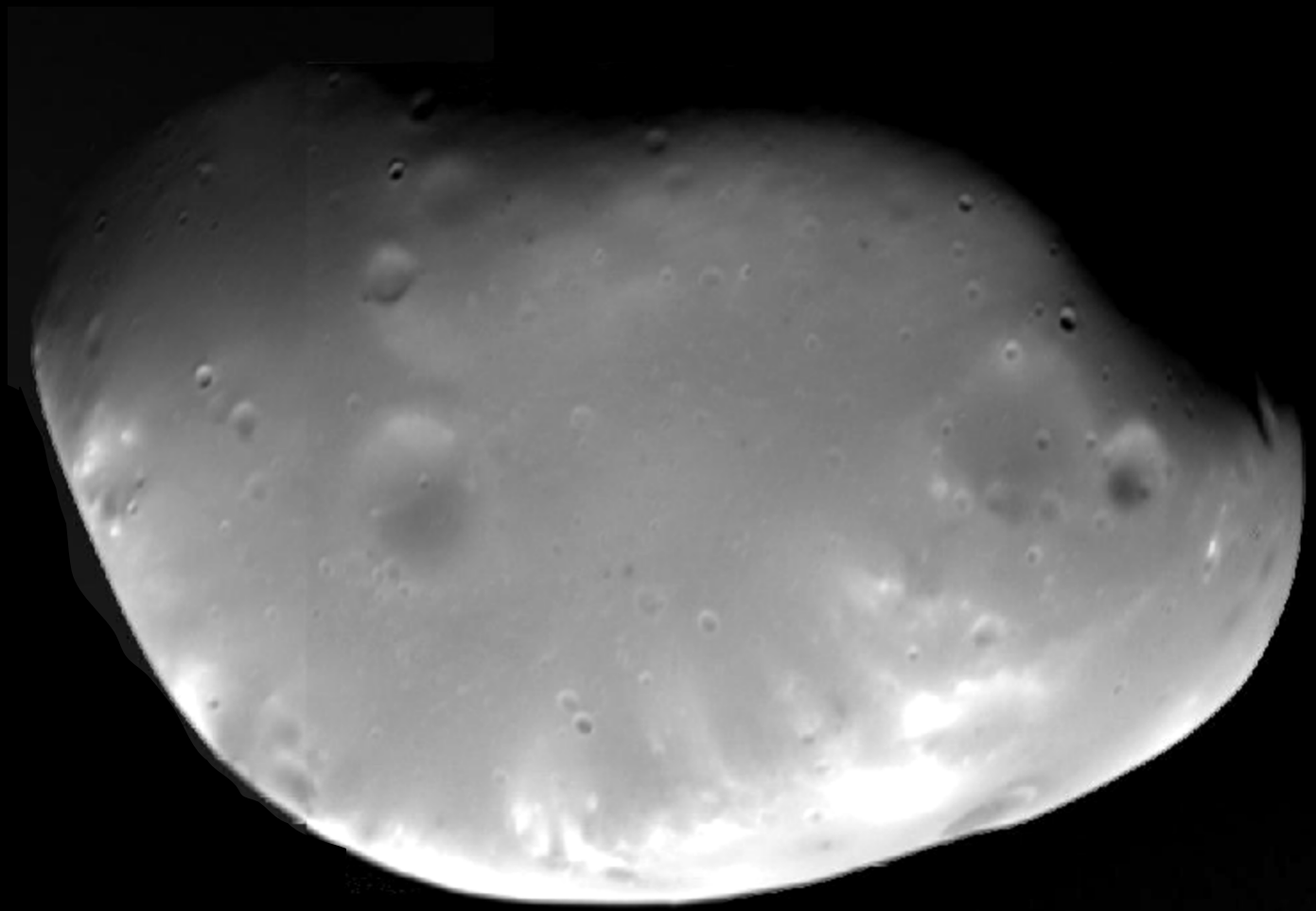


faulting after impact

Phobos
13 km



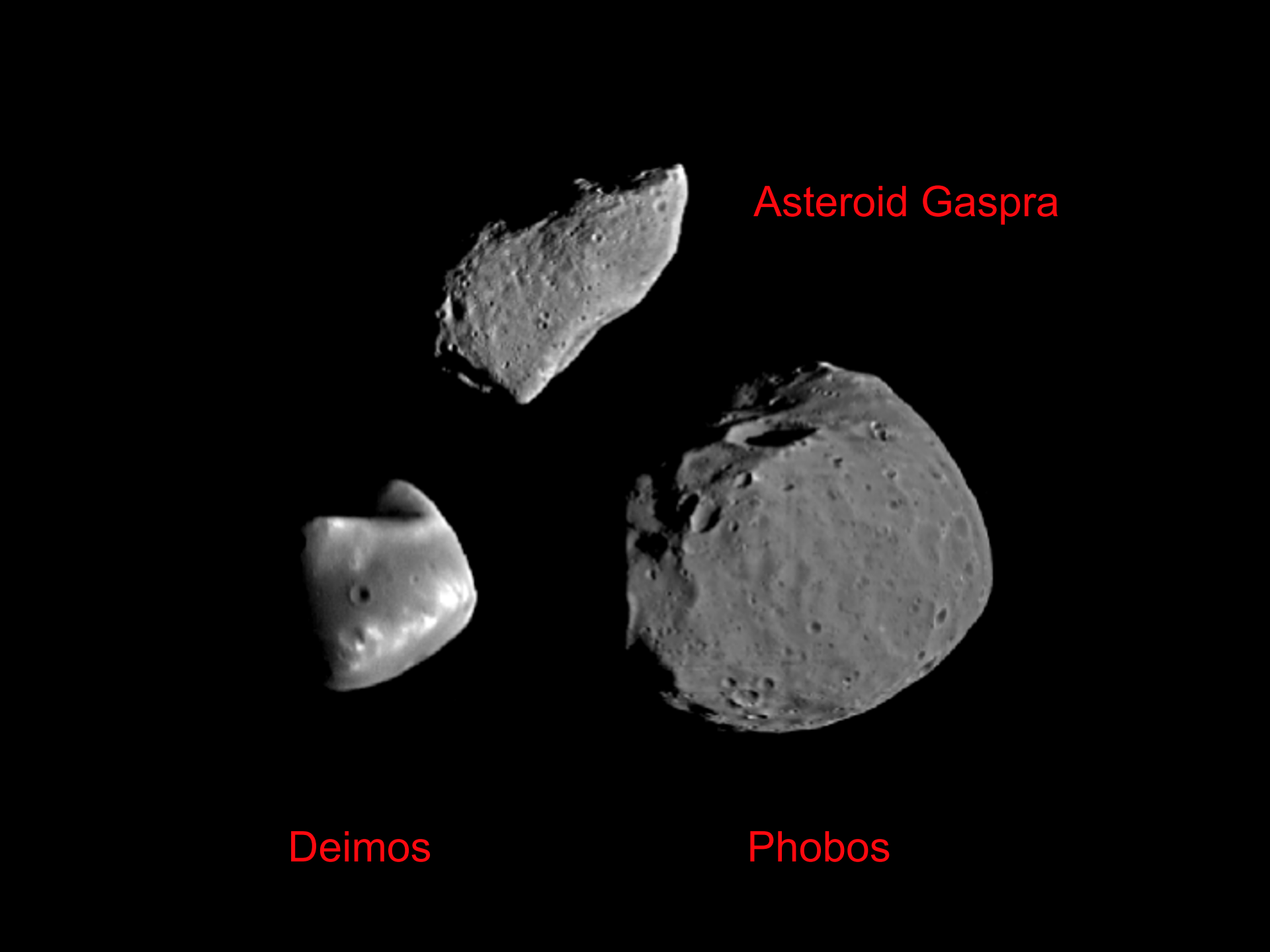
Phobos orbits only 5,800 km above Mars — in 100 million yrs it will either crash or tidal forces will disrupt it into a ring

