COSMOLOGY REVIEW

http://unitedcats.files.wordpress.com/2010/05/flammarion_woodcut_colour.jpg

Voyager 1 becomes first human-made object to leave solar system

By Elizabeth Landau, CNN
Updated 11:36 AM ET, Wed October 2, 2013

Voyager 1 launched 1977 40 years of Solar escape

https://sunearthday.nasa.gov/2008/multimedia/gal_031.php

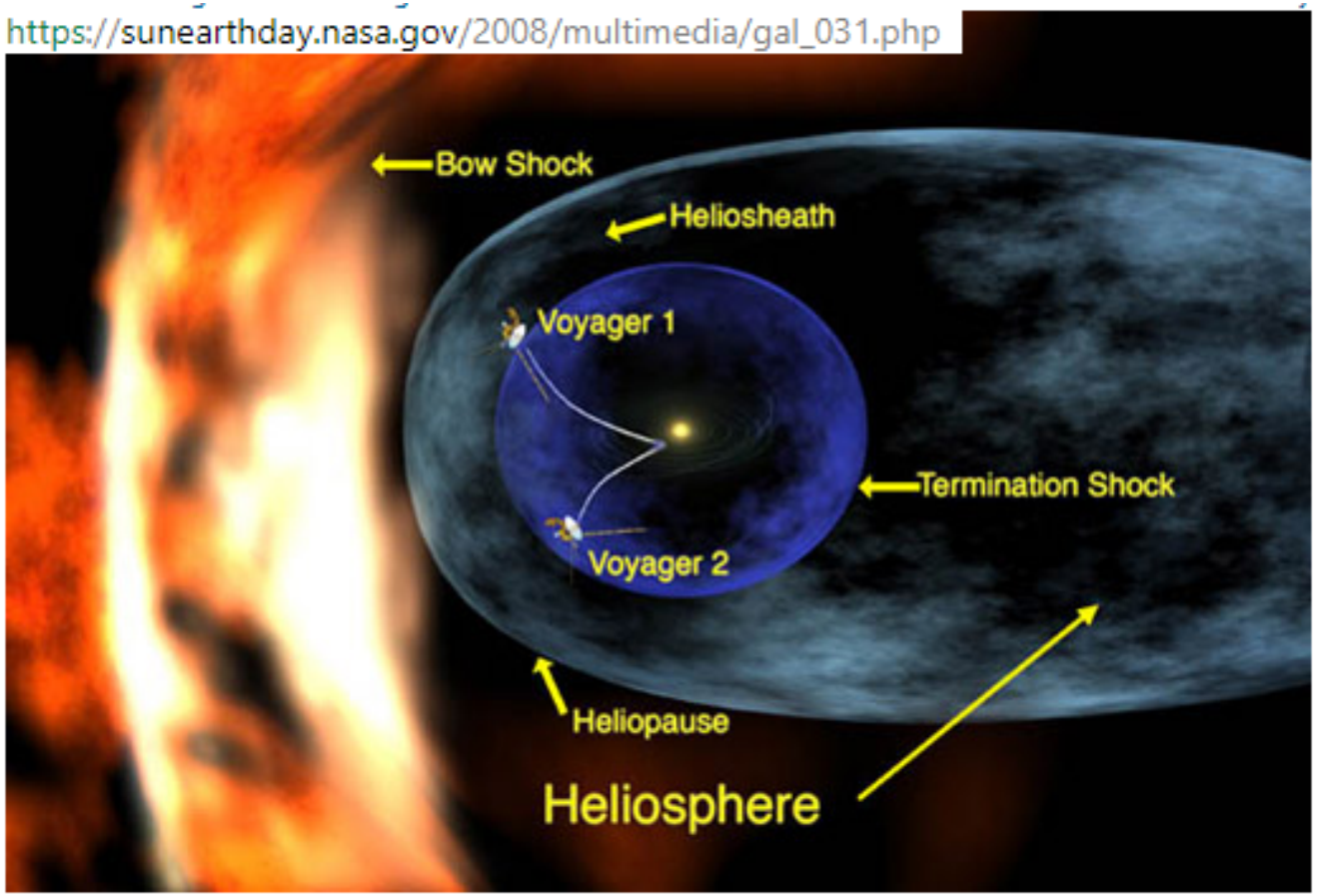
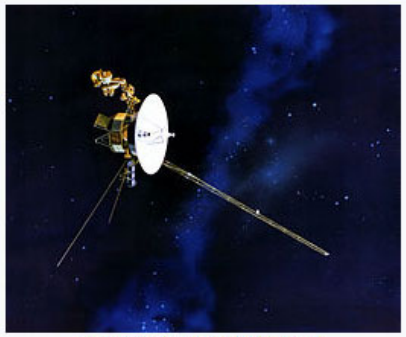