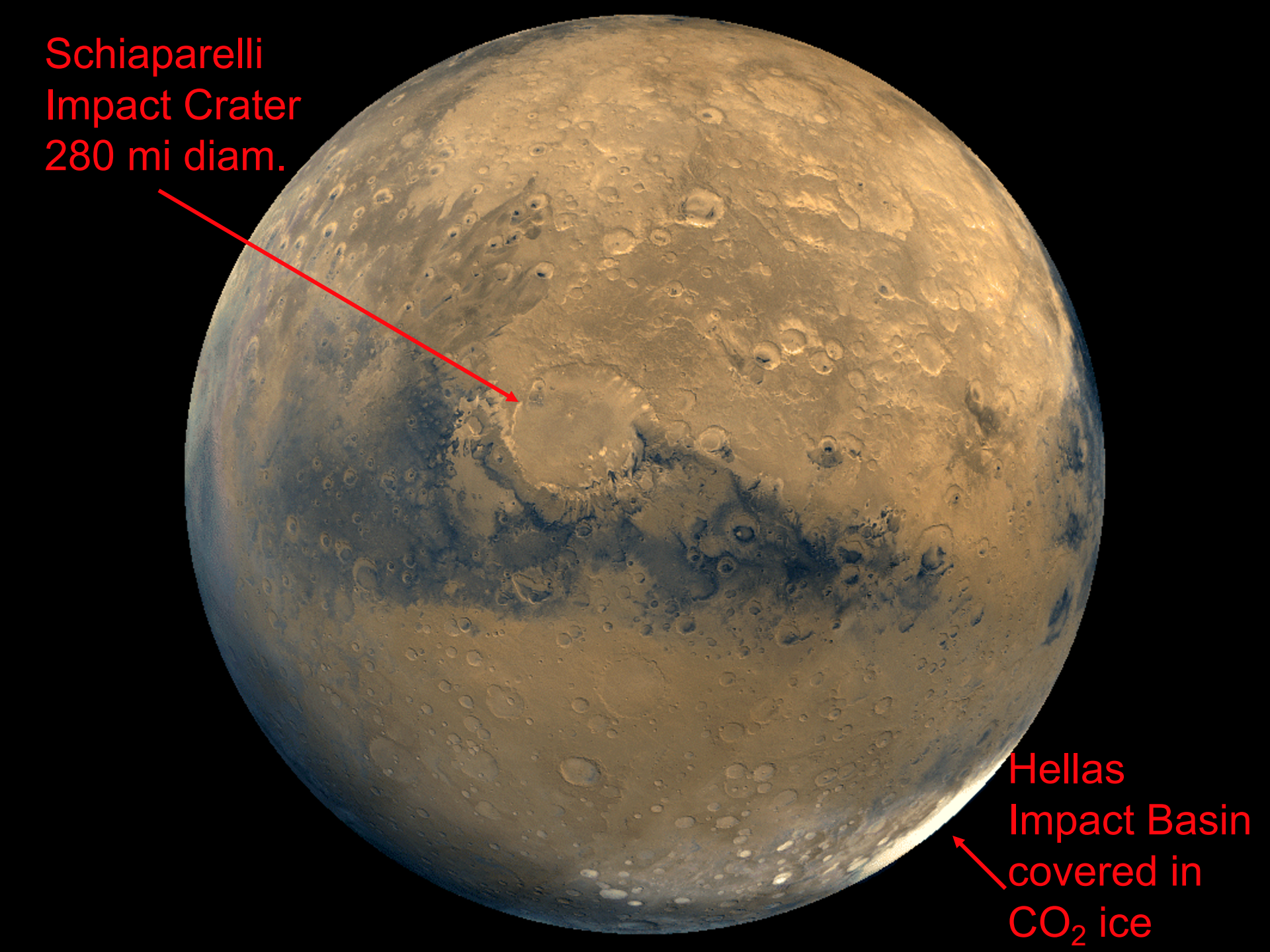


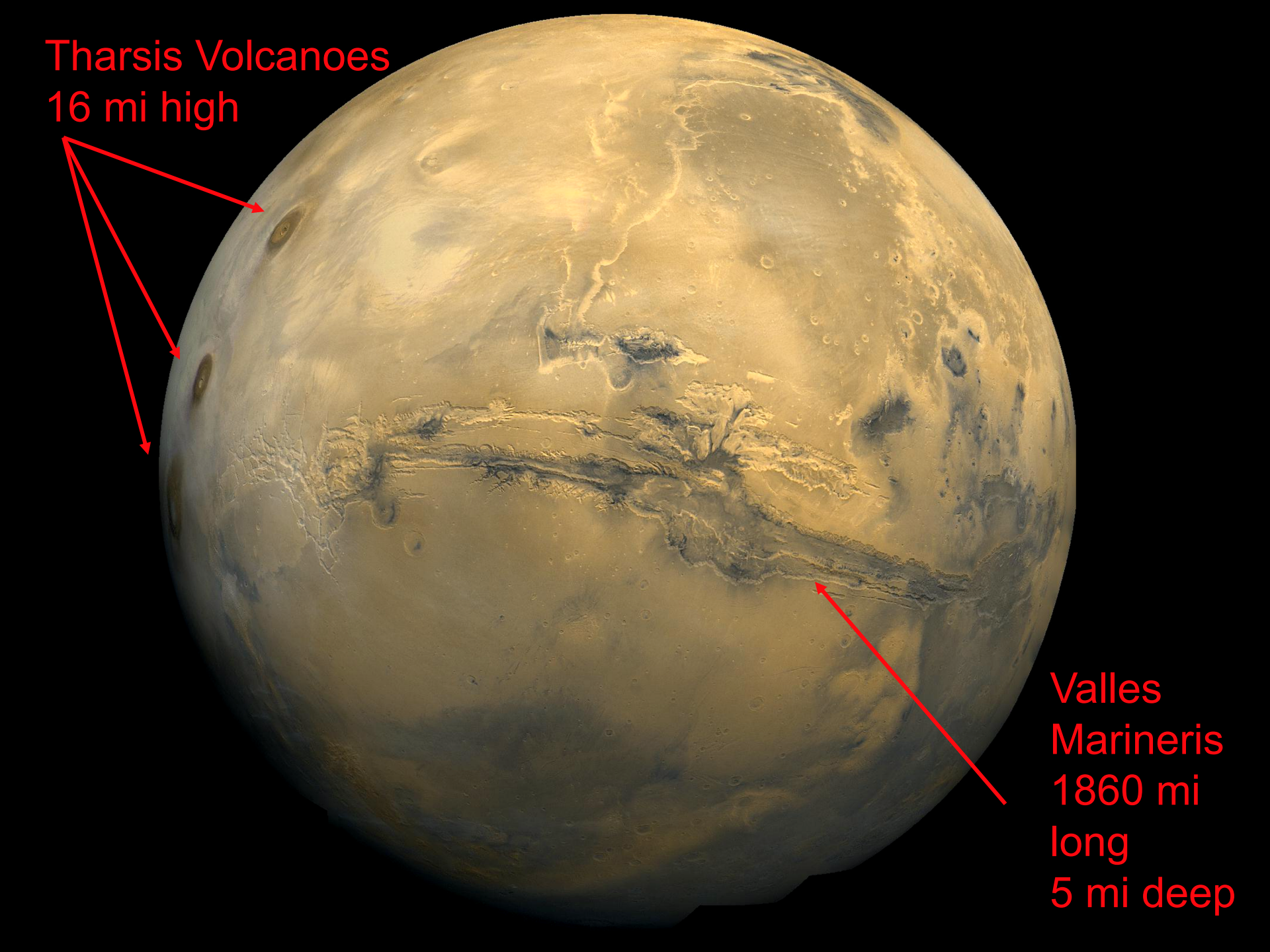
Deimos (panic)
7 km



Deimos


Asteroid Gaspra
Deimos
Phobos

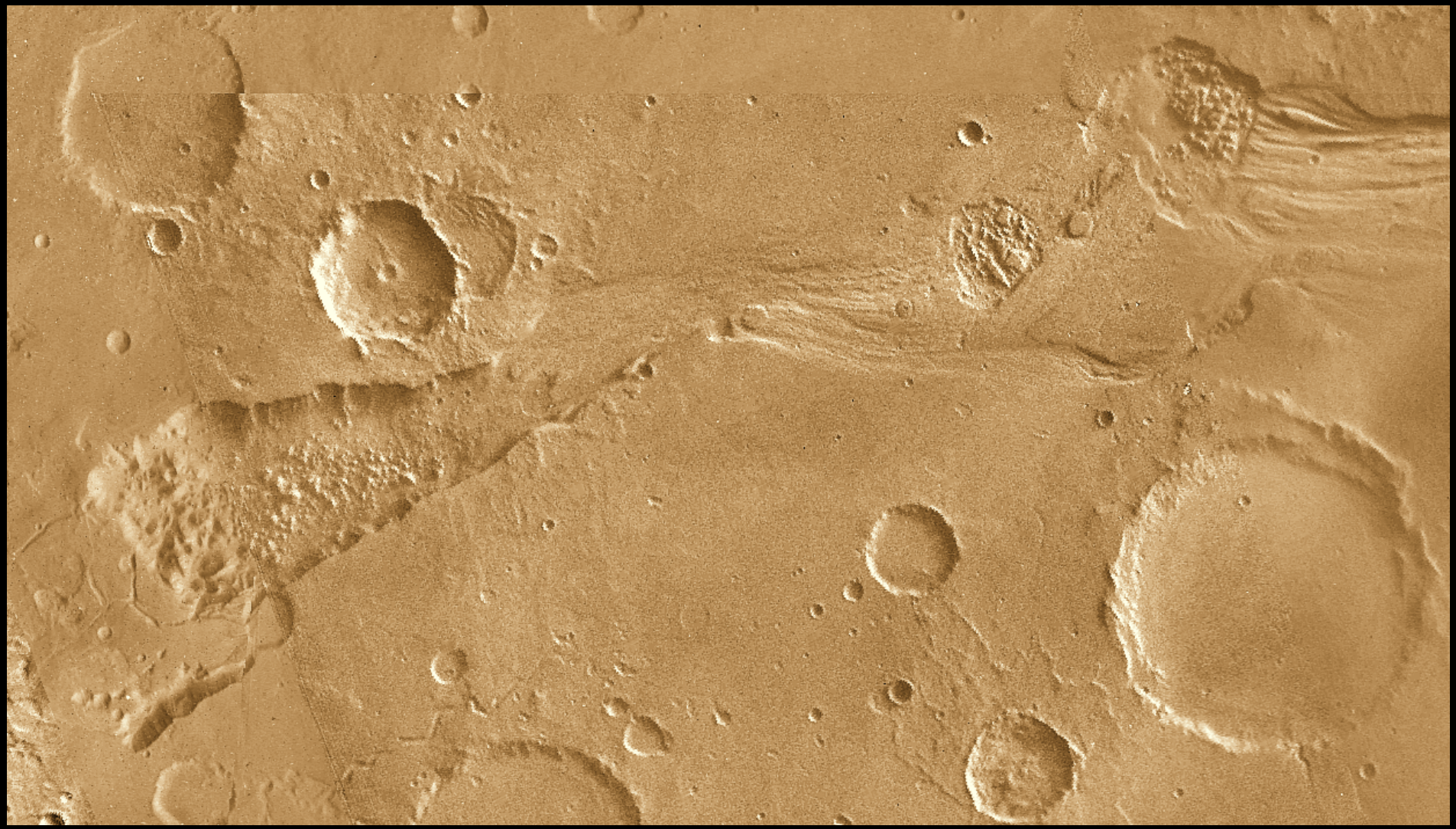

Schiaparelli
Impact Crater
280 mi diam.
Hellas
Impact Basin
covered in
CO_2 ice


Tharsis Volcanoes
16 mi high
Valles
Marineris
1860 mi
long
5 mi deep

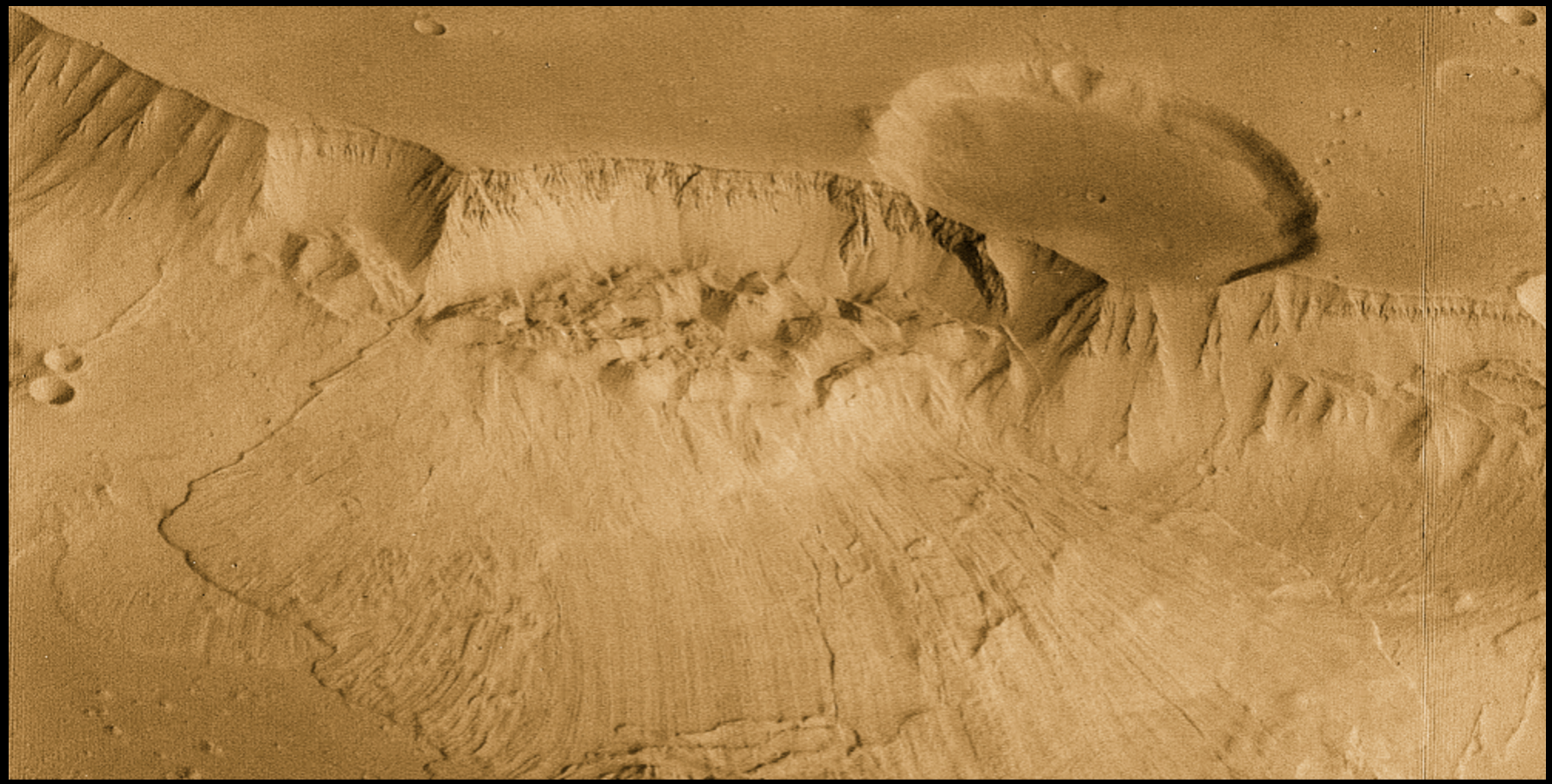


Valles Marineris compared to US

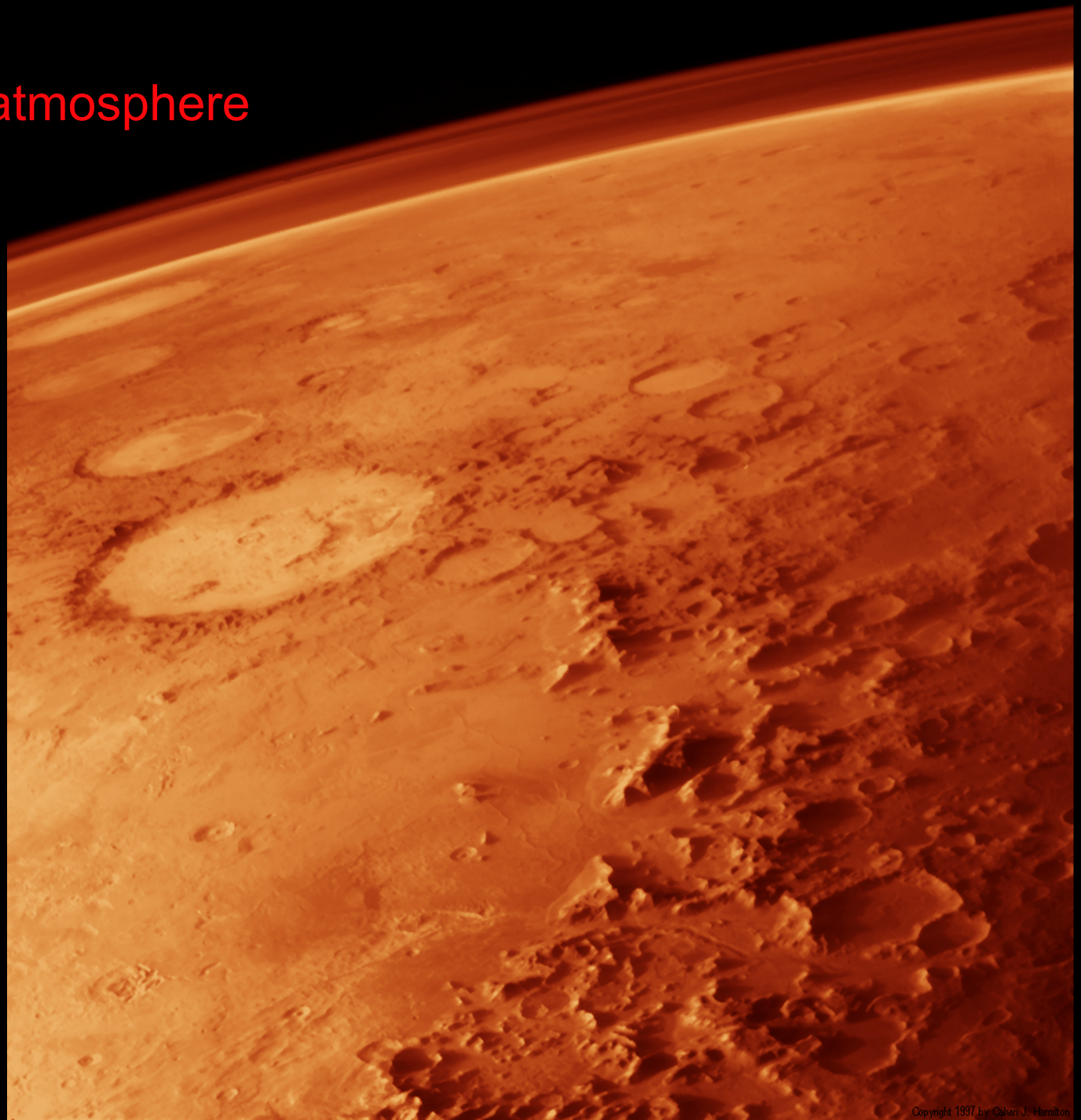
Ravi Valles shows structures that were carved out by high-flow liquid water released abruptly under high pressure from under a layer of frozen ground



Landslide in Valles Marineris

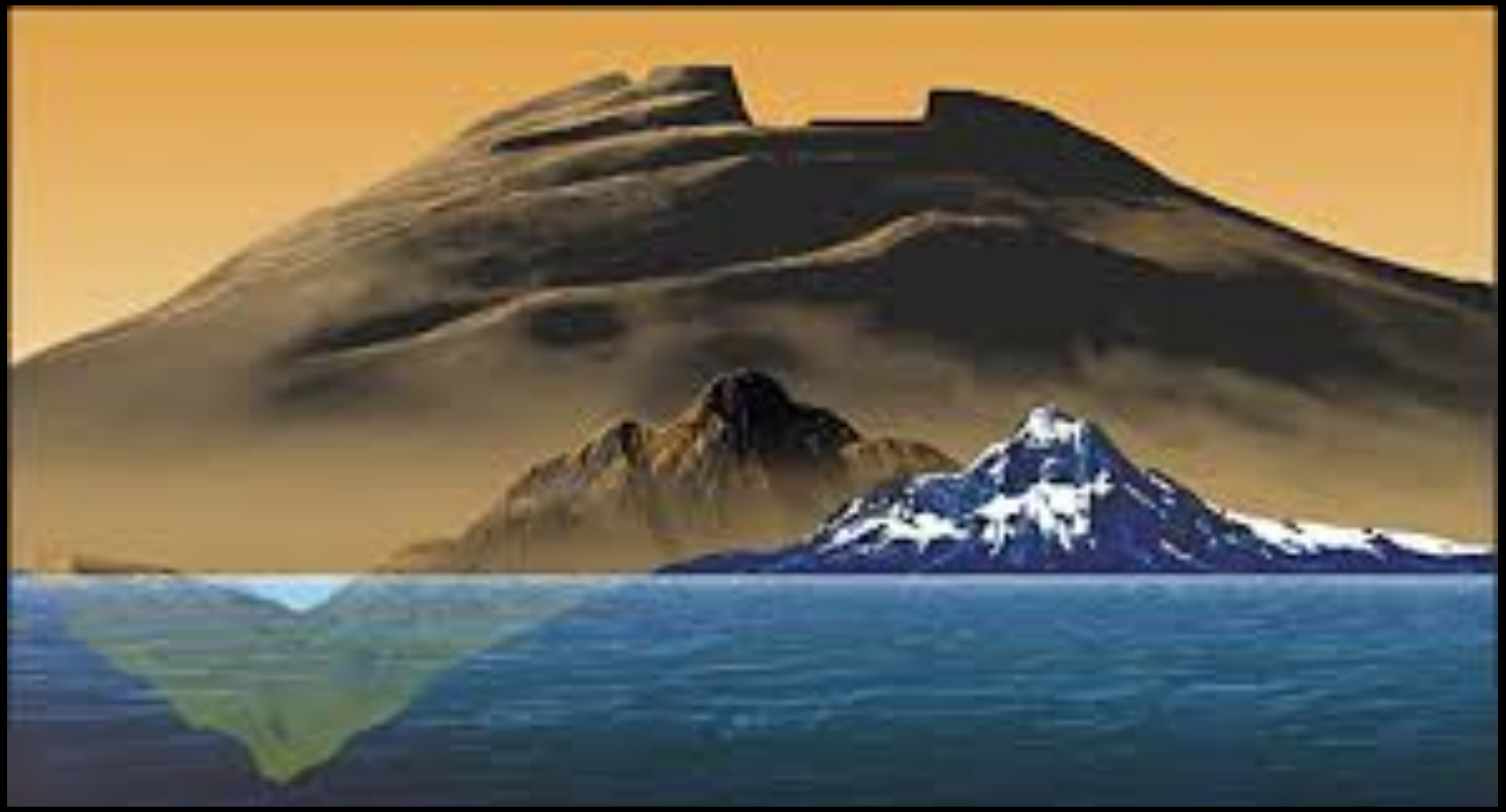


atmosphere

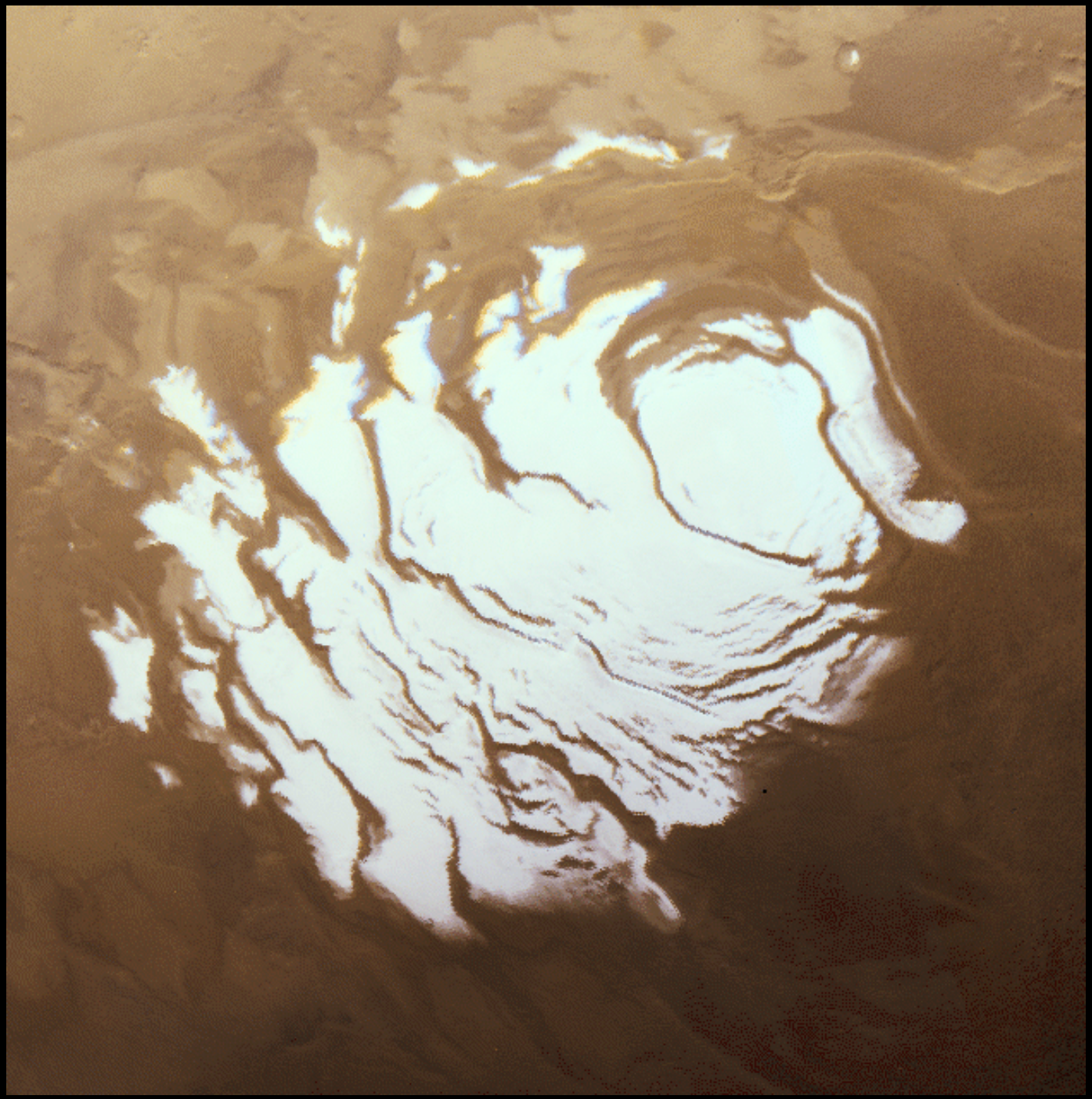




Olympus Mons
82,000 ft



Olympus Mons
82,000 ft



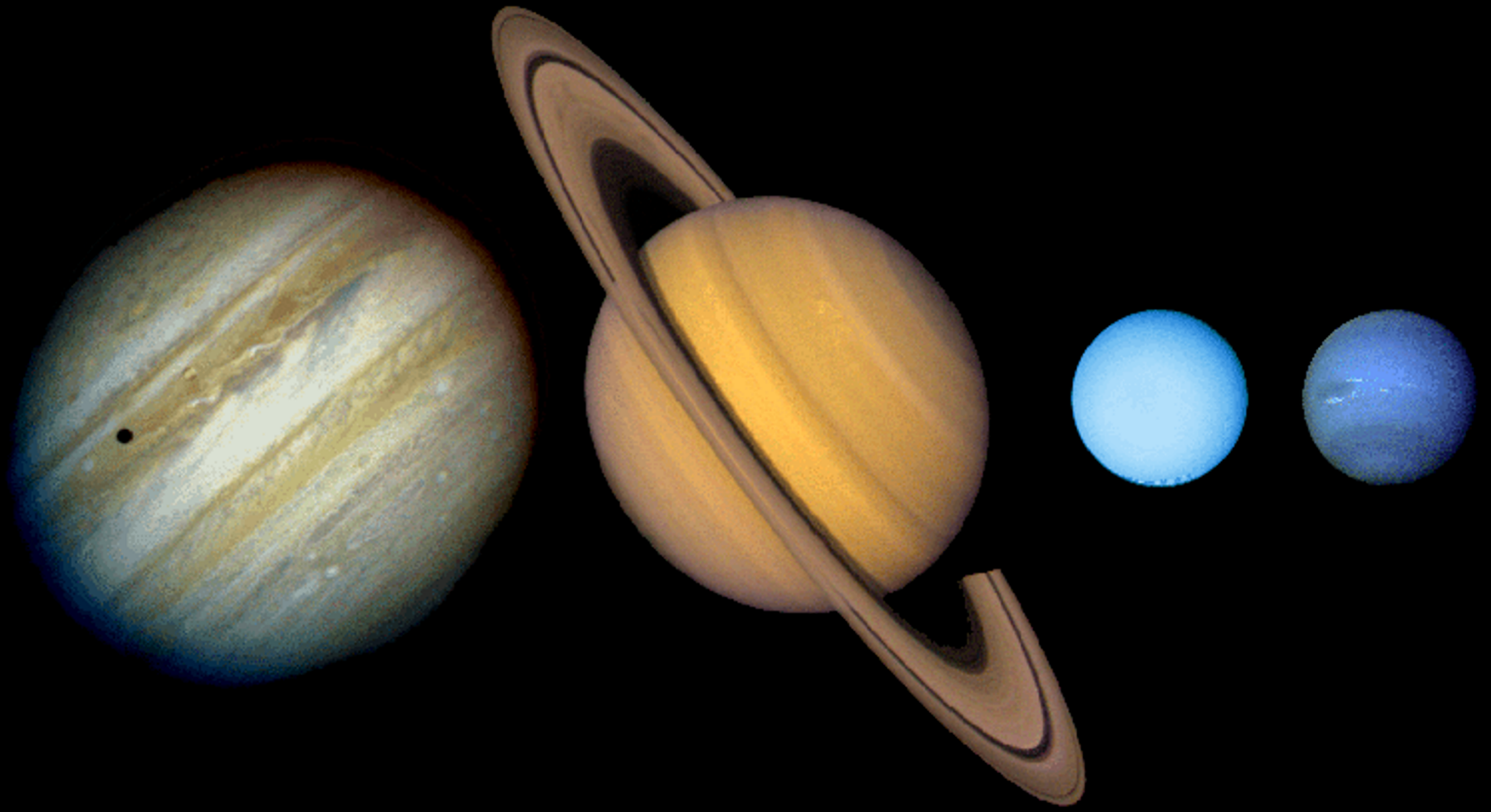
South Pole

250 mi diam.

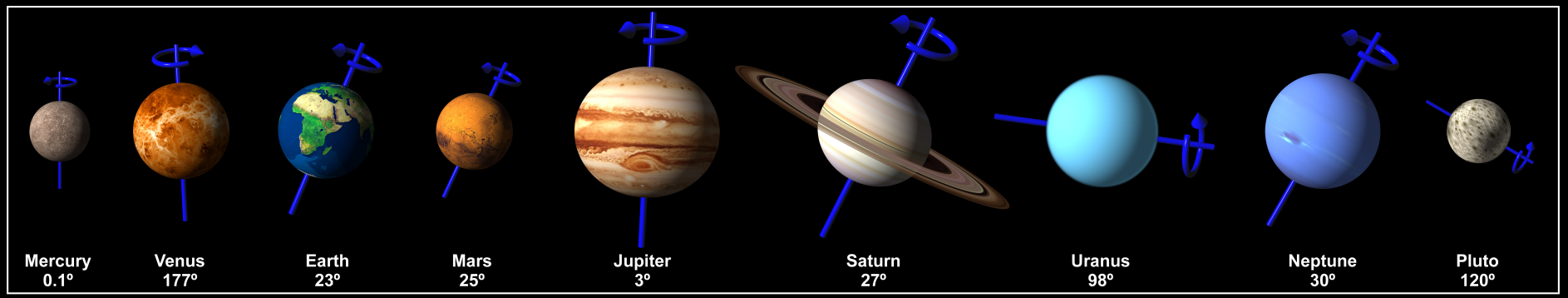
Mostly
frozen CO_2



The Gas Giants



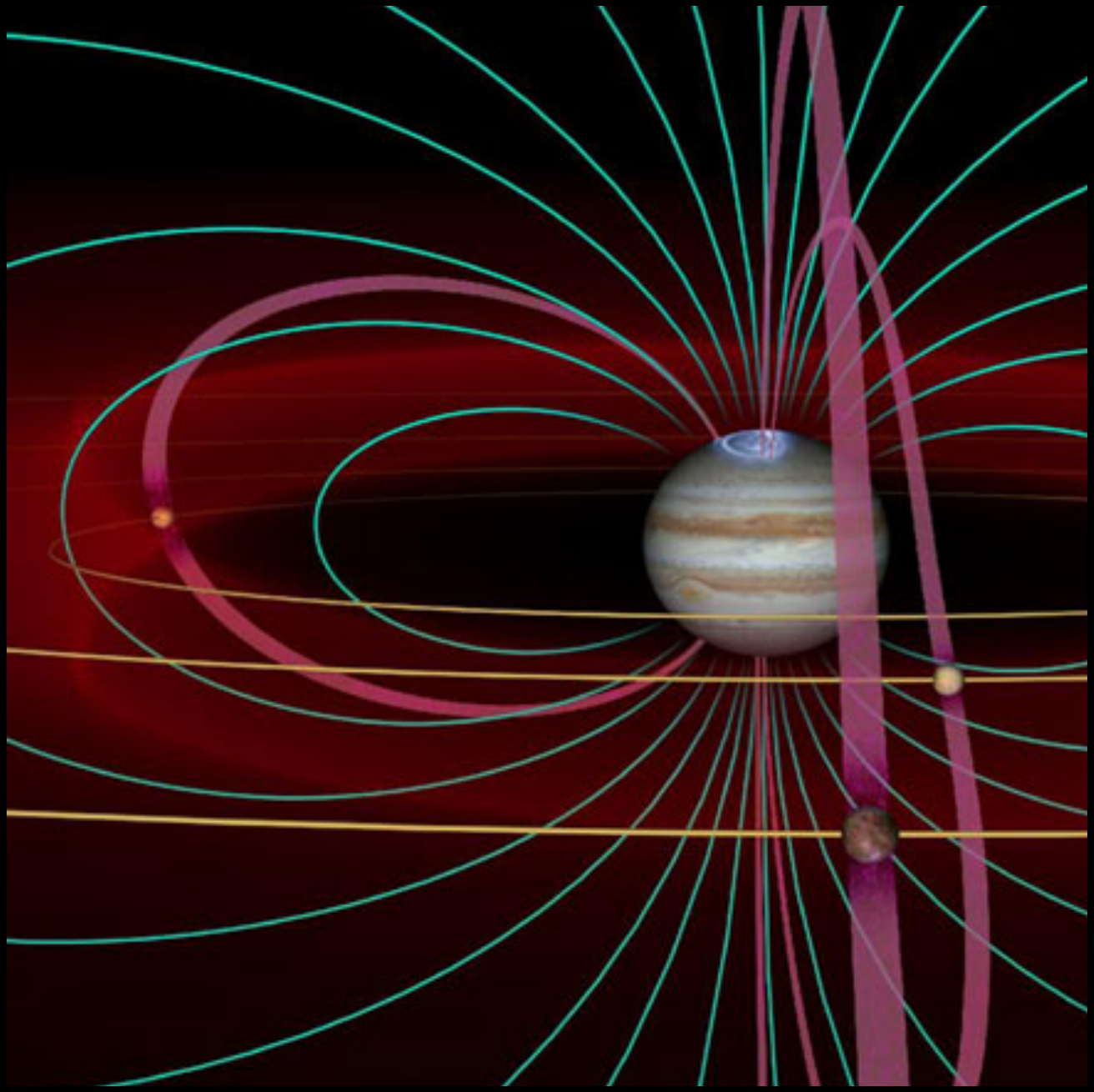
Jupiter Saturn Uranus Netpune

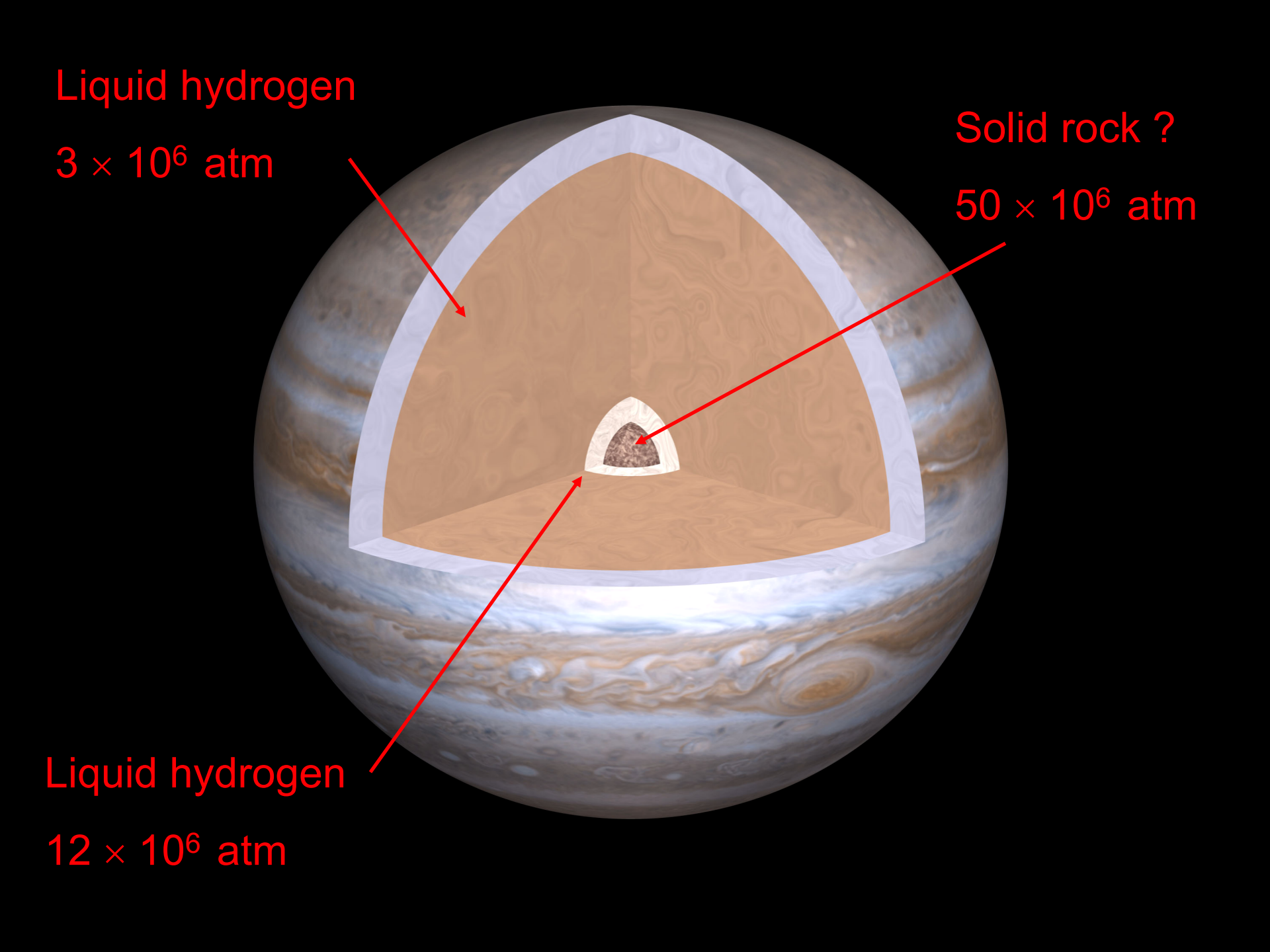

Mercury
0.1º
Venus
177º
Earth
23º
Mars
25º
Jupiter
3º
Saturn
27º
Uranus
98º
Neptune
30º
Pluto
120º

142,800 km diameter



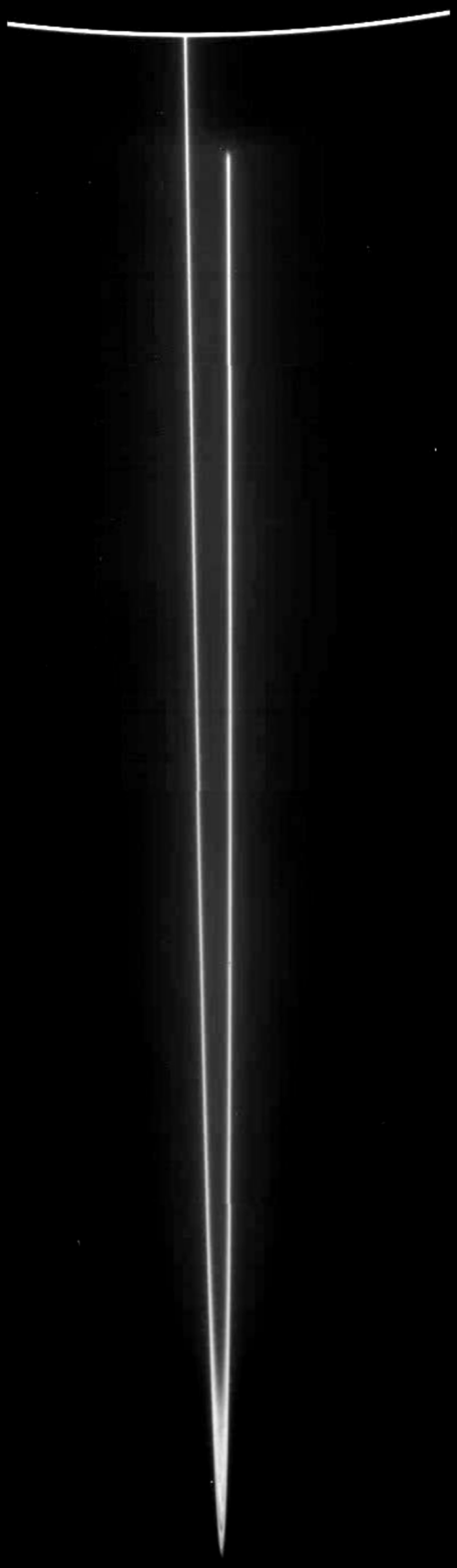
Jupiter

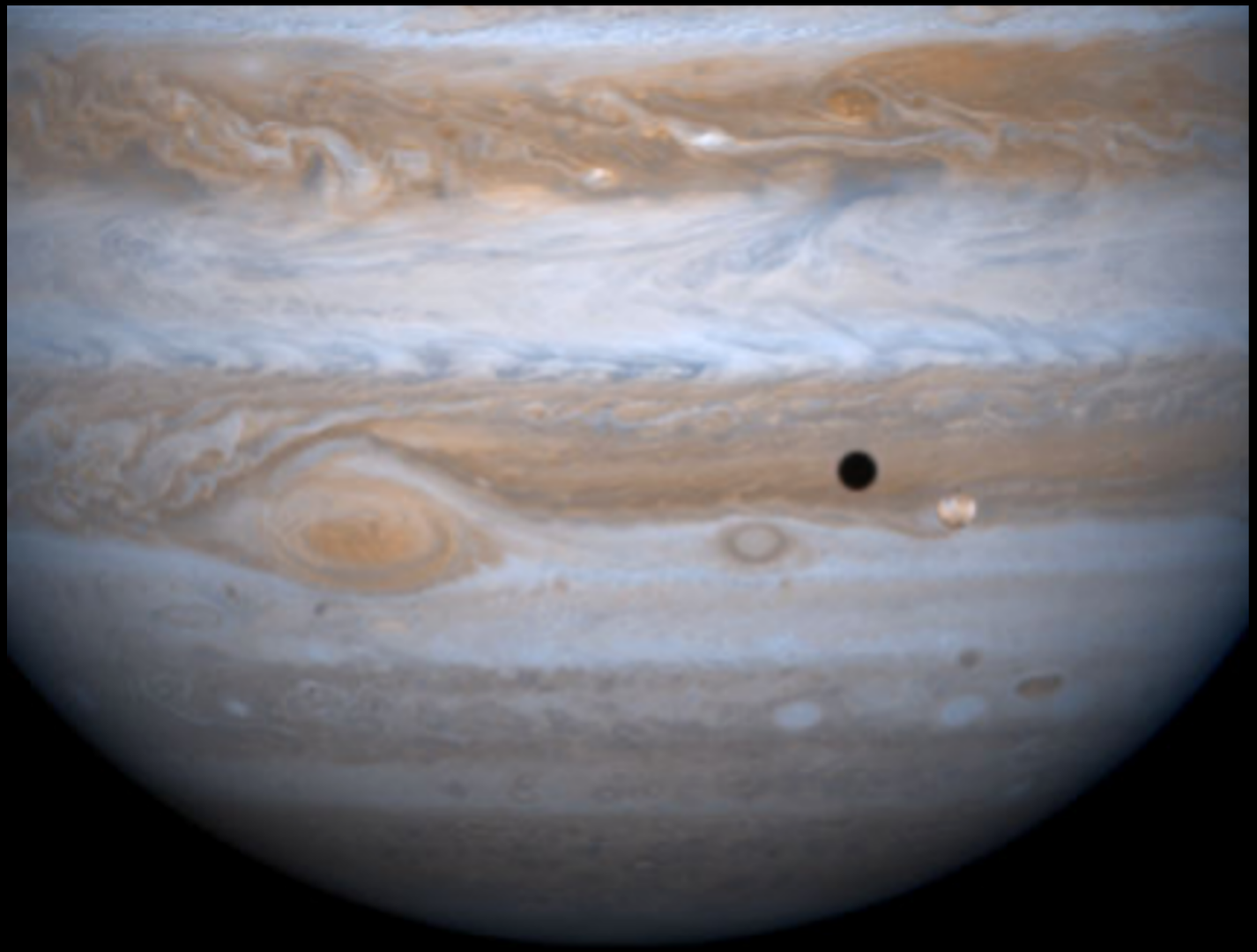


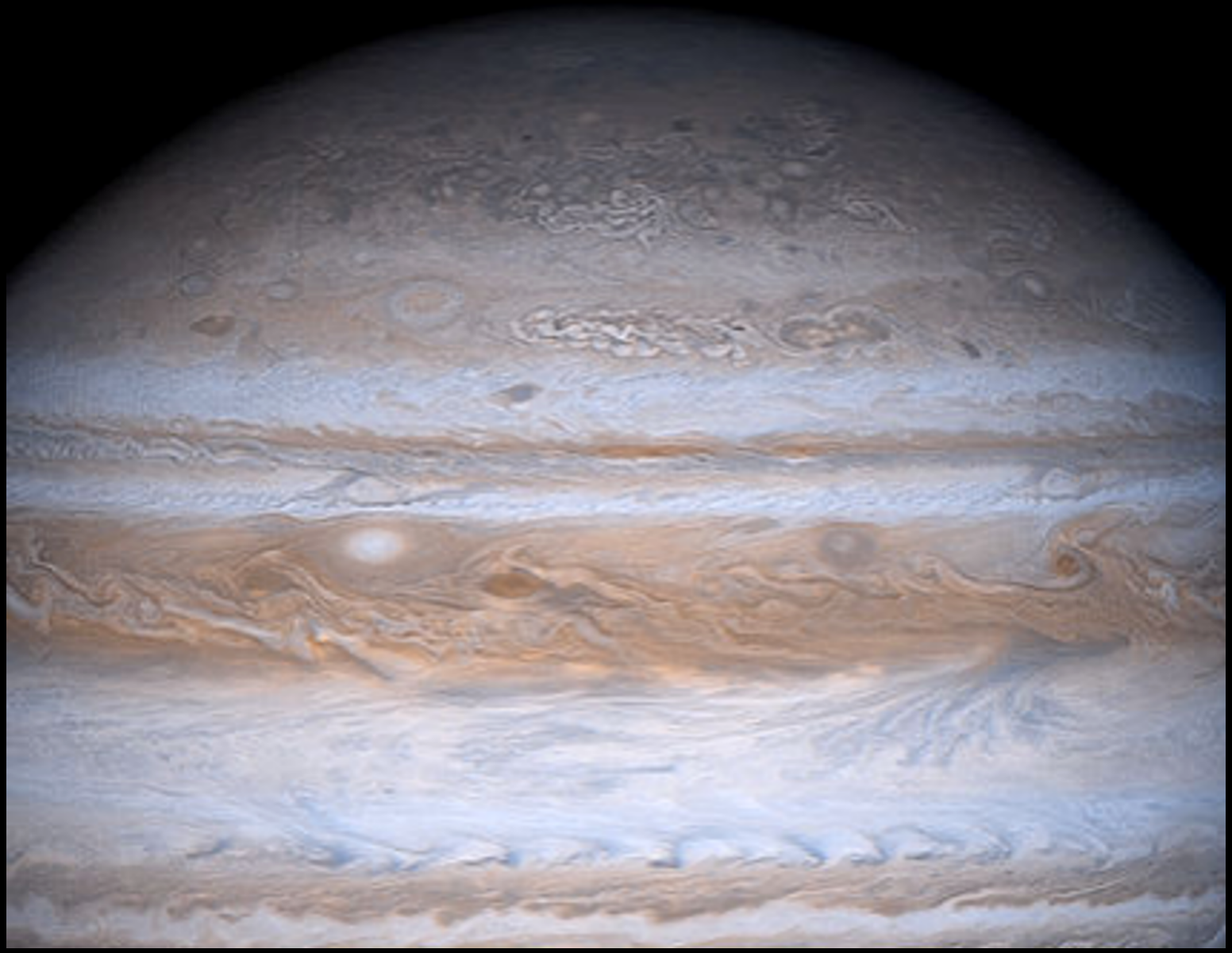

Liquid hydrogen
3×10^6 atm
Solid rock ?
50×10^6 atm
Liquid hydrogen
12×10^6 atm



Jupiter’s rings

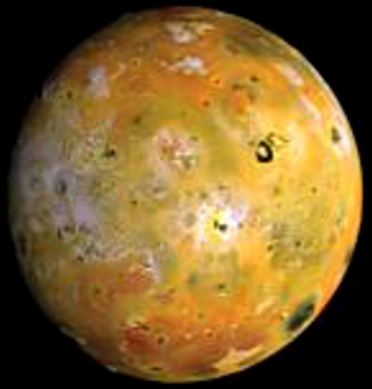






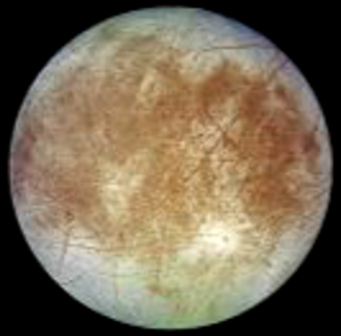
DIAMETERS

3,640 km



Io

3,122 km



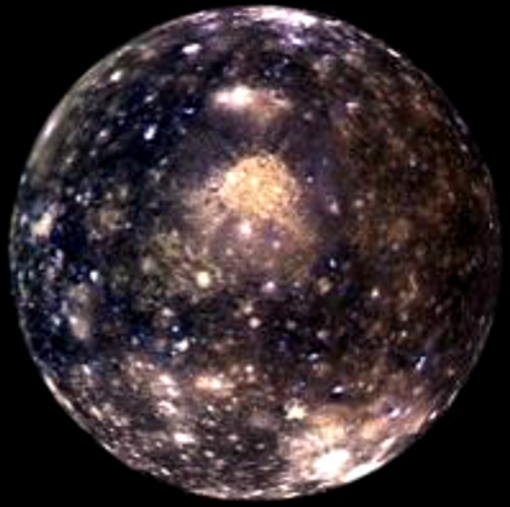
Europa

5,270 km

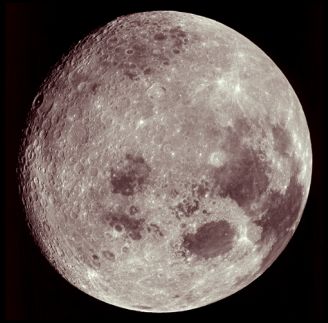


Ganymede

5,000 km across

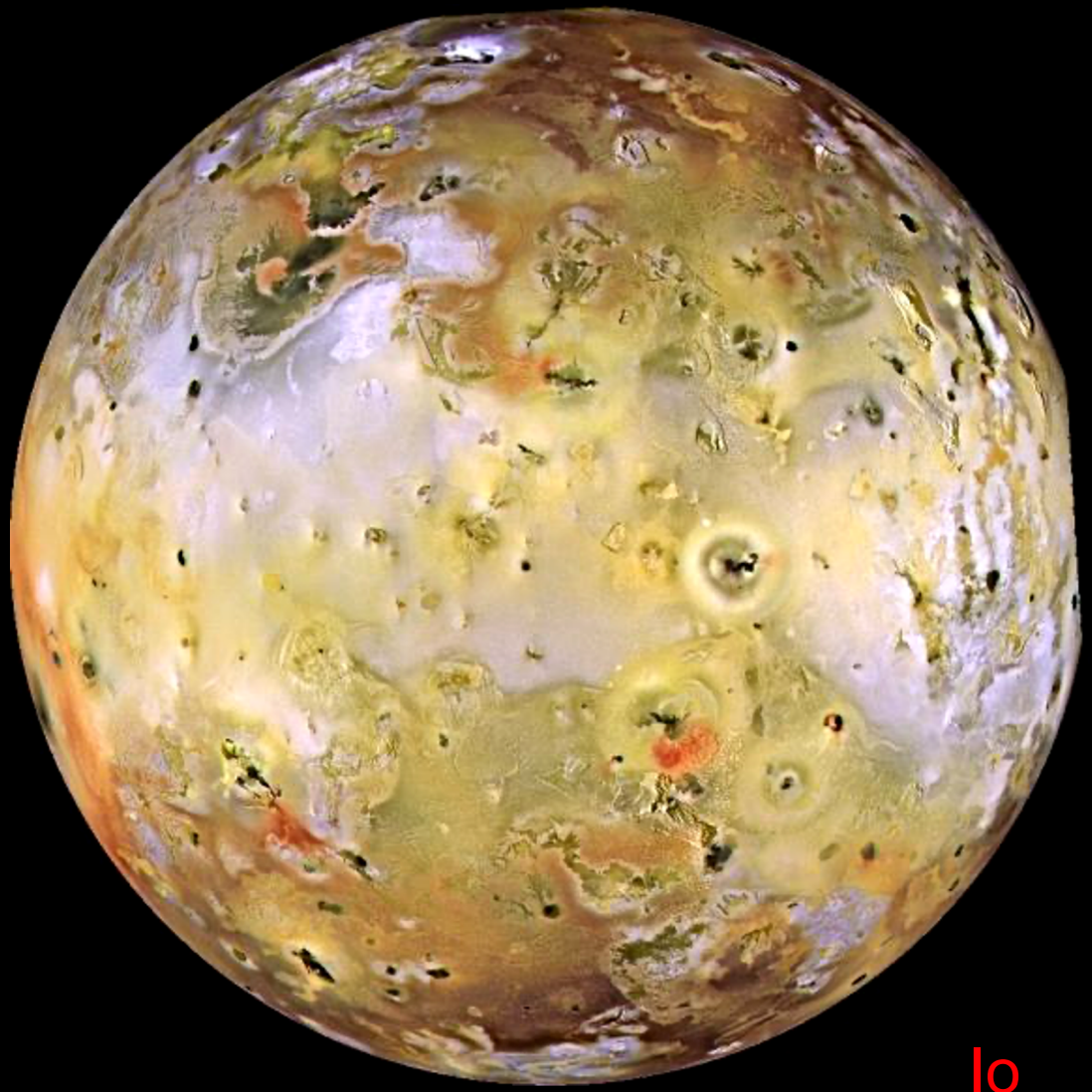


Callisto

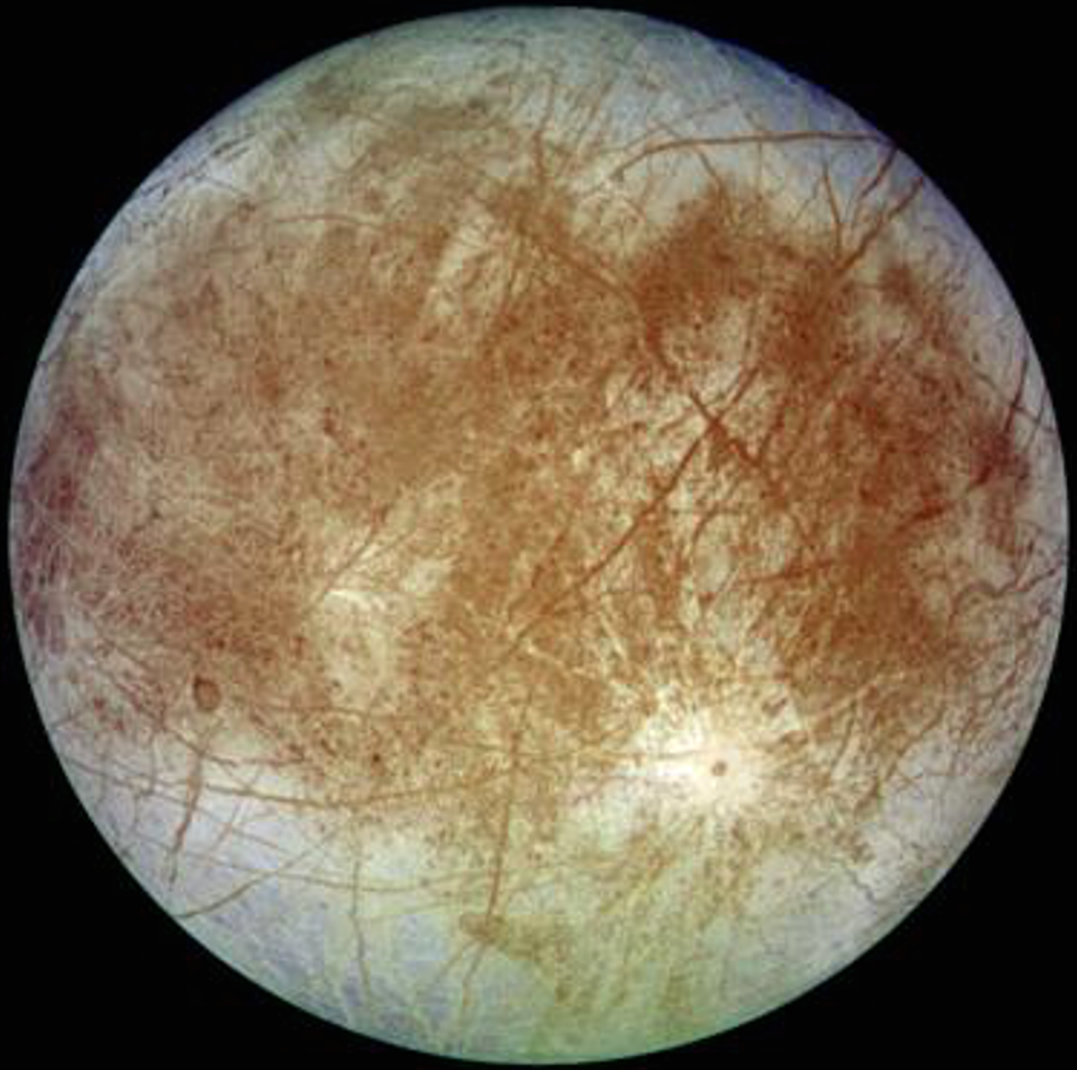


Earth's Moon

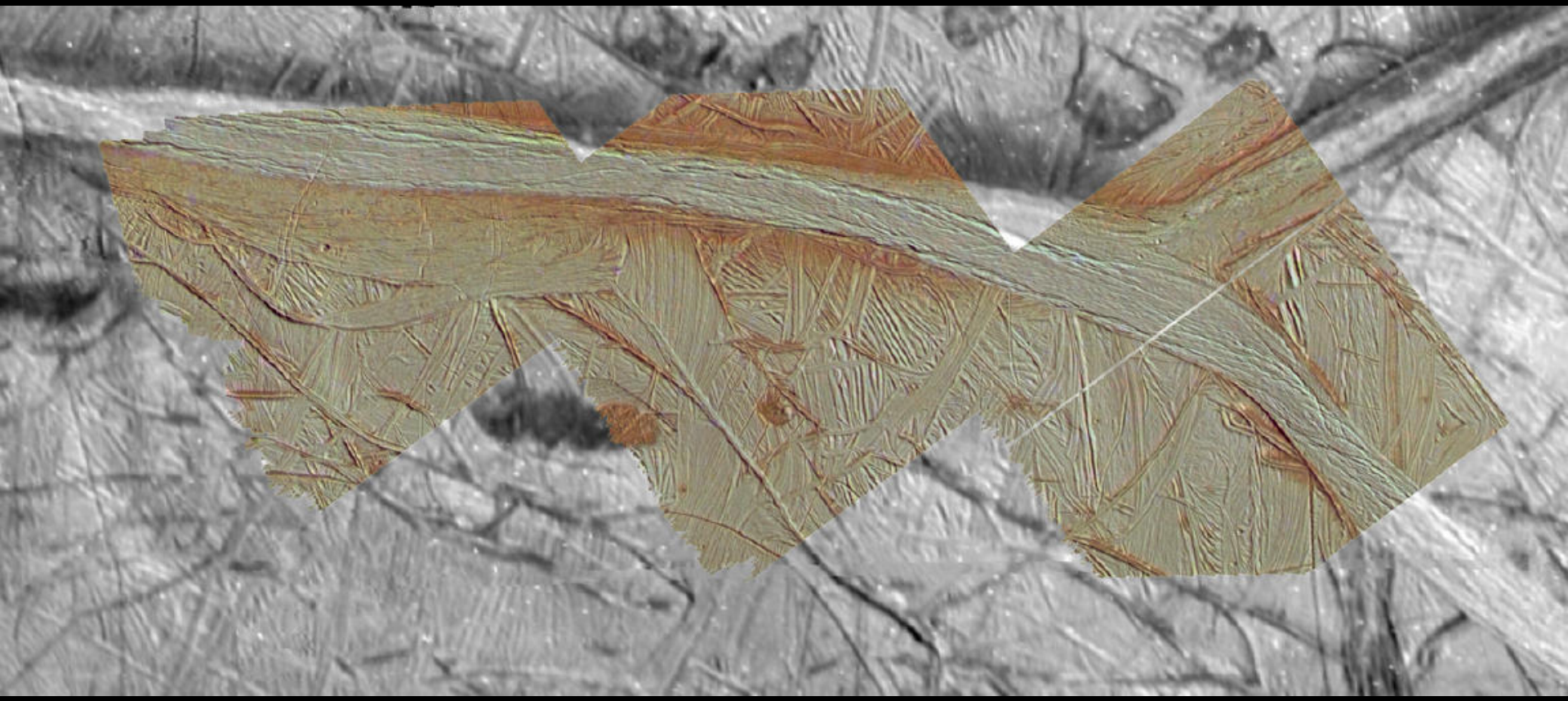
3,474 km