Figure 2: This is a 'scary' diagram showing the regions of the heliosphere (click on image for larger view). There really isn't any fire-like cloud ramming into the heliosphere! It also shows the approximate locations of Voyagers 1 and 2. Voyager 1 is traveling faster and has crossed into the heliosheath. *(Courtesy: NASA / Walt Feimer).*

Image explanation on following page



Voyager 1, artist's impression

Mission type	Outer planetary, heliosphere, and interstellar medium exploration
Operator	NASA / JPL
COSPAR ID	1977-084A[1]
SATCAT no.	10321[2]
Website	voyager.jpl.nasa.gov
Mission duration	40 years, 3 months and 14 days elapsed Planetary mission: 3 years, 3 months, 9 days Interstellar mission: 37 years and 5 days elapsed (continuing)
Spacecraft properties	
Manufacturer	Jet Propulsion Laboratory
Launch mass	825.5 kg (1,820 lb)
Power	420 W
Start of mission	
Launch date	September 5, 1977, 12:56:00 UTC
Rocket	Titan IIIE
Launch site	Cape Canaveral LC-41
Flyby of Jupiter	
Closest approach	March 5, 1979
Distance	349,000 km (217,000 mi)
Flyby of Saturn	
Closest approach	November 12, 1980
Distance	124,000 km (77,000 mi)
Flyby of Titan (atmosphere study)	
Closest approach	November 12, 1980
Distance	6,490 km (4,030 mi)

This is an artist's concept of our Heliosphere as it travels through our galaxy with the major features labeled.

Termination Shock:
Blowing outward billions of kilometers from the Sun is the solar wind, a thin stream of electrically charged gas. This wind travels at an average speed ranging from 300 to 700 kilometers per second (700,000 - 1,500,000 miles per hour) until it reaches the termination shock. At this point, the speed of the solar wind drops abruptly as it begins to feel the effects of interstellar wind.

Heliosphere:
The solar wind, emanating from the Sun, creates a bubble that extends far past the orbits of the planets. This bubble is the heliosphere, shaped like a long wind sock as it moves with the Sun through interstellar space.

Heliosheath:
The heliosheath is the outer region of the heliosphere, just beyond the termination shock, the point where the solar wind slows abruptly, becoming denser and hotter. The solar wind piles up as it presses outward against the approaching wind in interstellar space.

Heliopause:
The boundary between solar wind and interstellar wind is the heliopause, where the pressure of the two winds are in balance. This balance in pressure causes the solar wind to turn back and flow down the tail of the heliosphere.

Bow shock:
As the heliosphere plows through interstellar space, a bow shock forms, similar to what forms as a ship plowing through the ocean.

Also present in this illustration are the two Voyager spacecraft with their approximate paths out of the Heliosphere. Voyager I was deflected northward above the plane of the planets' orbits when it swung by Saturn in 1980. Voyager II was deflected downward by Neptune and is heading southward below the plane of the planets.
Credit: NASA/Goddard/Walt Feimer

HISTORY OF CONCEPTS

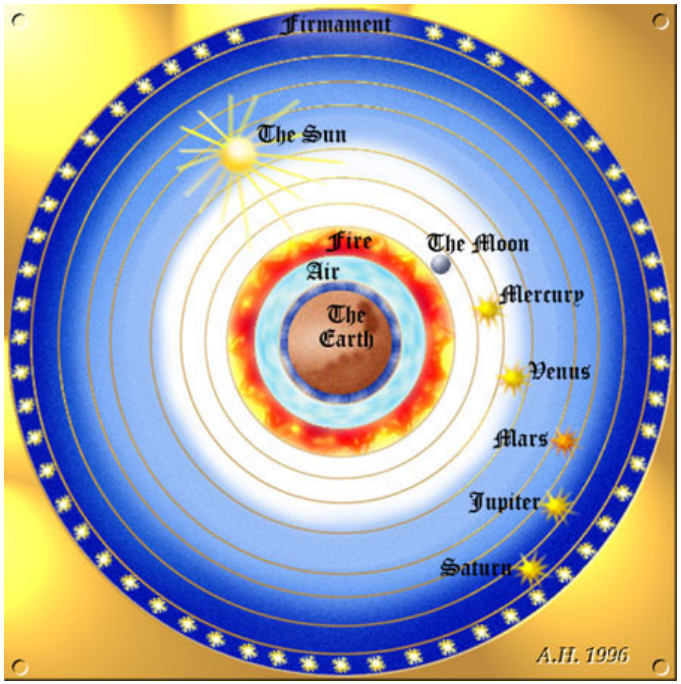
~1000 BC Homer

Earth is a flat disk with water at edges and land in middle.