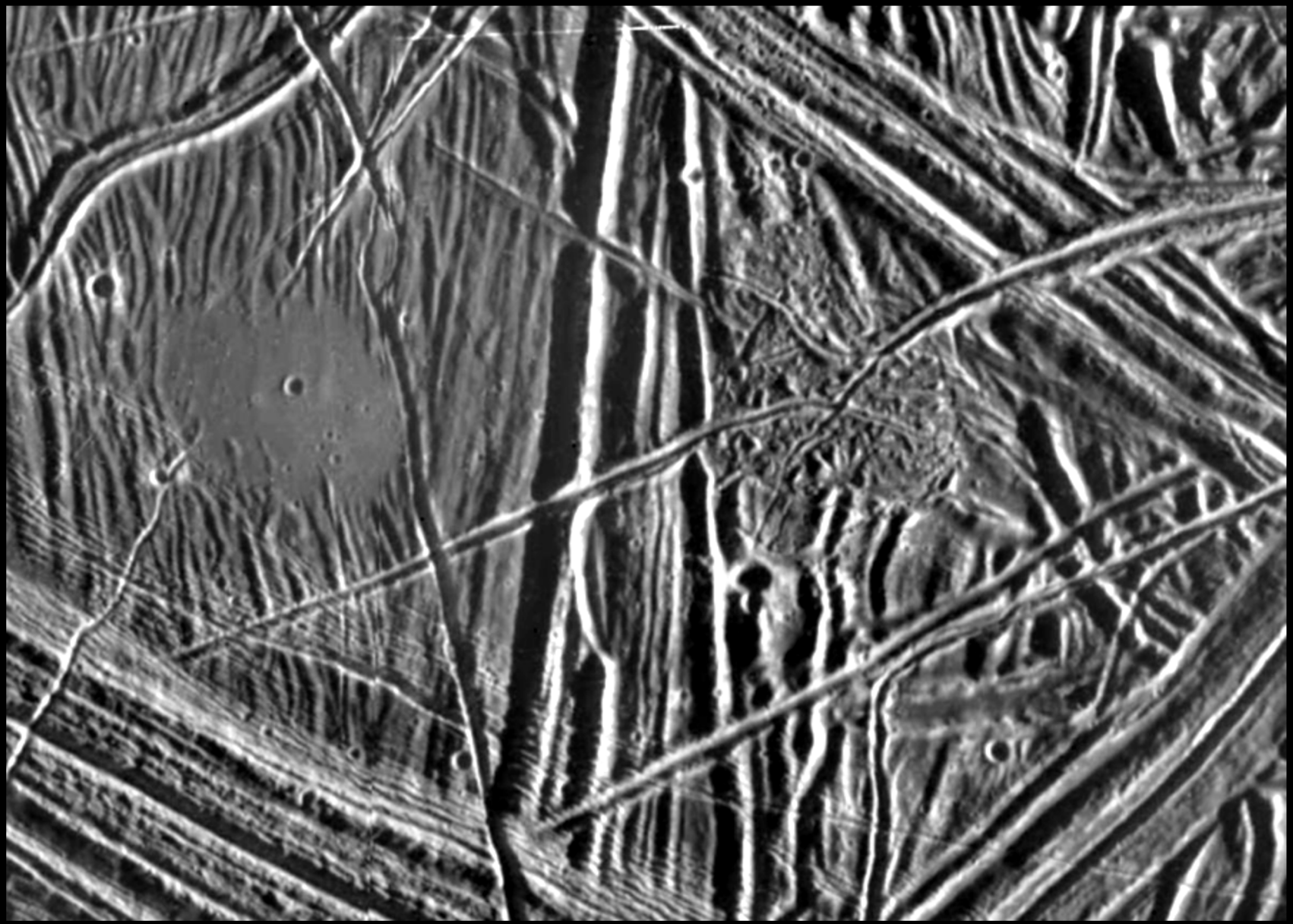

Io



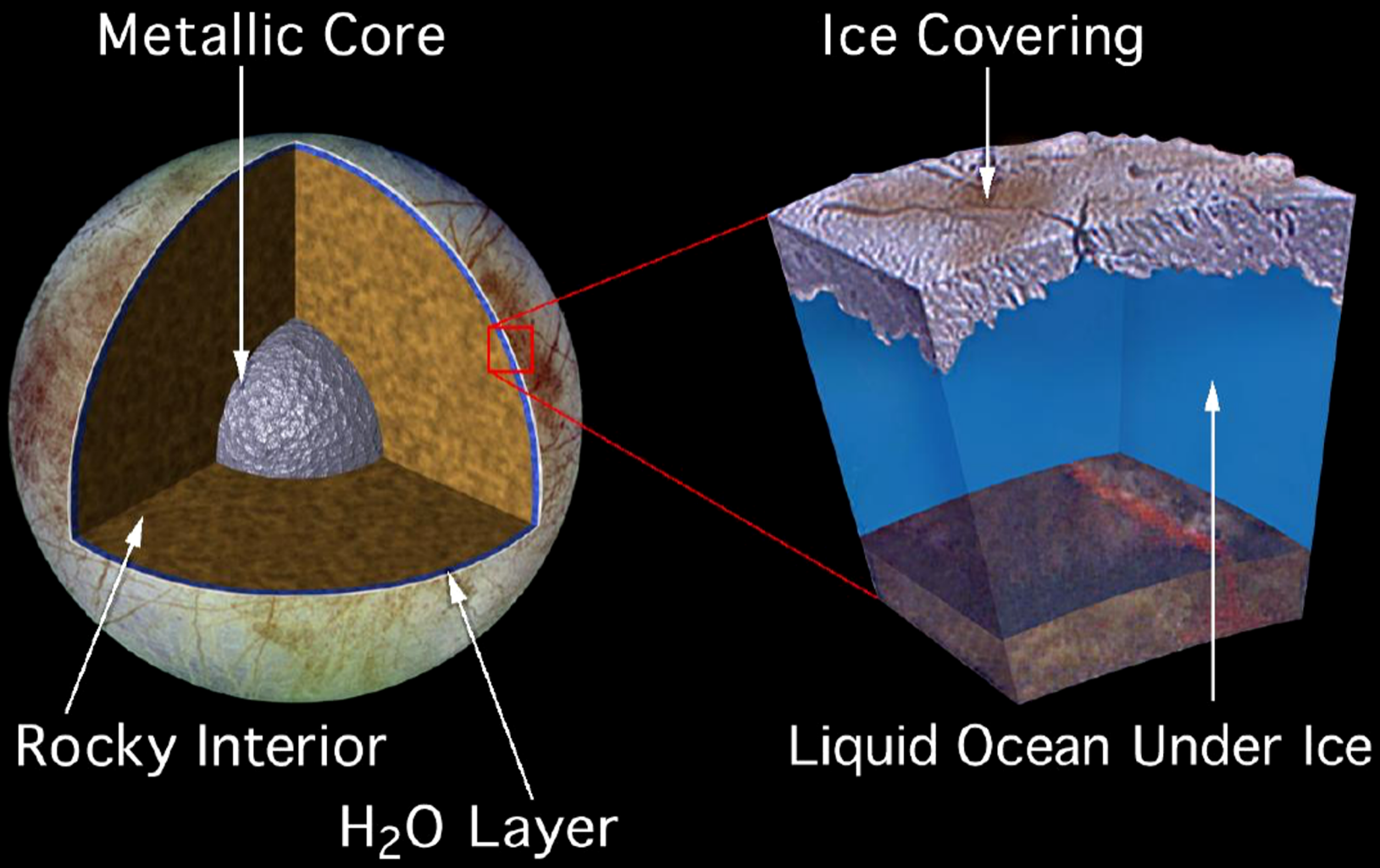


Europa



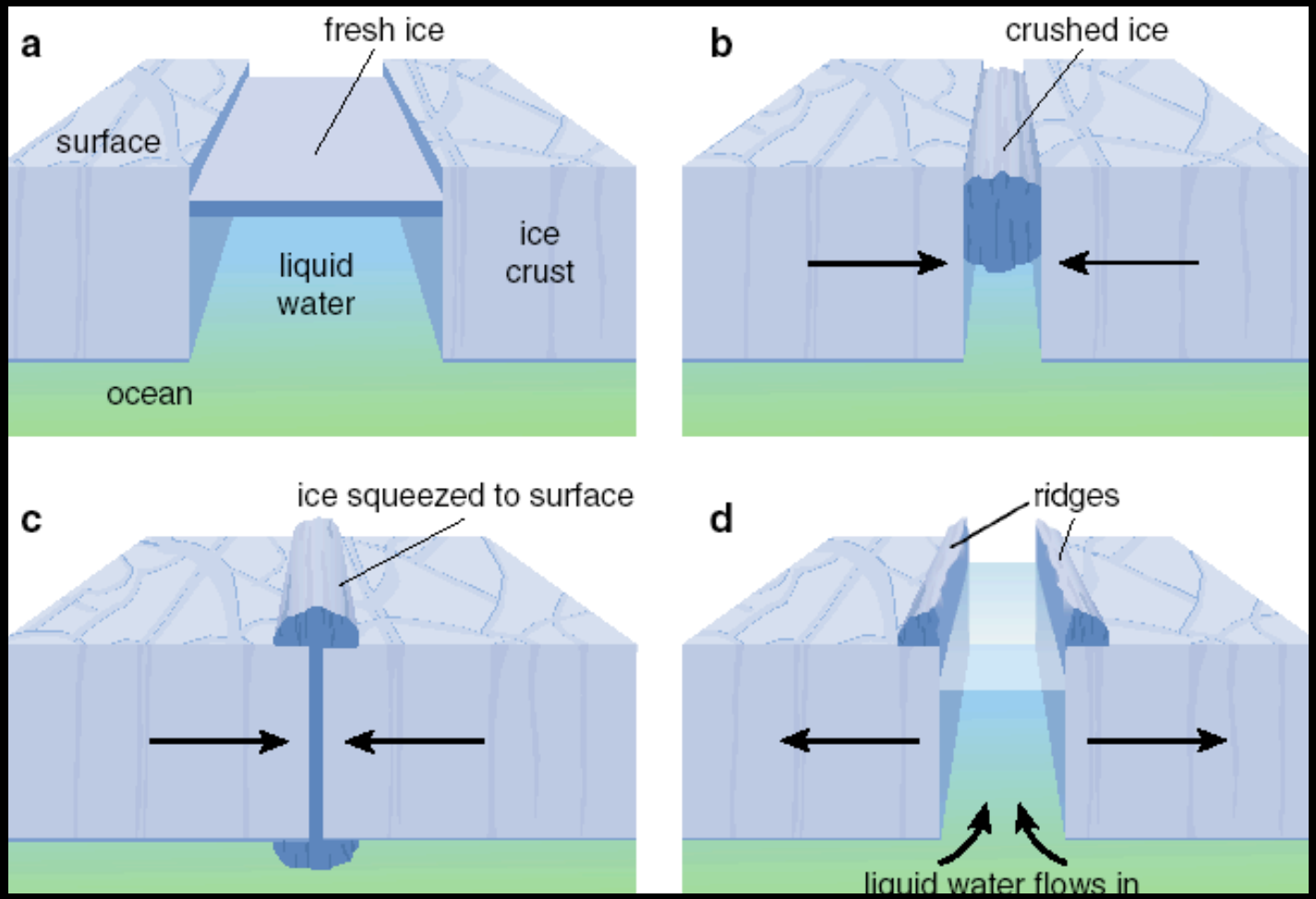


Europa might have a subsurface ocean of water



Tidal squeezing model

- tides open and close cracks in ice
- while a crack is open, water and slush enter the crack and this material is squeezed up as crack closes

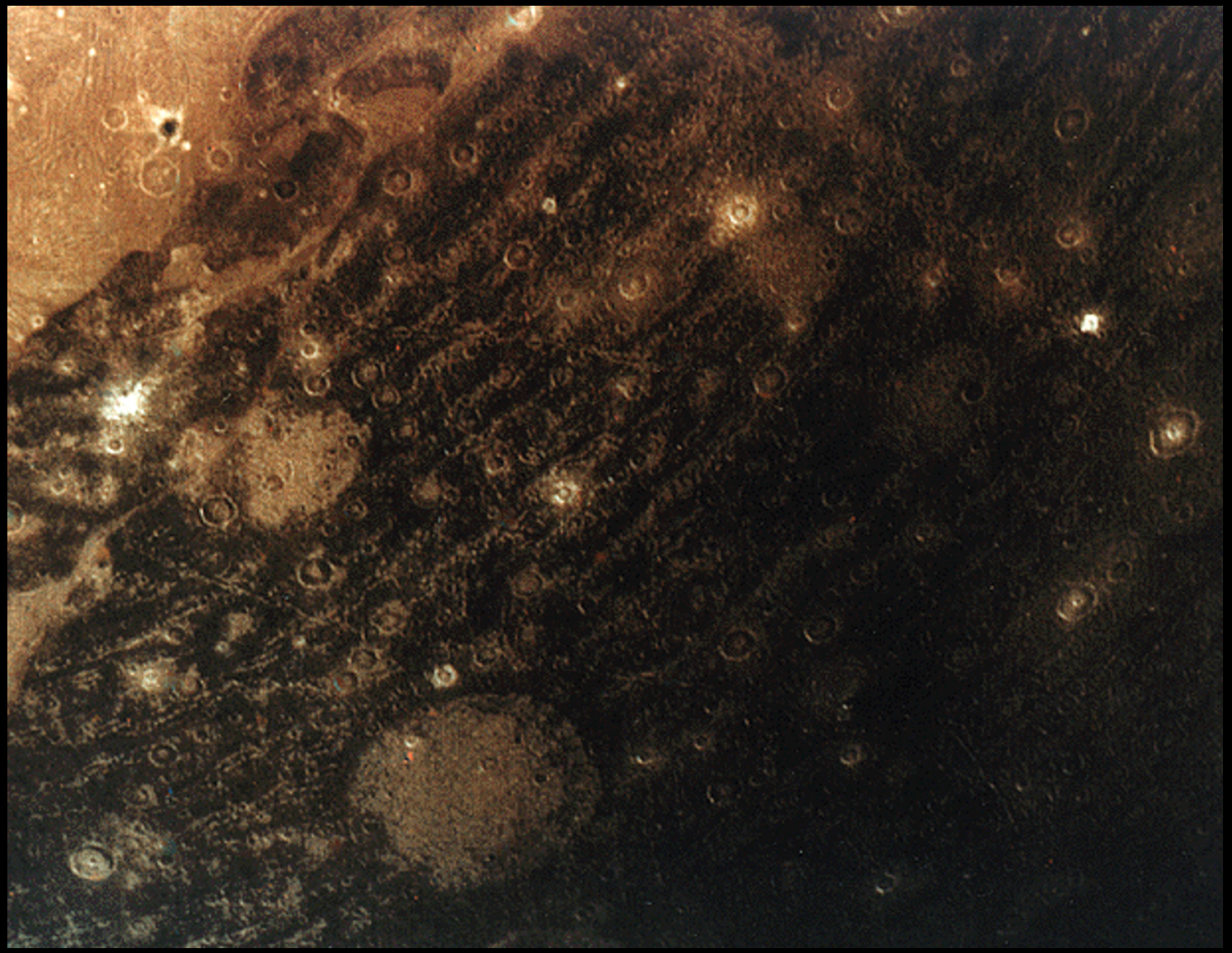


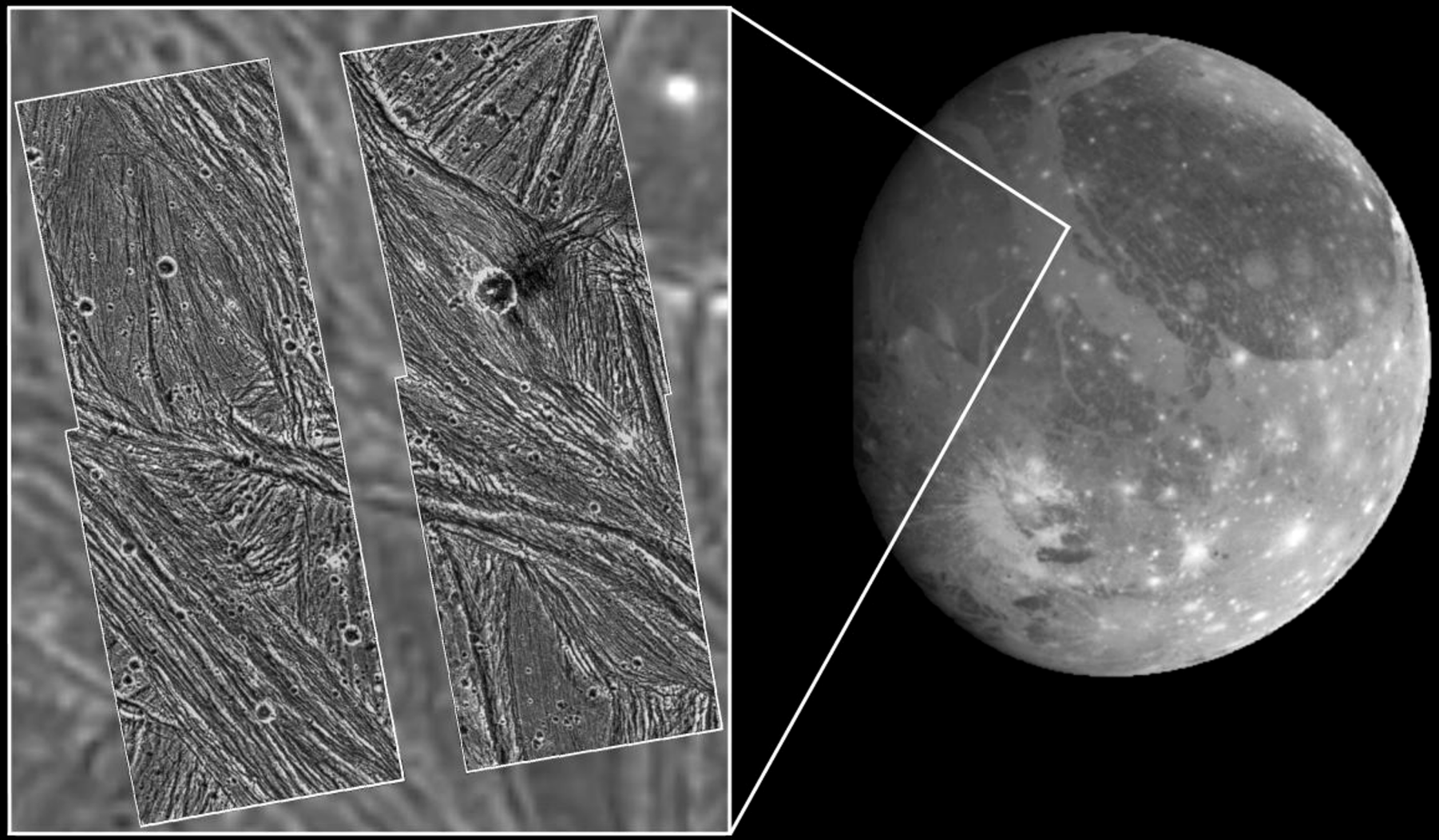
Europa has the Ingredients for Life

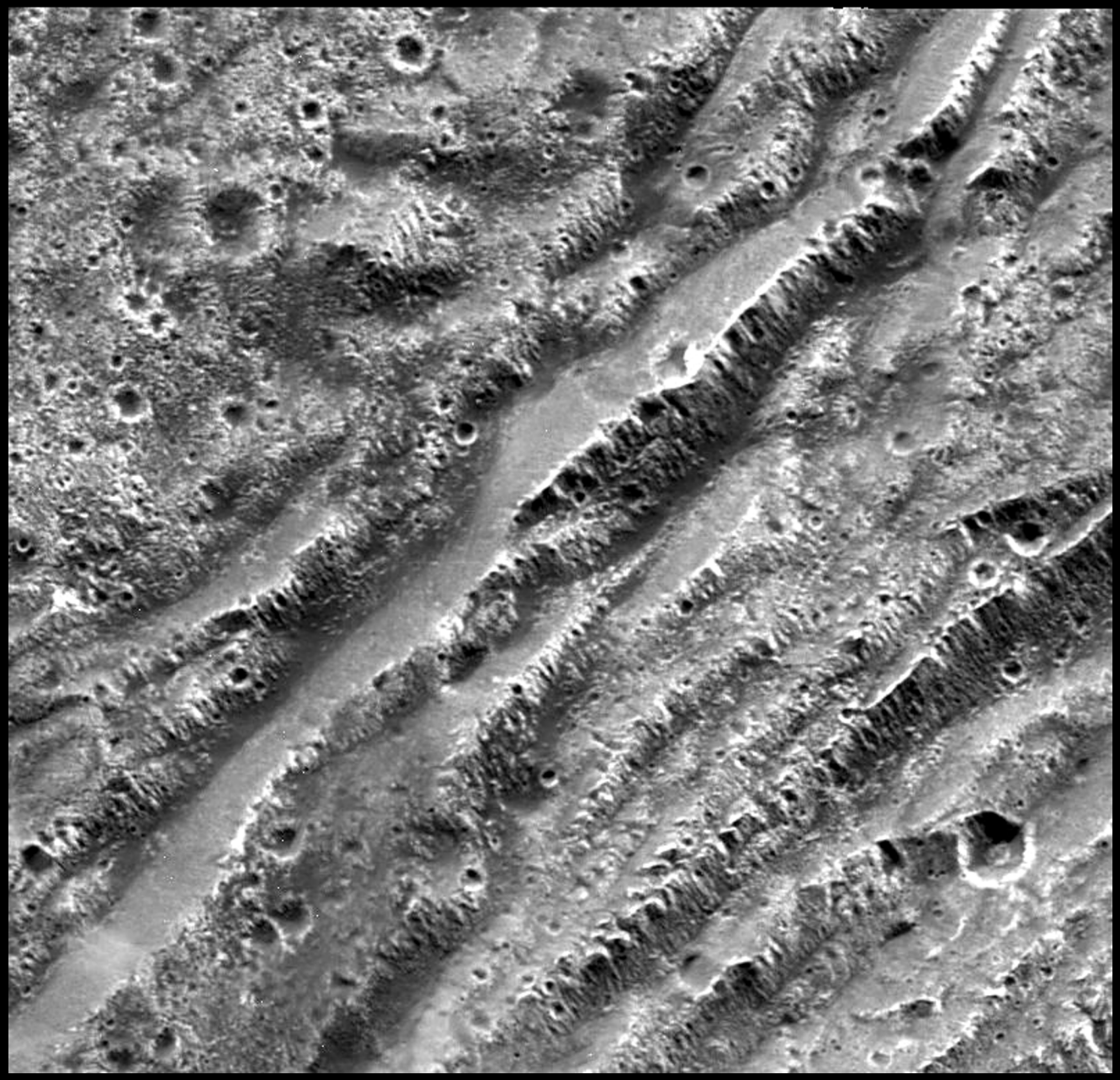
1. Water in the form of a sub-surface ocean
2. Carbon-rich nutrients from meteoritic debris which percolate down from the surface
3. Geothermal energy from tidal flexing



Ganymede

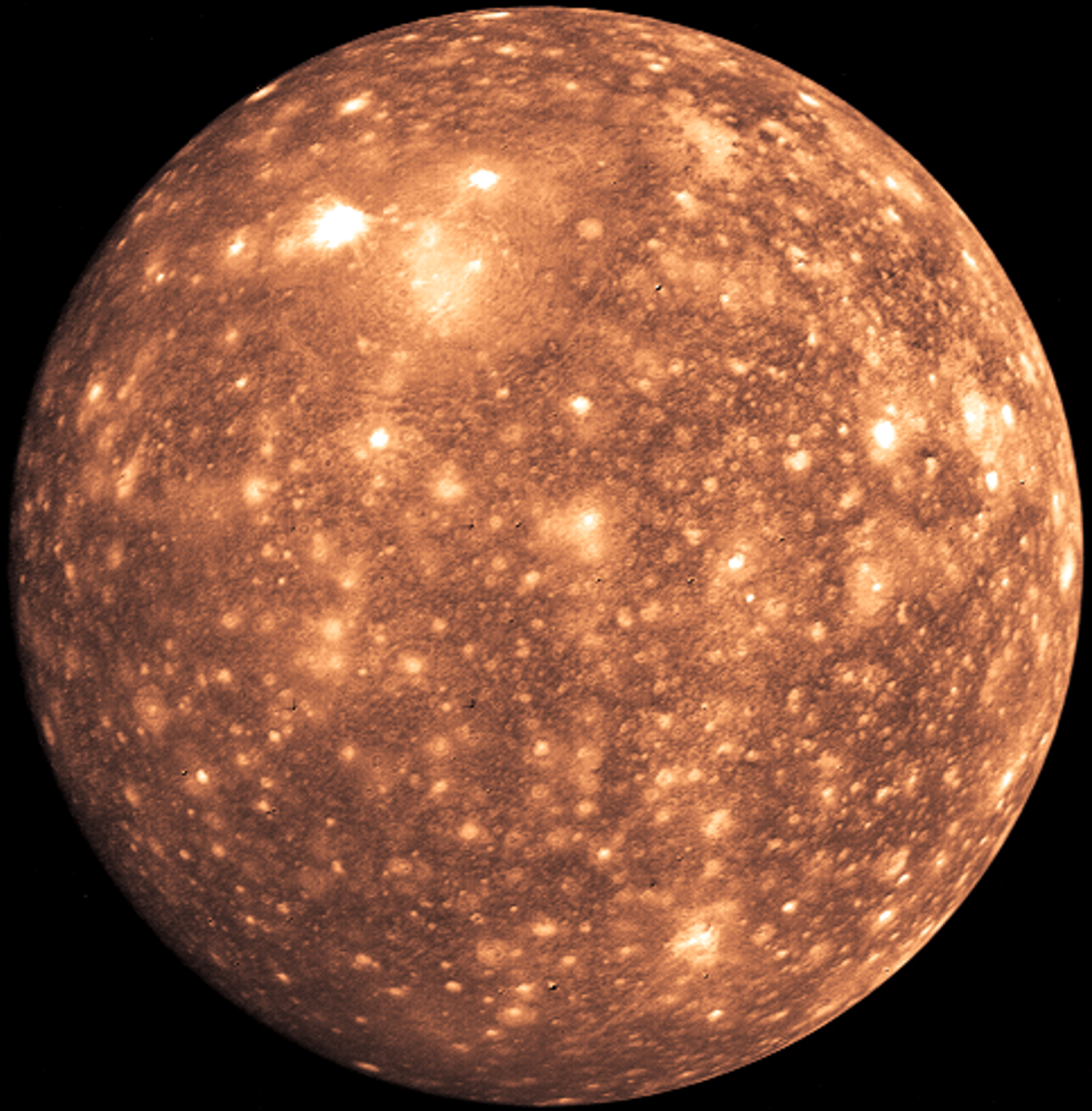






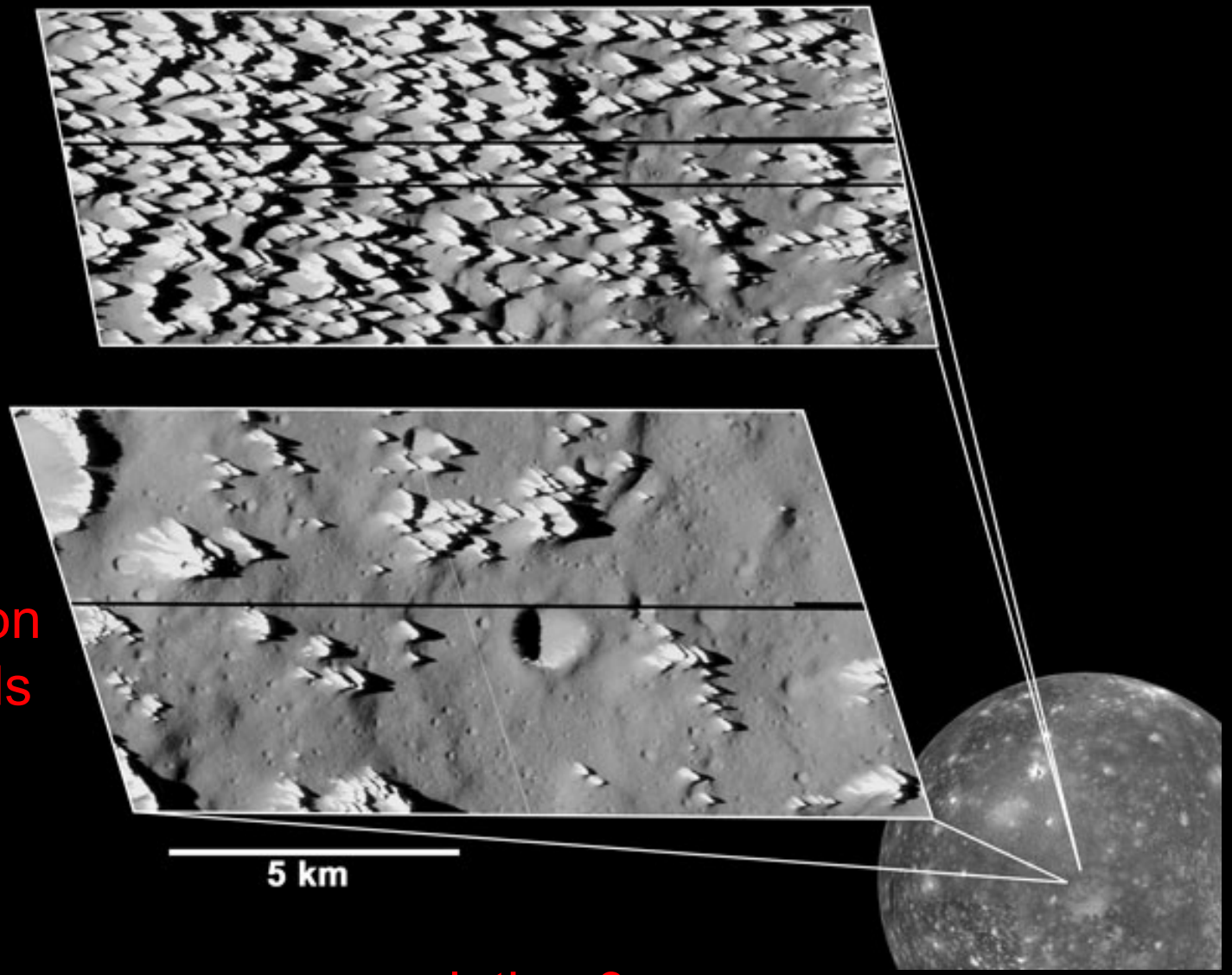
On Earth, similar types of features form when tectonic faulting breaks the crust and the intervening blocks are pulled apart and rotate.

Taken at a range of 2,090 km



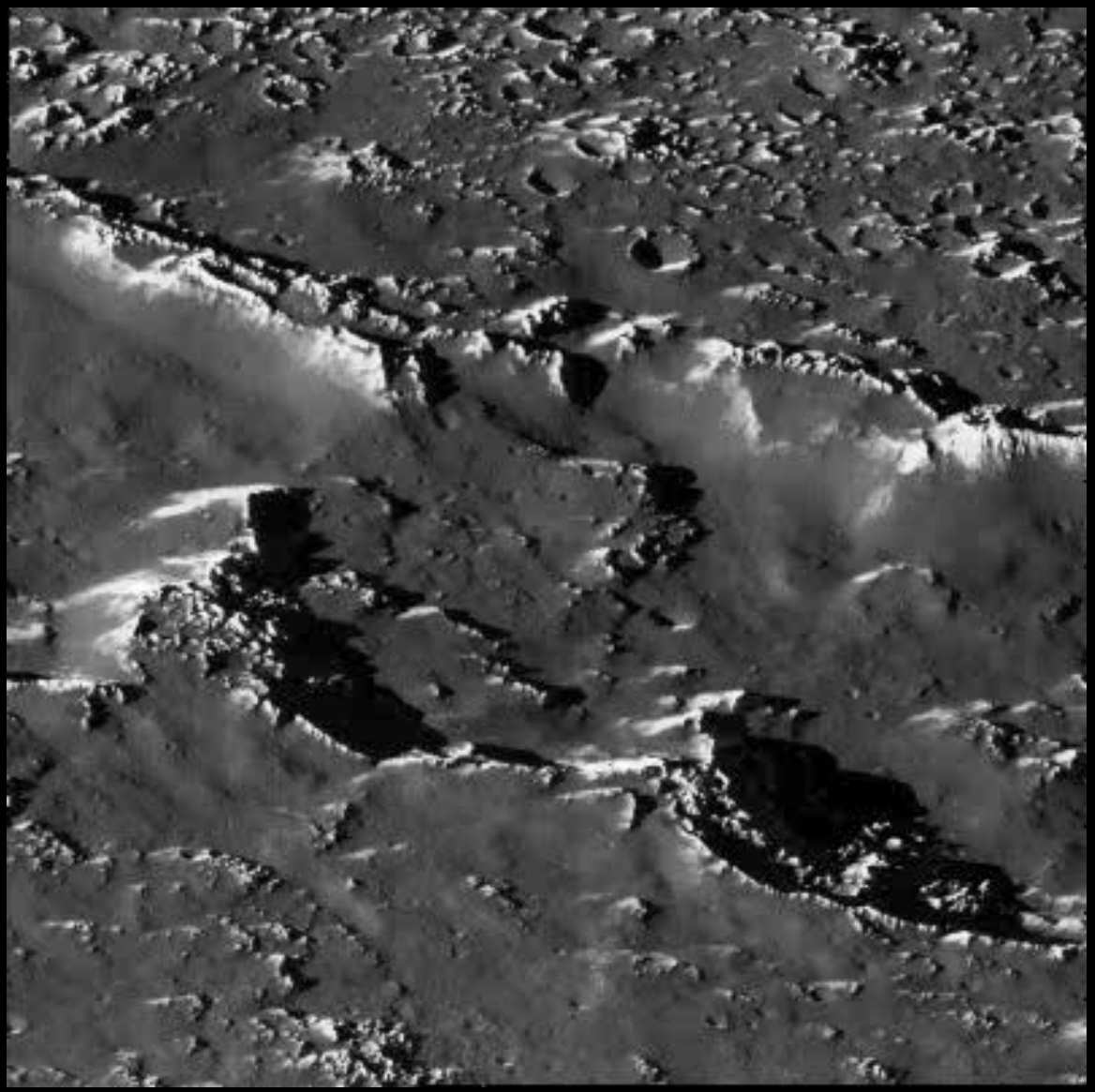
Callisto

mounds 100 m high due to ejecta from an impact

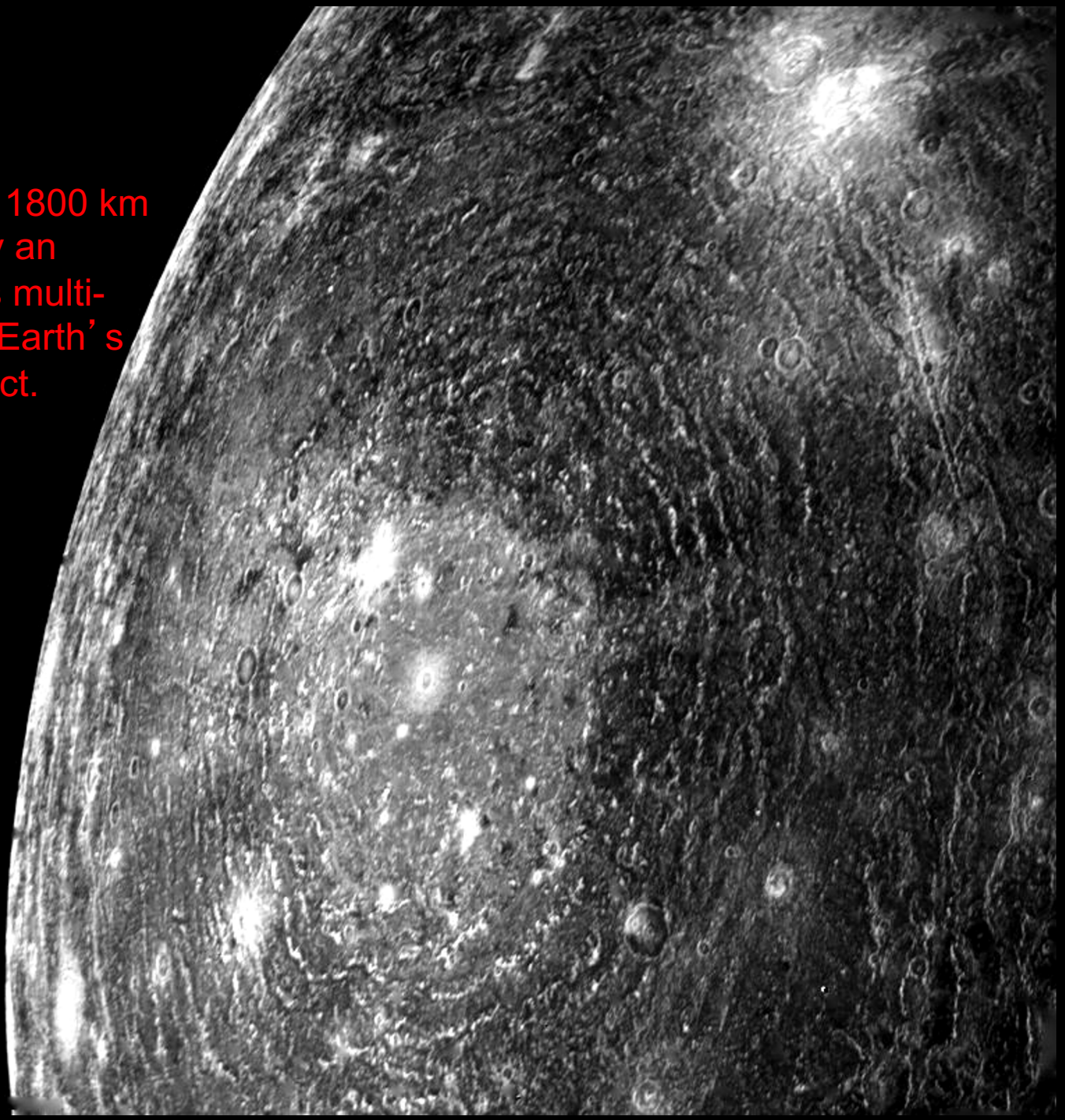


ice erosion of mounds

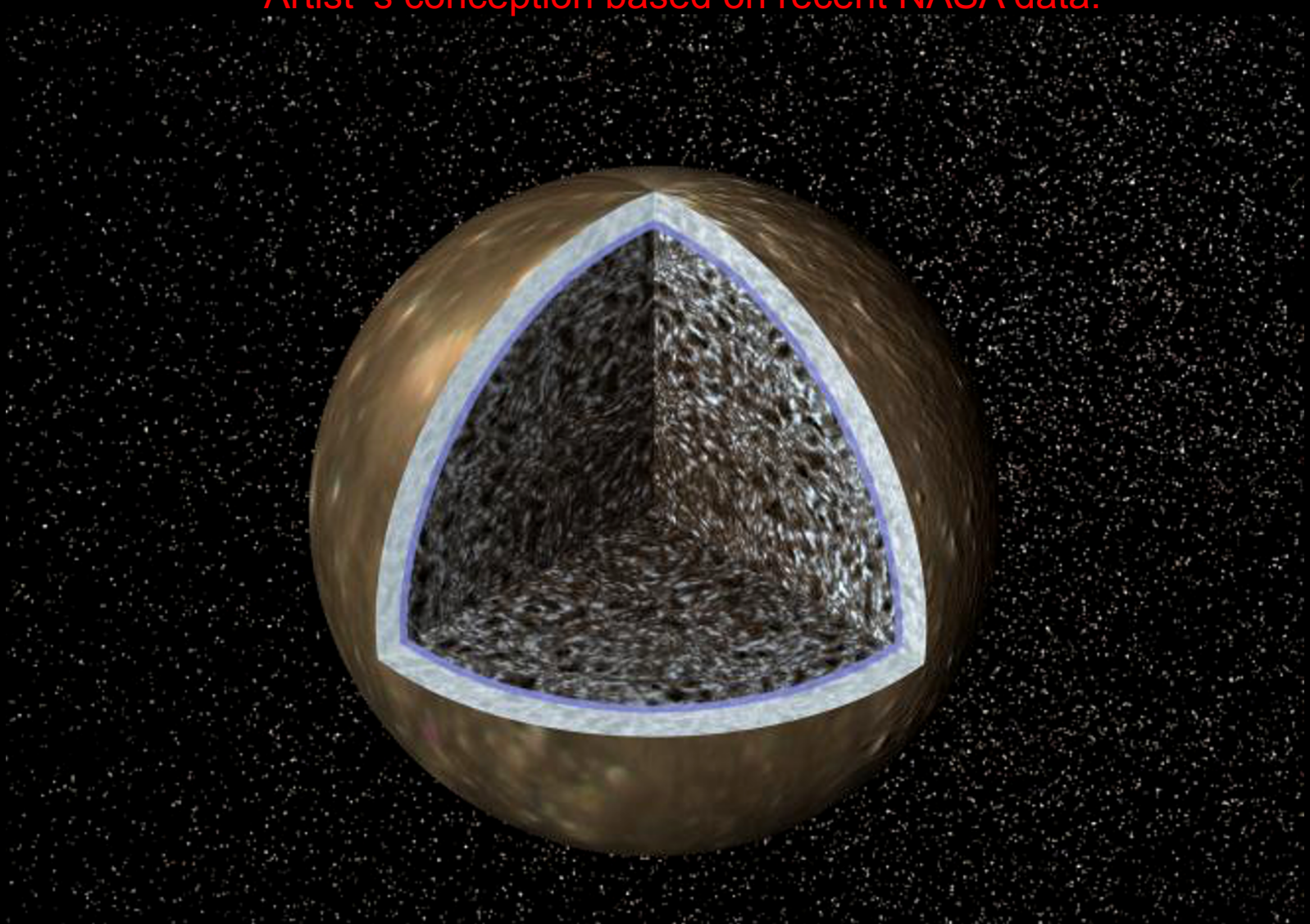
resolution 3 m



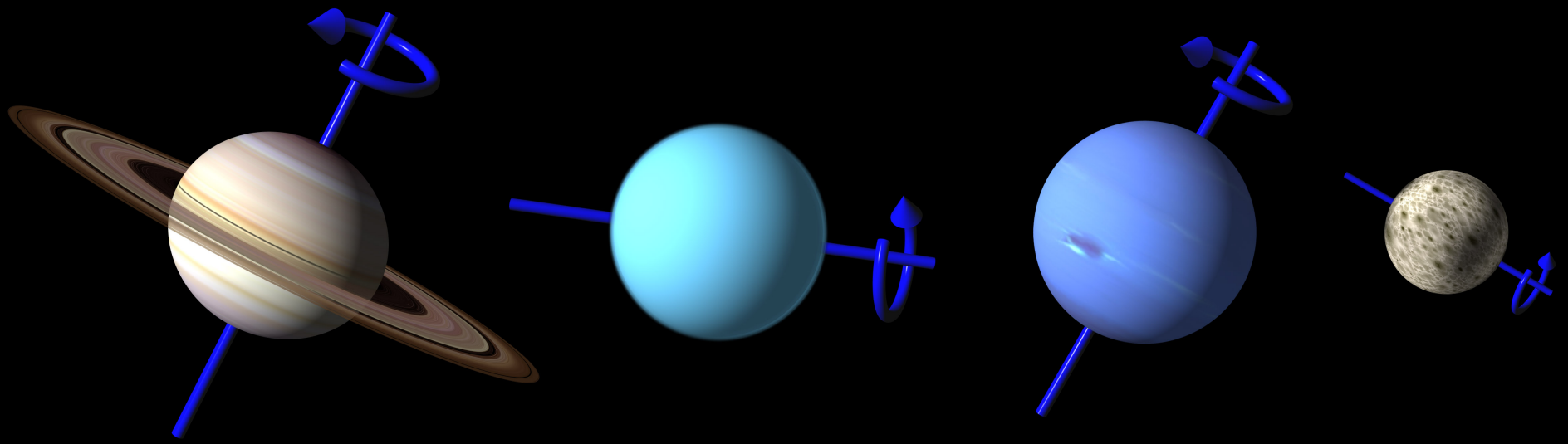
This circular structure, 1800 km across, was caused by an impact, and resembles multi-ring impact craters on Earth's Moon — Valhalla impact.



Artist's conception based on recent NASA data.



Findings show that Calisto might have a salty ocean beneath the icy crust which is 200 km thick. The ocean below is something more than 6 km, and the interior is made of cold rock and ice — no tidal flexing.



Saturn
27º

Uranus
98º

Neptune
30º

Pluto
120º

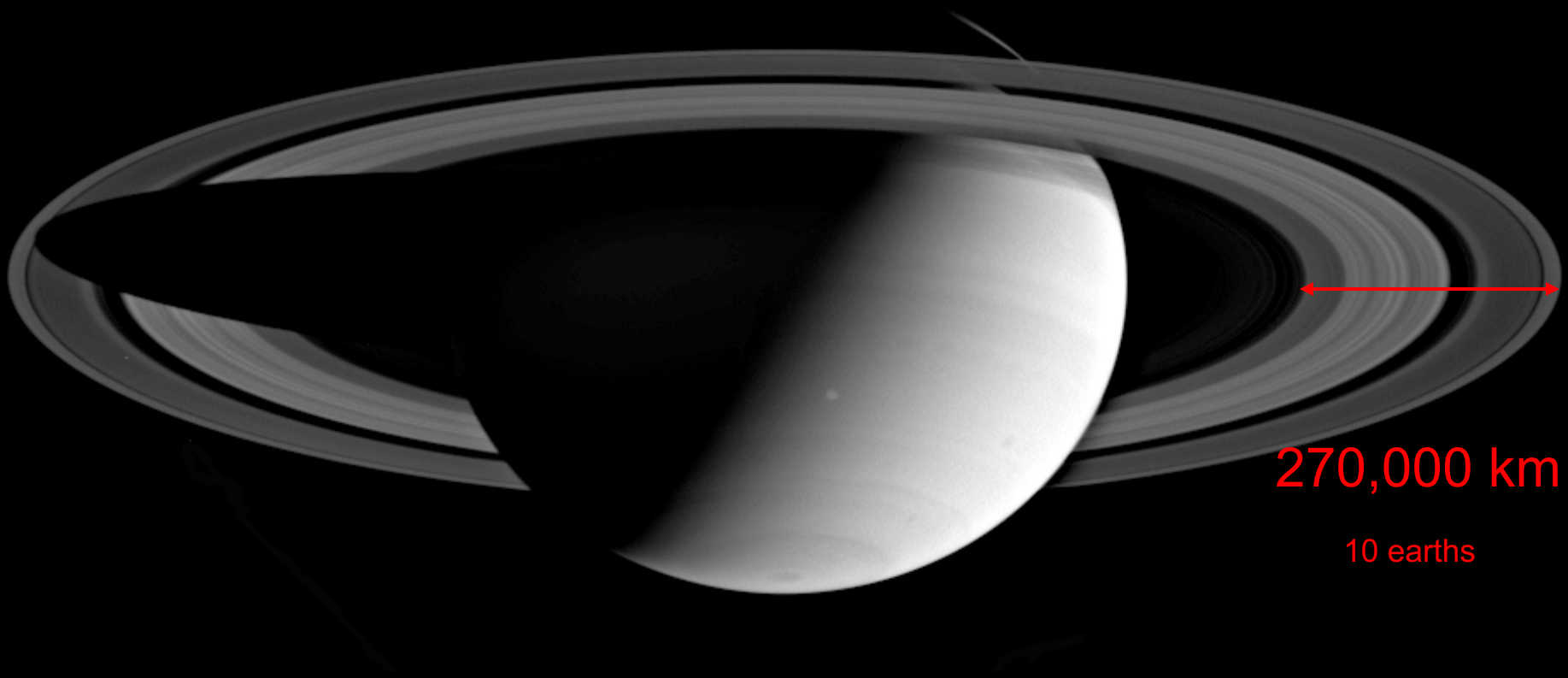
20% smaller than Jupiter

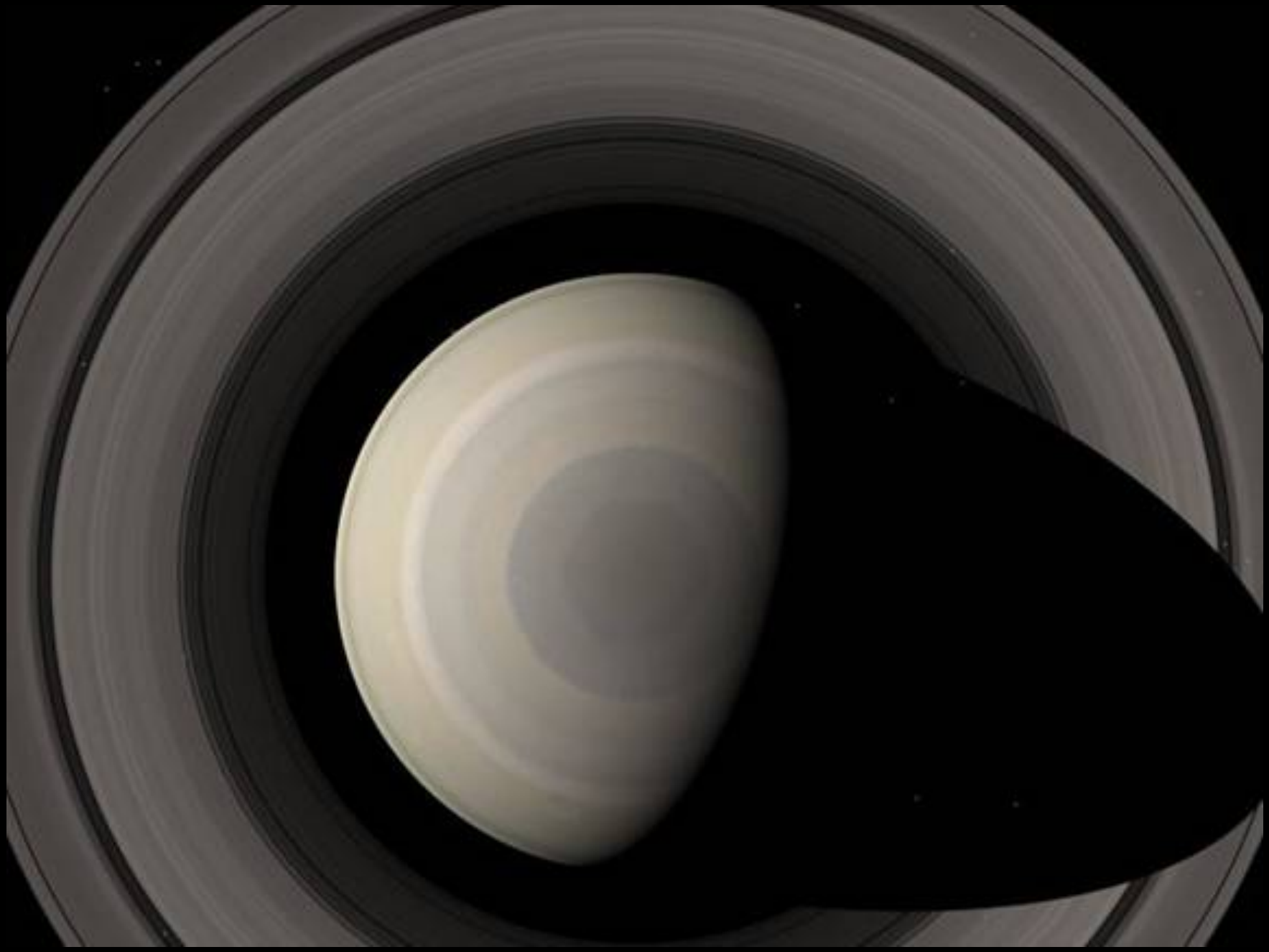
about 4 times larger than Earth

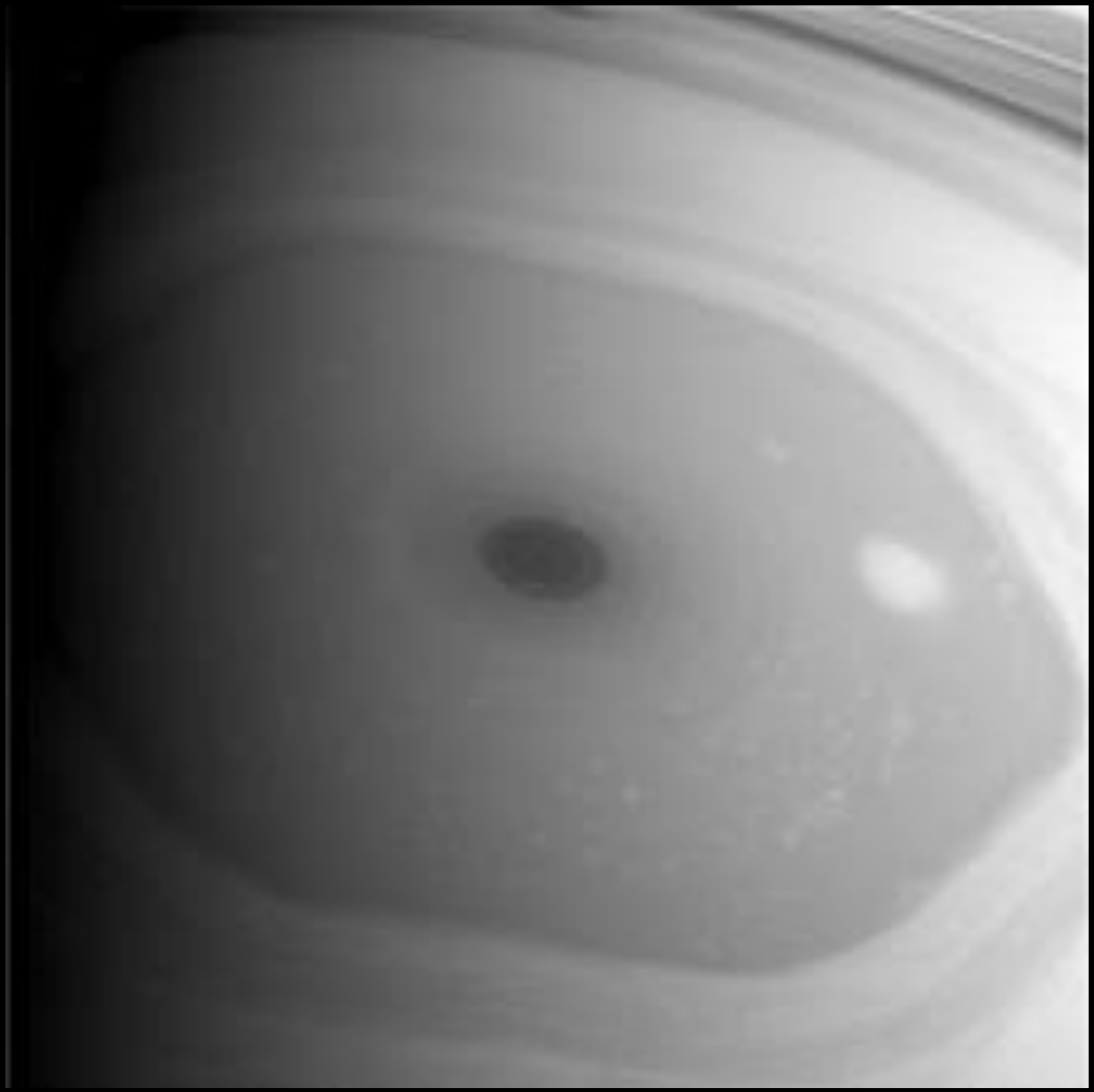
2300 km

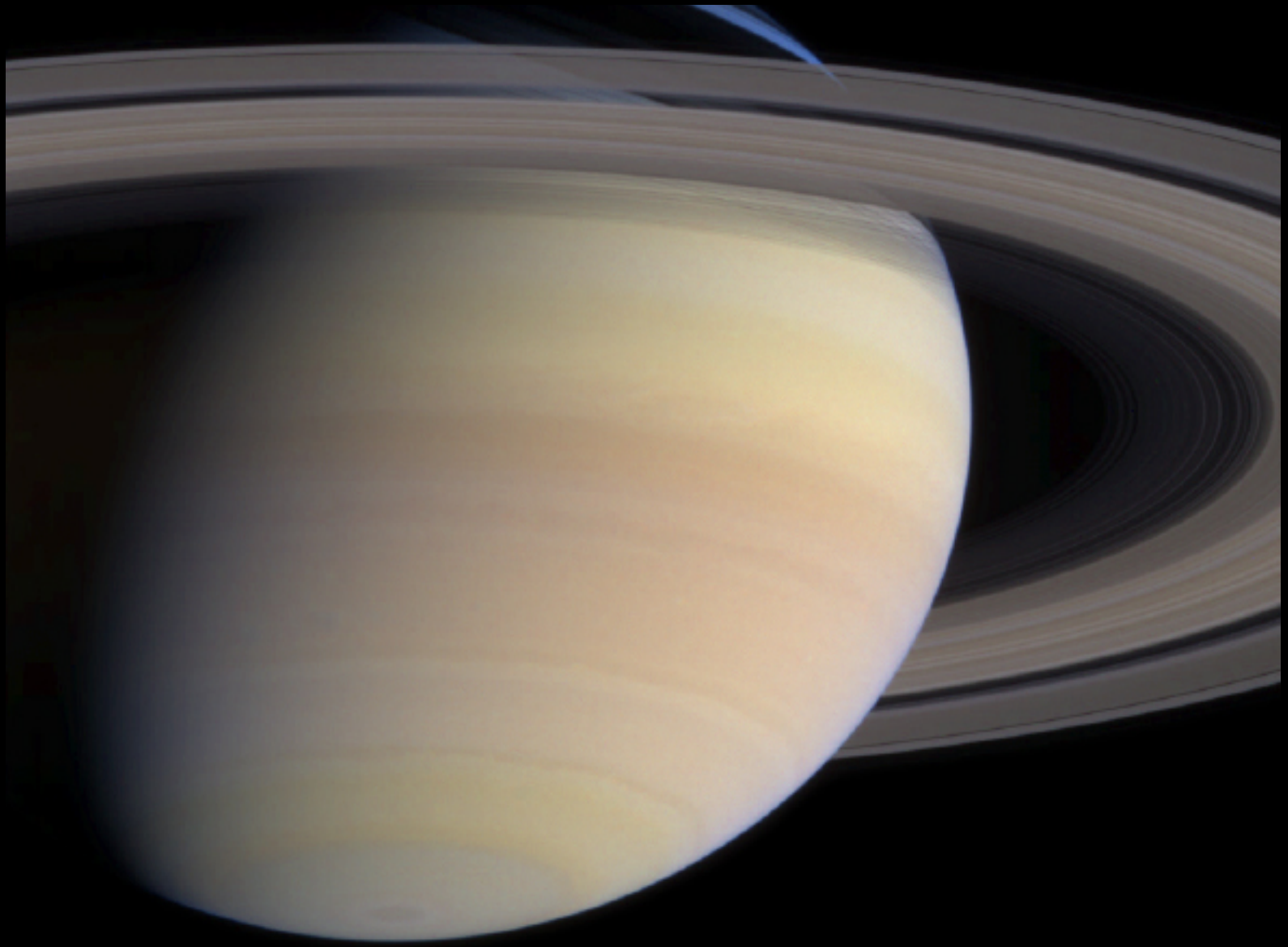


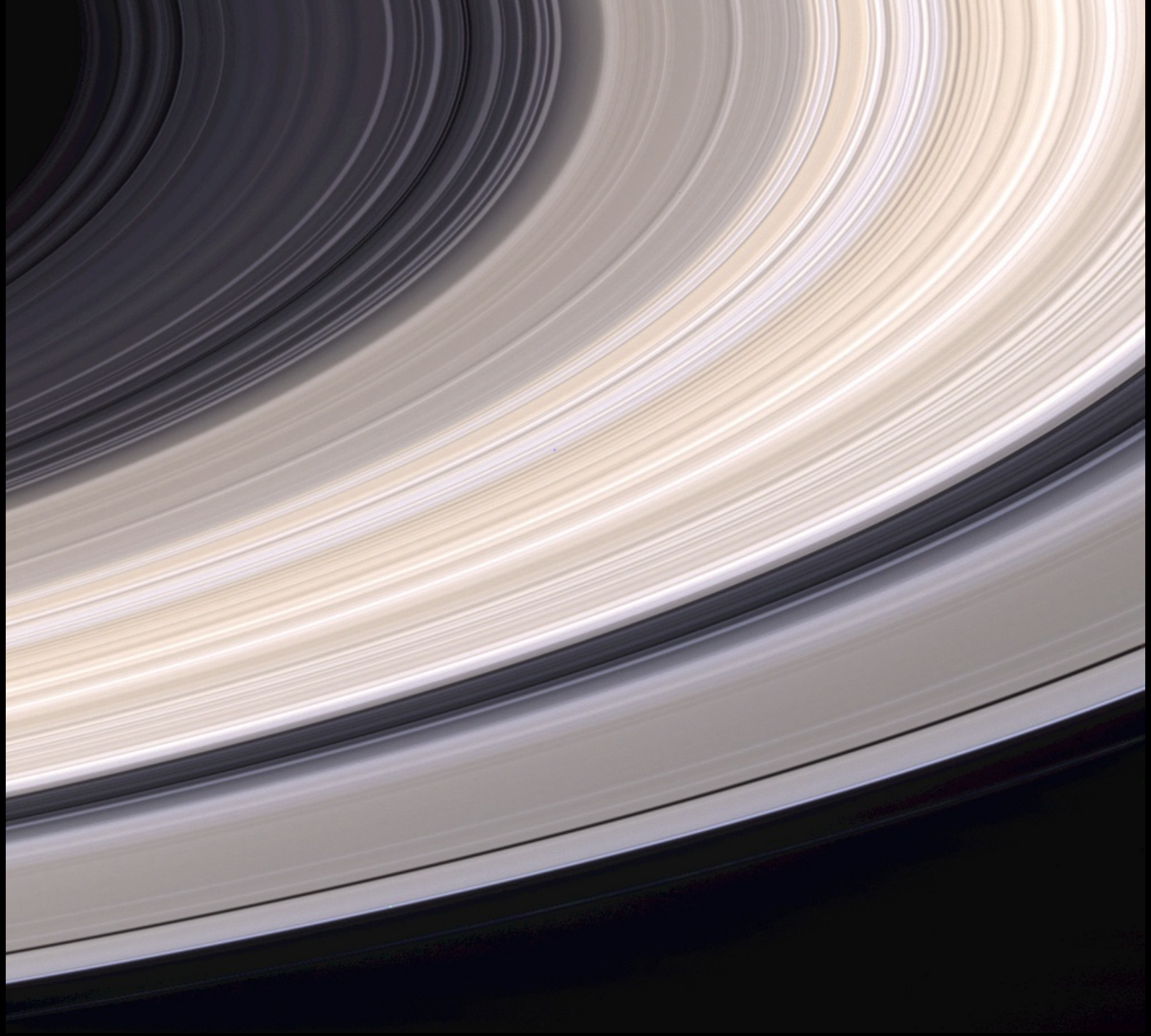
Saturn


270,000 km
10 earths
60,268 km diameter

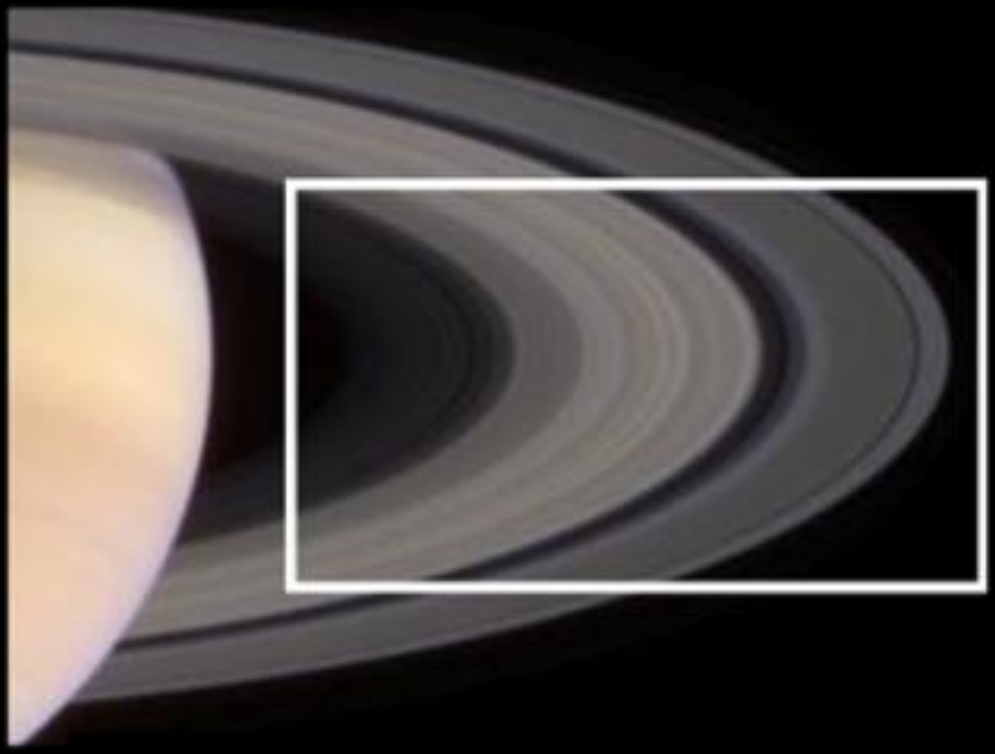




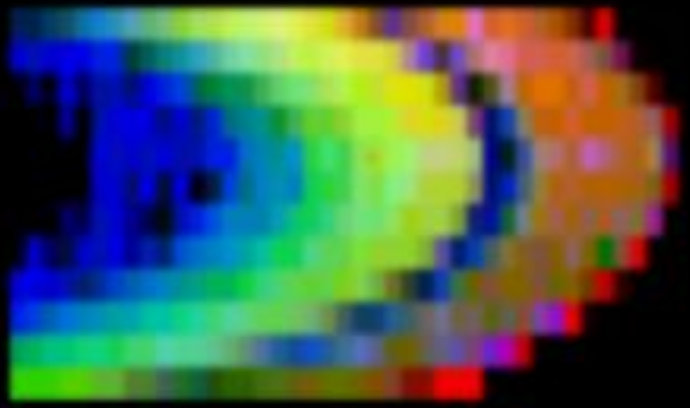




Cassini Visual and Infrared Mapping Spectrometer



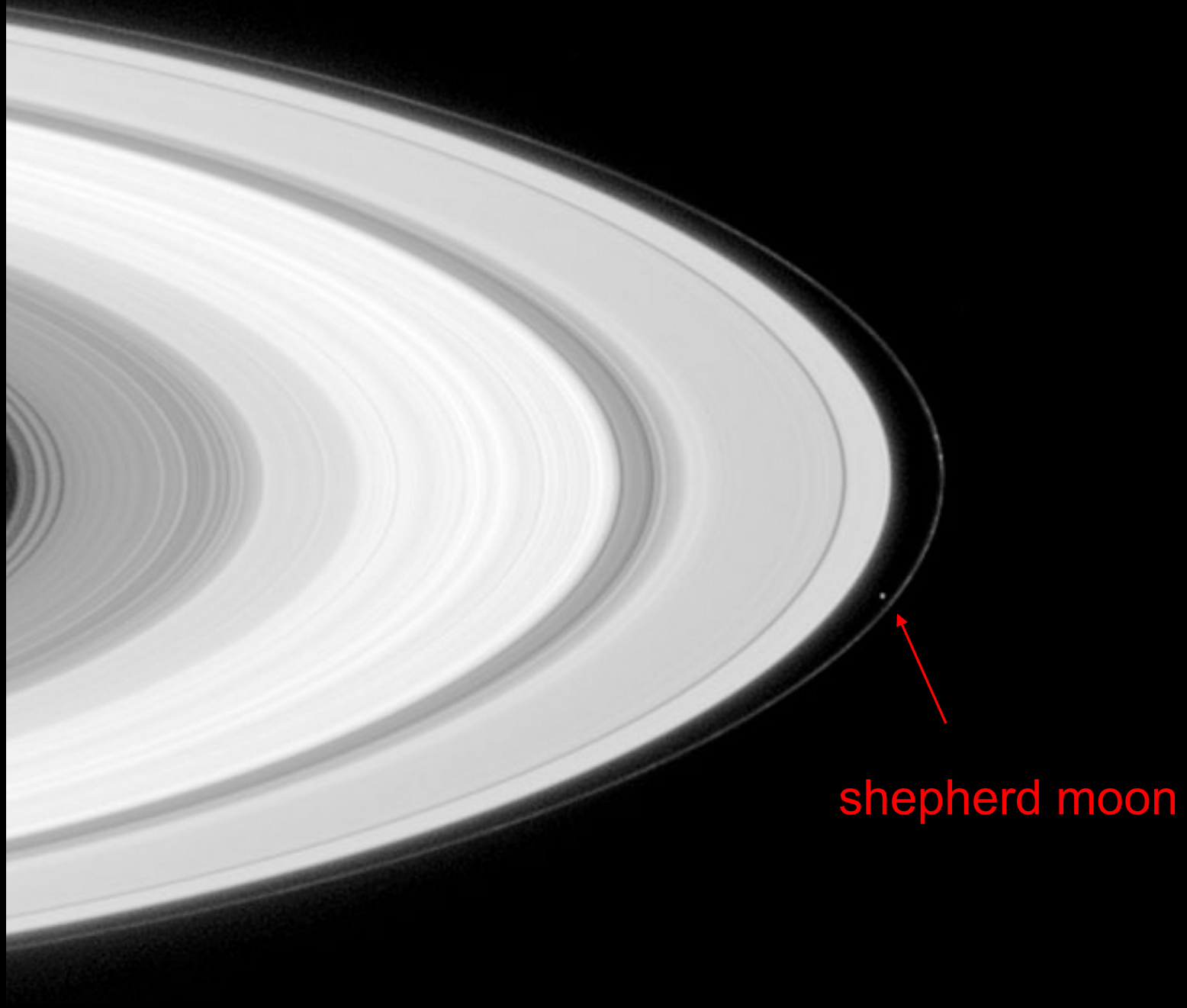
grain-size composite



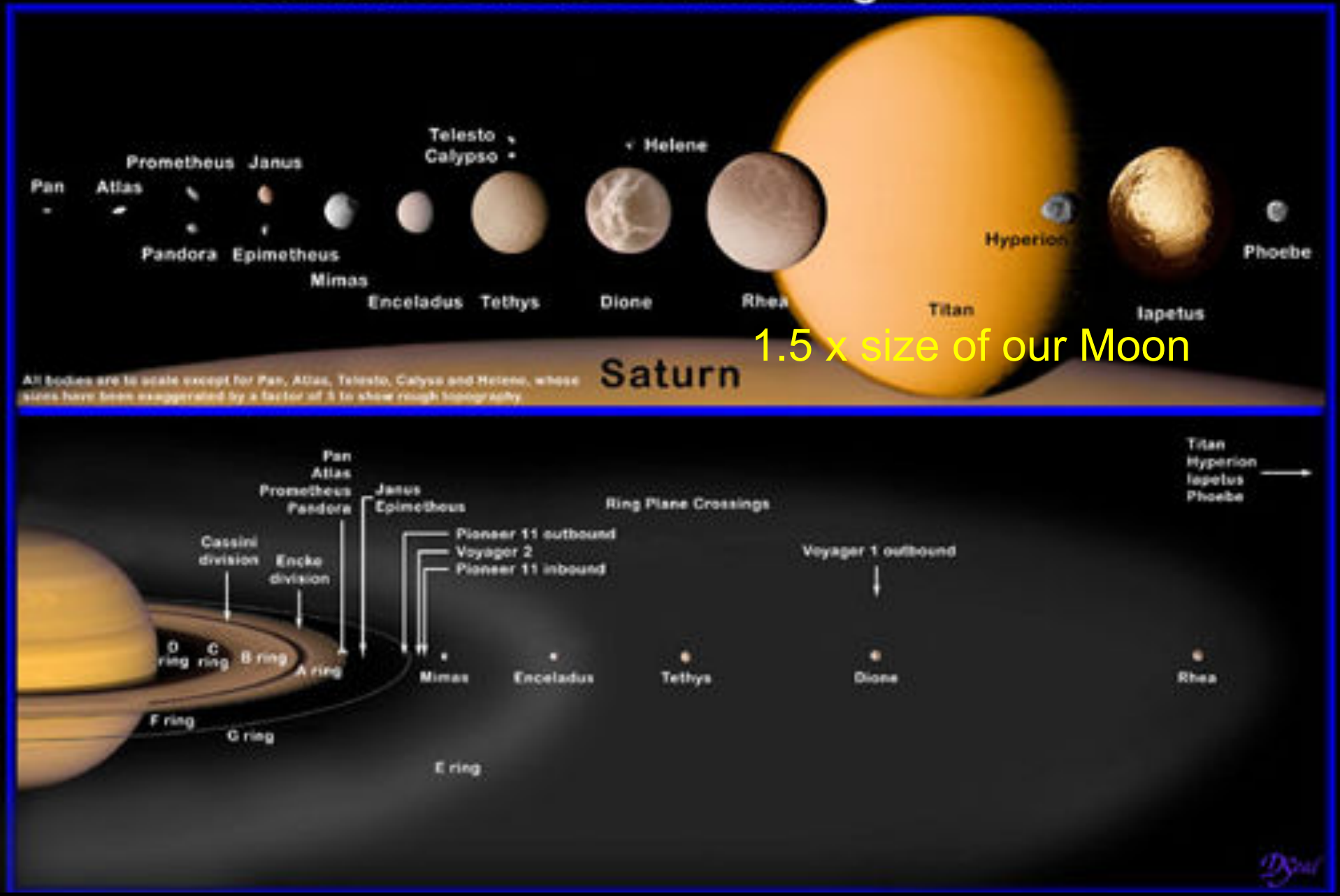
small large

powdery snow

snow flakes

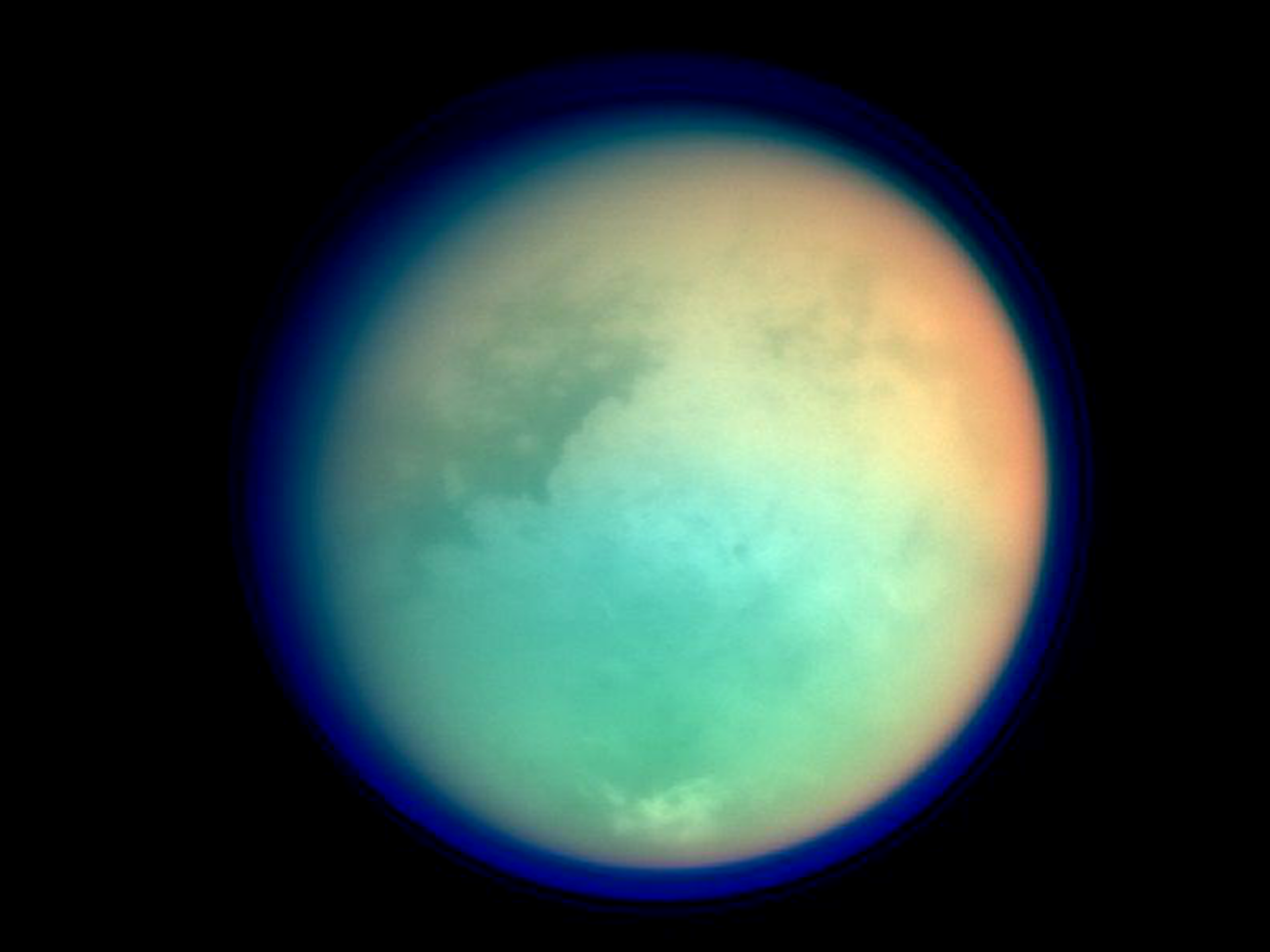

shepherd moon

Saturn's Satellites and Ring Structure





Titan

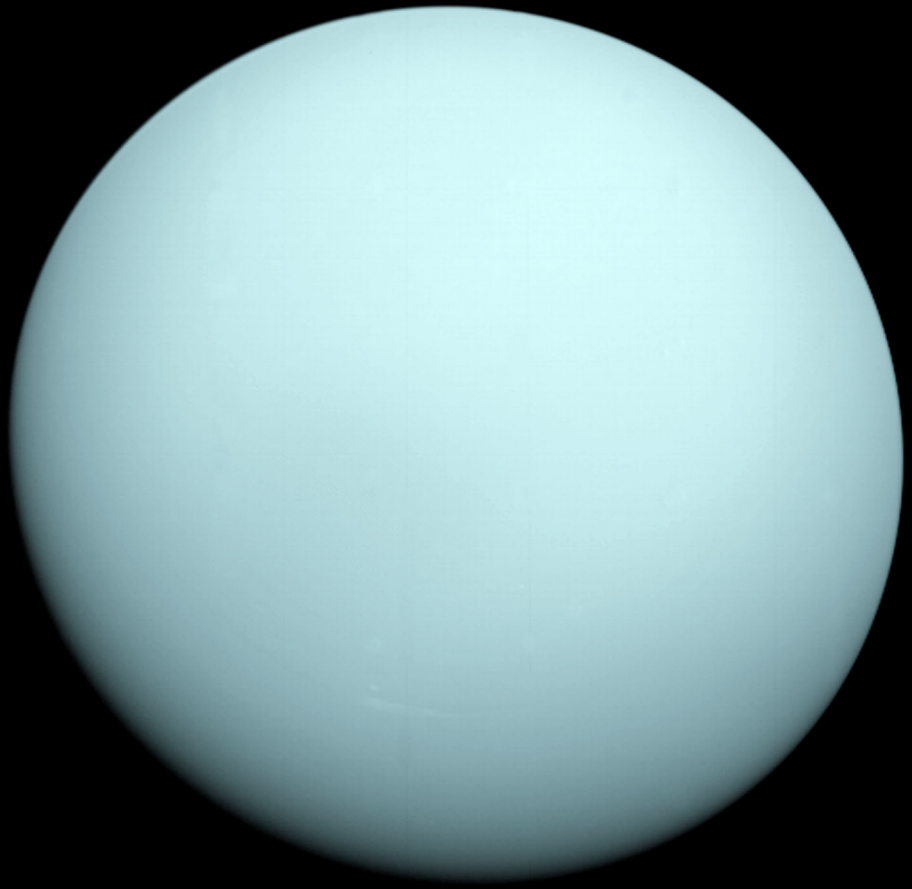




Enceladus

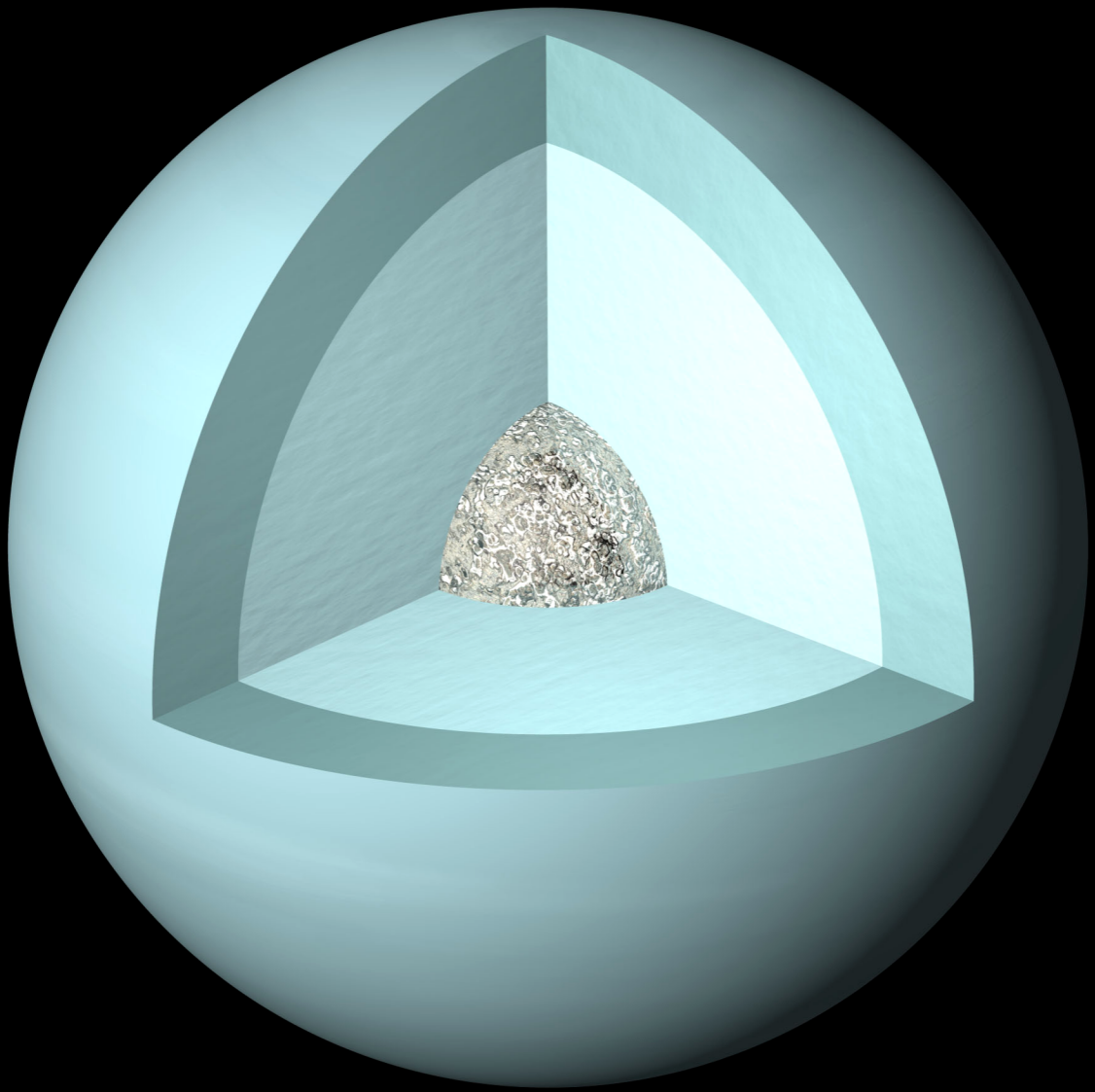


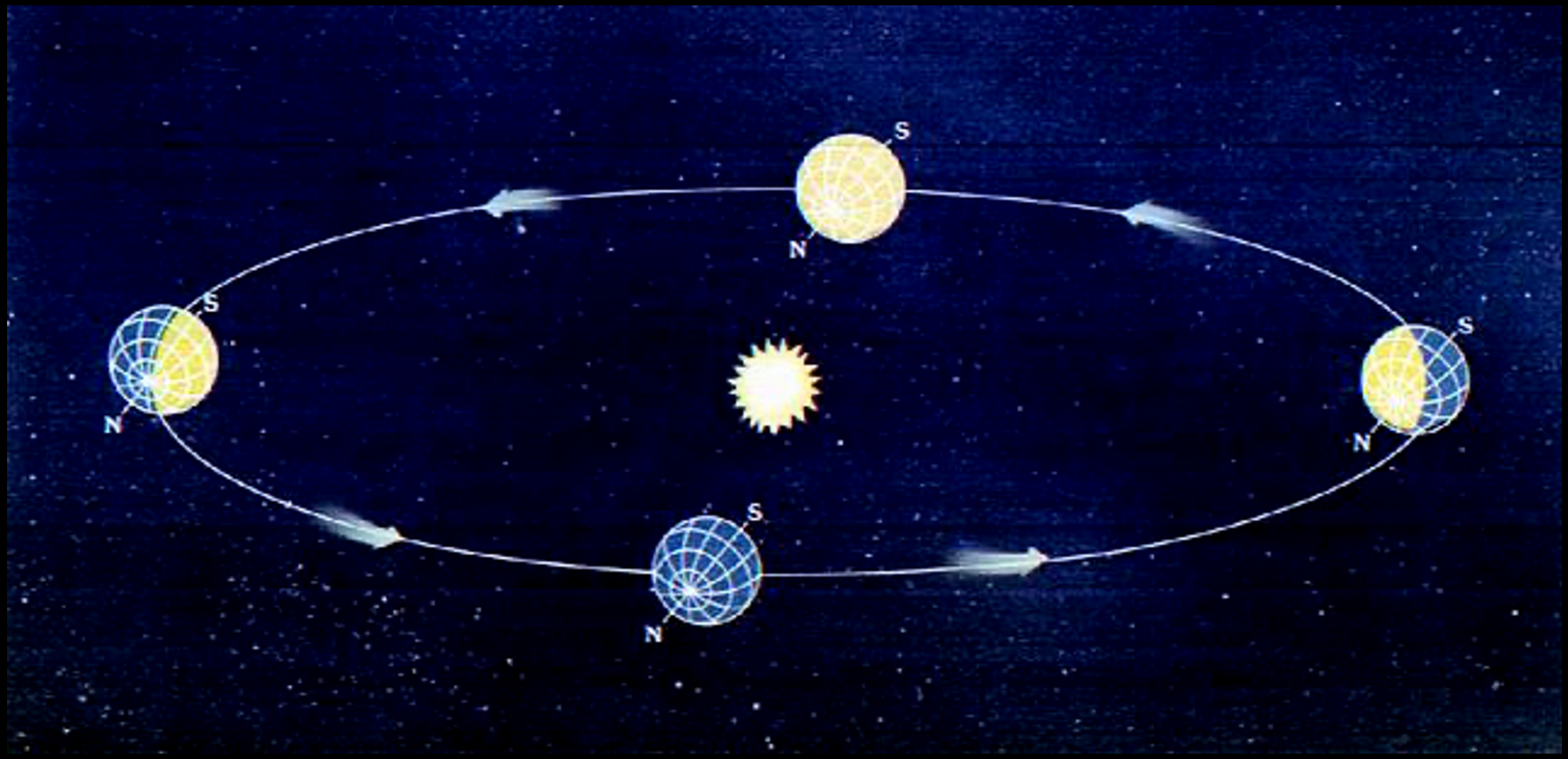
Tethys

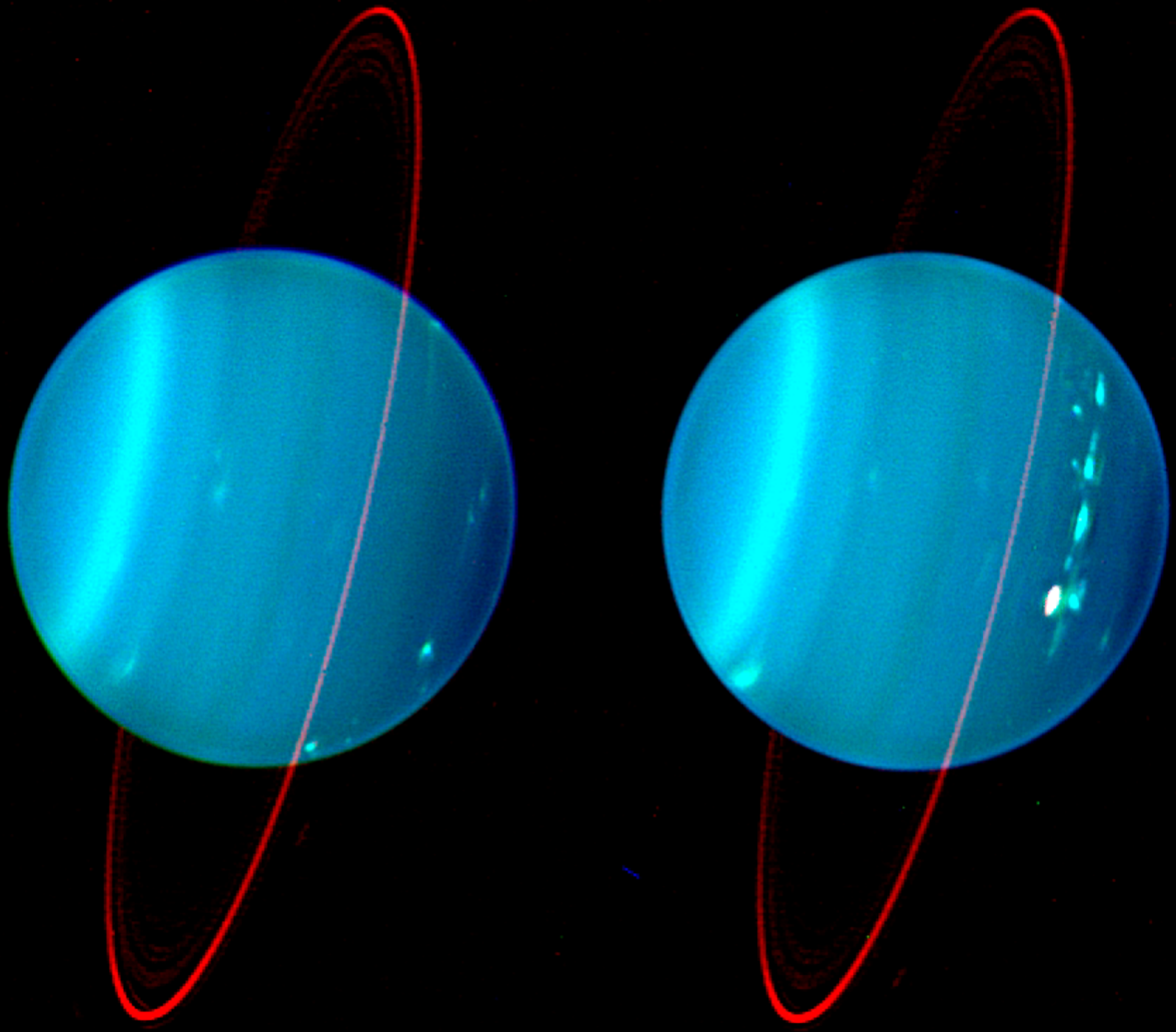


Uranus

51,118 km — 4 x diameter of Earth

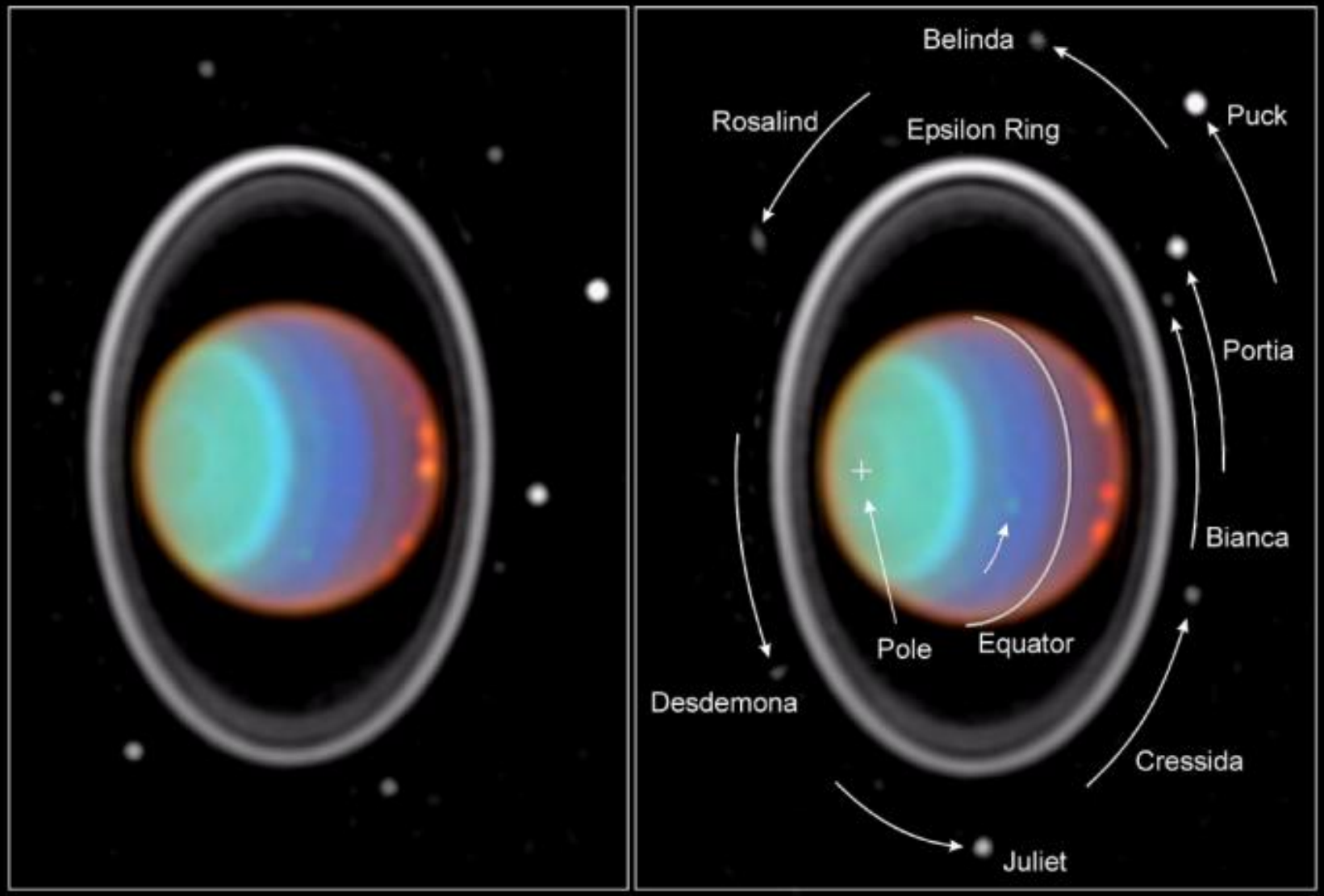


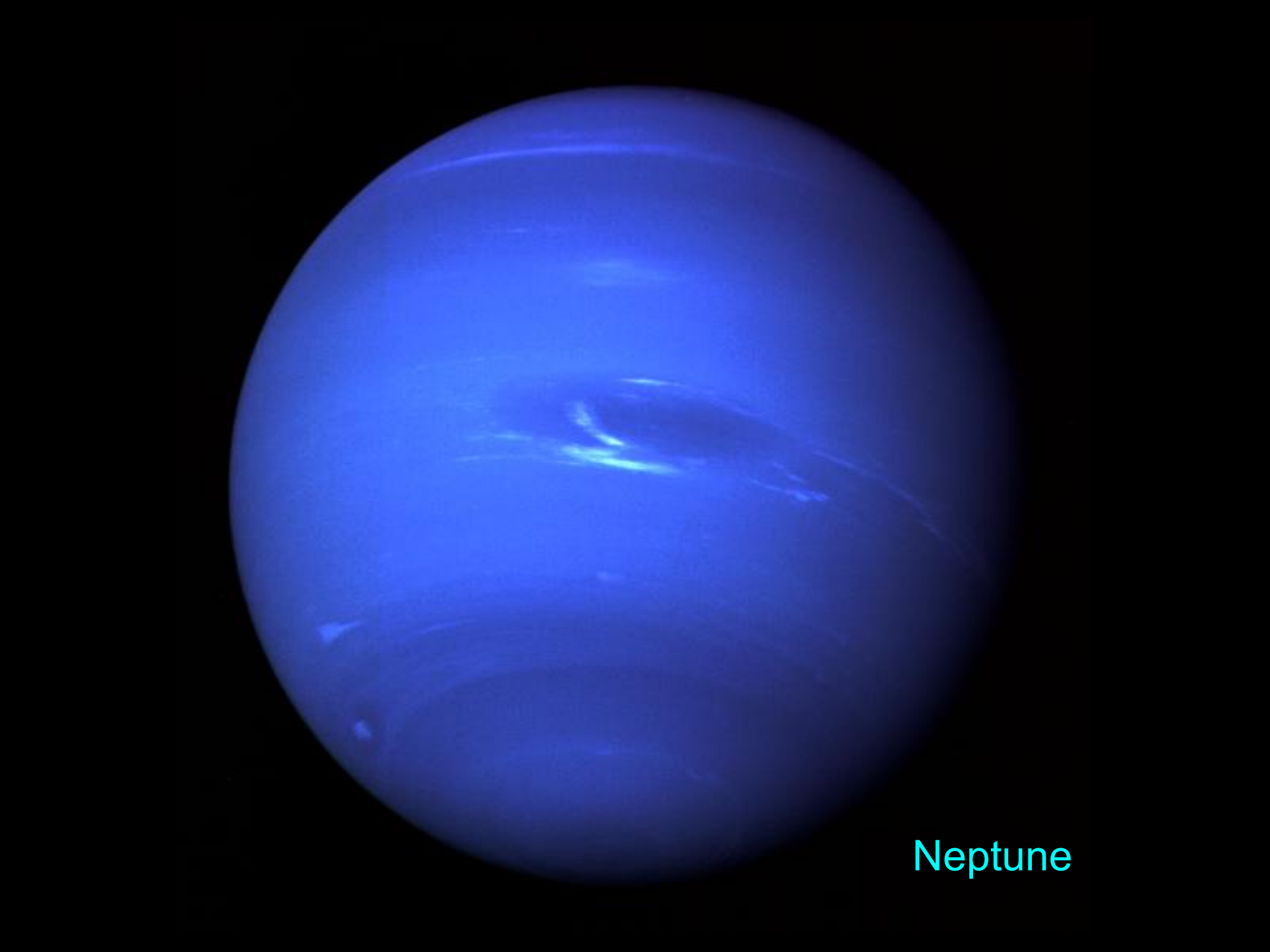

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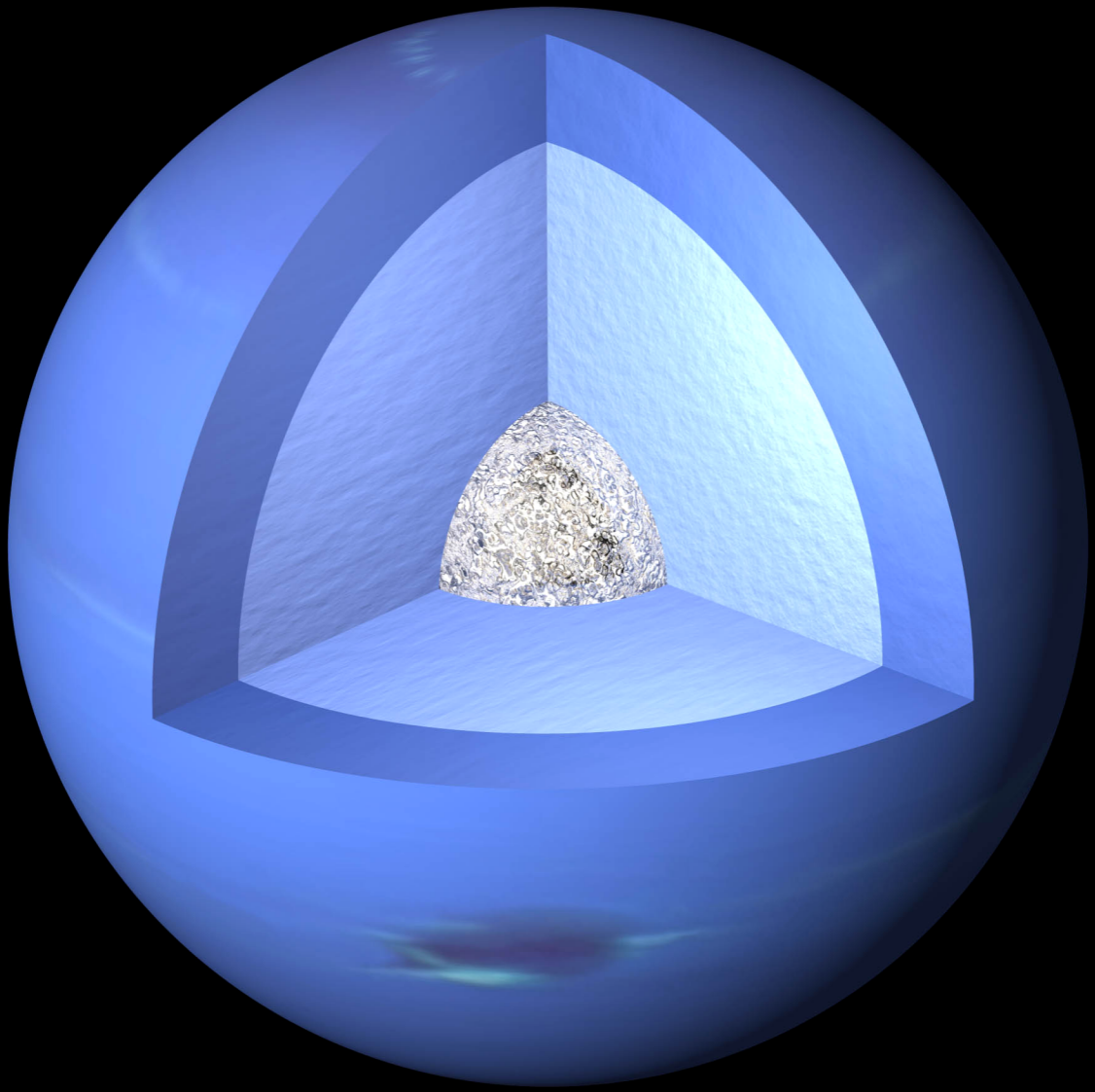
infrared



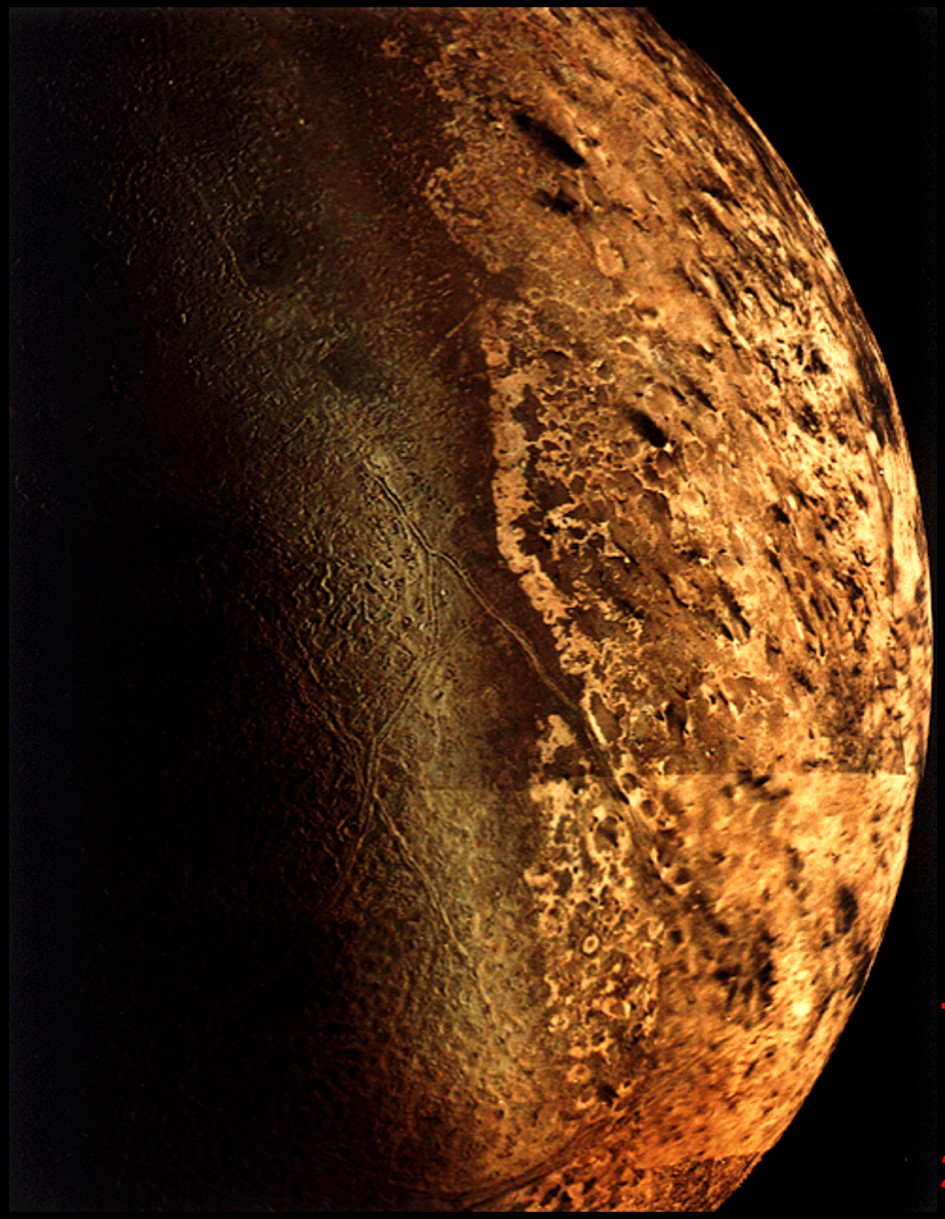

Belinda
Puck
Rosalind
Epsilon Ring
Portia
Bianca
Pole
Equator
Desdemona
Cressida
Juliet


Neptune





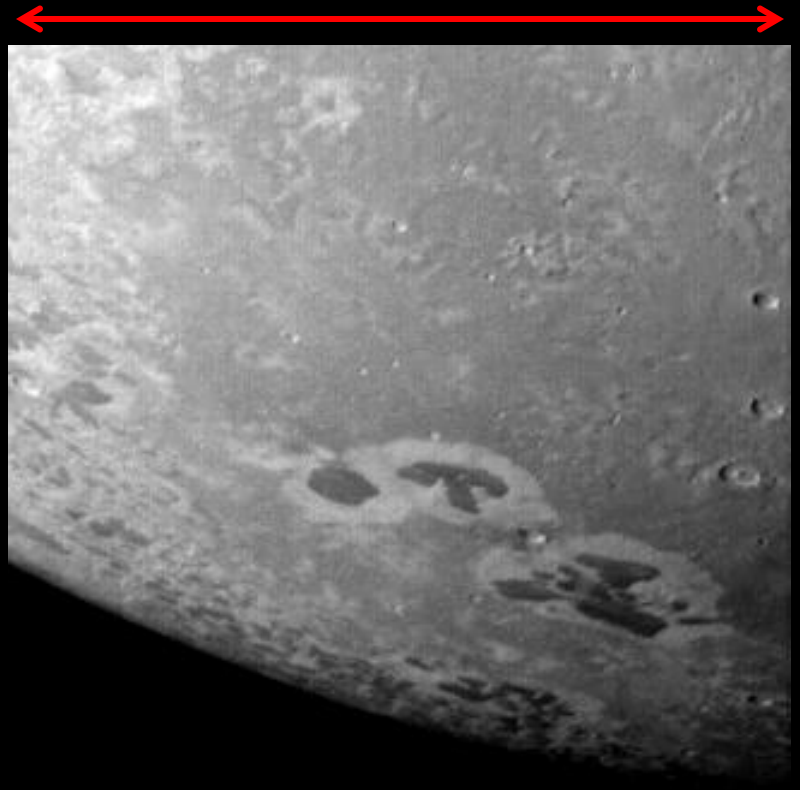




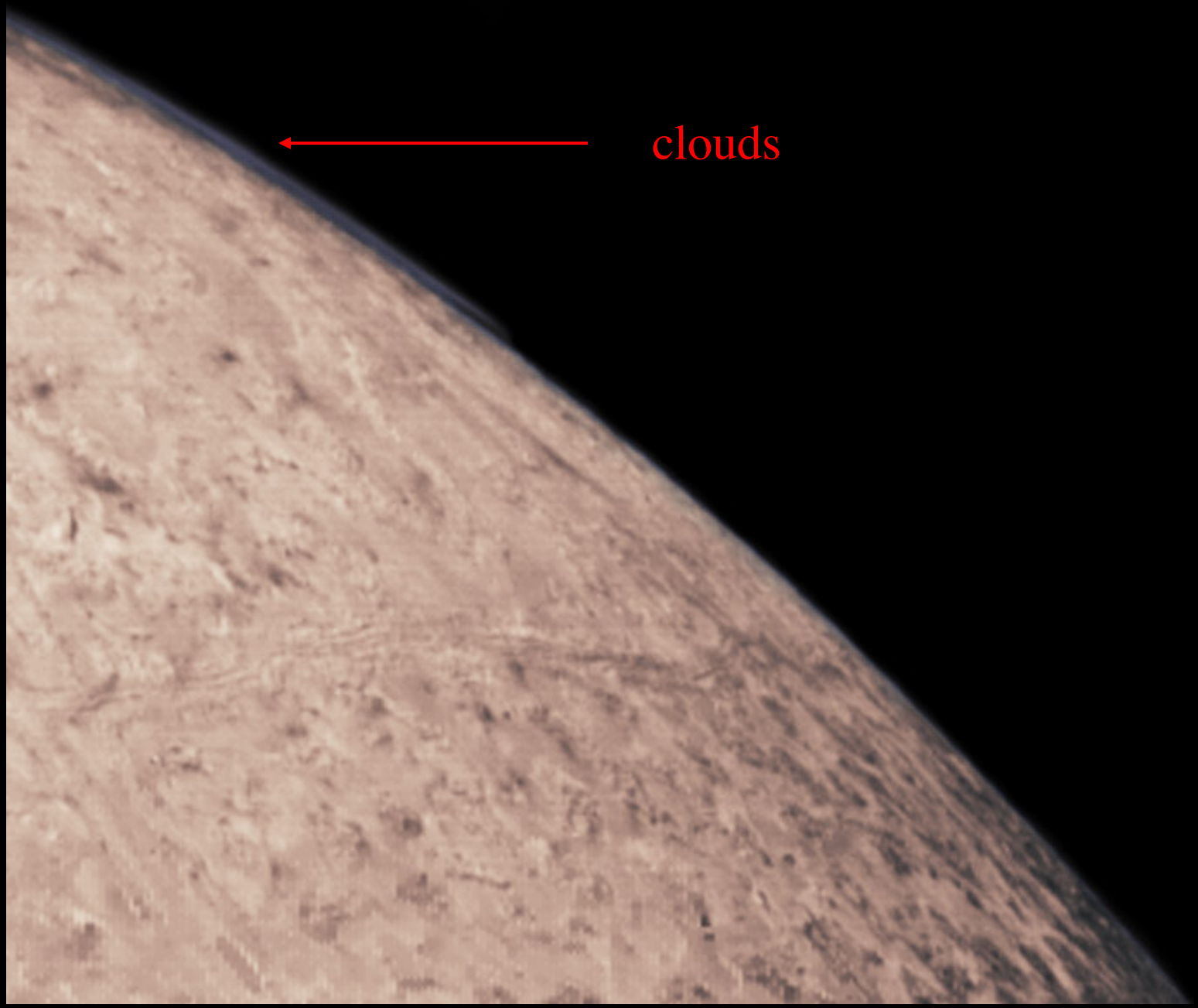
Triton

2,700 km (1,680 mi)

600 miles






clouds