Stars overhead in Celestial Sphere and Hades below

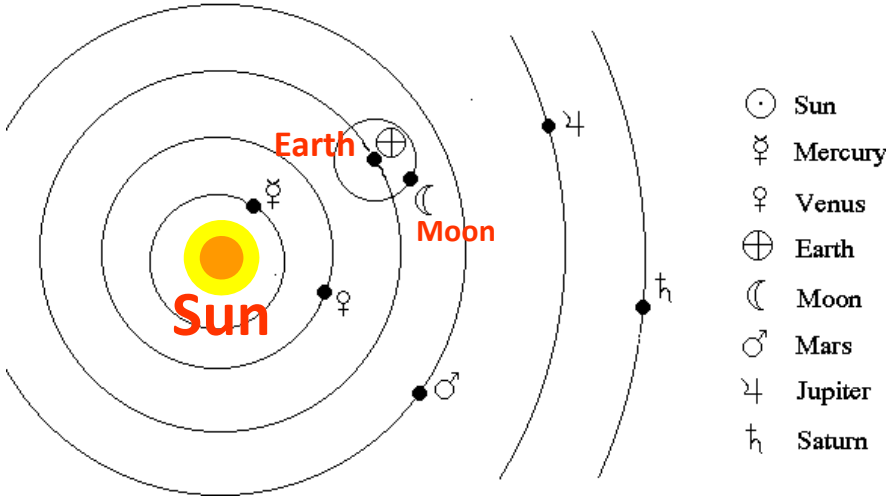
330 BC -Heraclides

formalized Plato's first Solar System model, called the Geocentric model



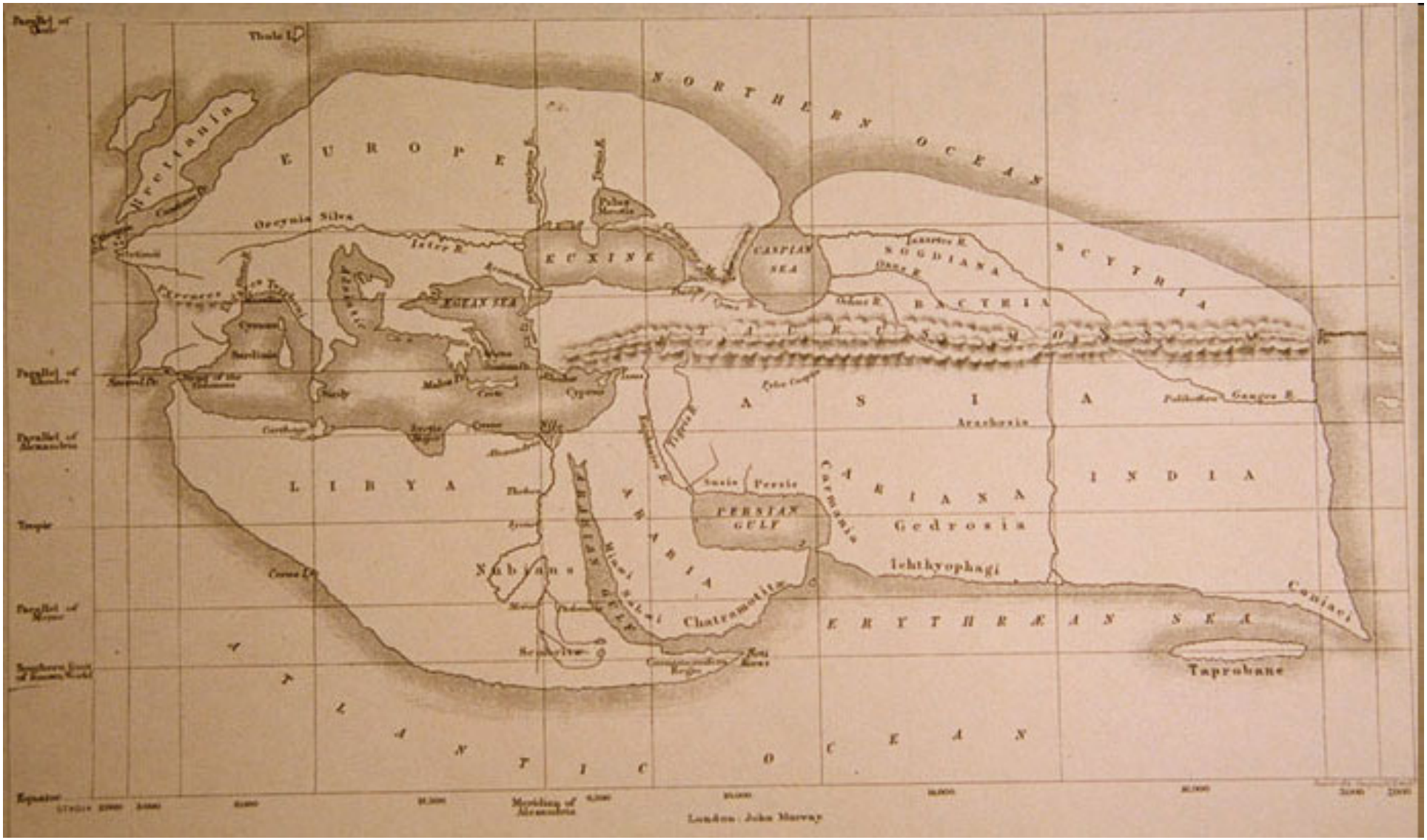
270 BC Aristarchus

1st Heliocentric Solar System Model

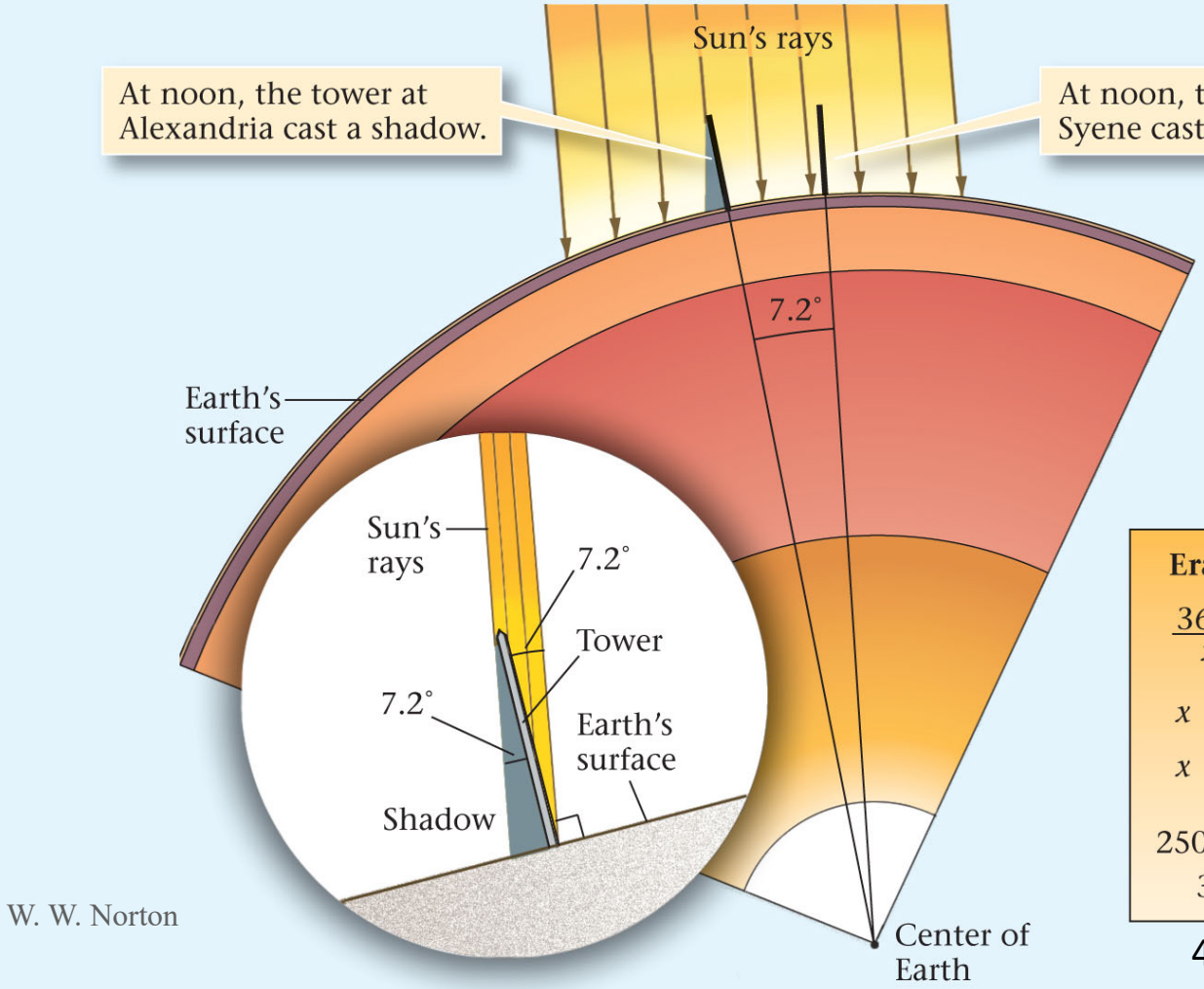


http://zebu.uoregon.edu/~js/ast121/lectures/lec01.html

200 BC ancient Greek view of Earth



~200 BC Eratosthenes (Libyan - Greek) calculated circumference of earth



Eratosthene's calculation:

$$\frac{360°}{x} = \frac{7.2°}{5{,}000 \text{ stadia}}$$

$$x = \frac{360° \times 5{,}000 \text{ stadia}}{7.2°}$$

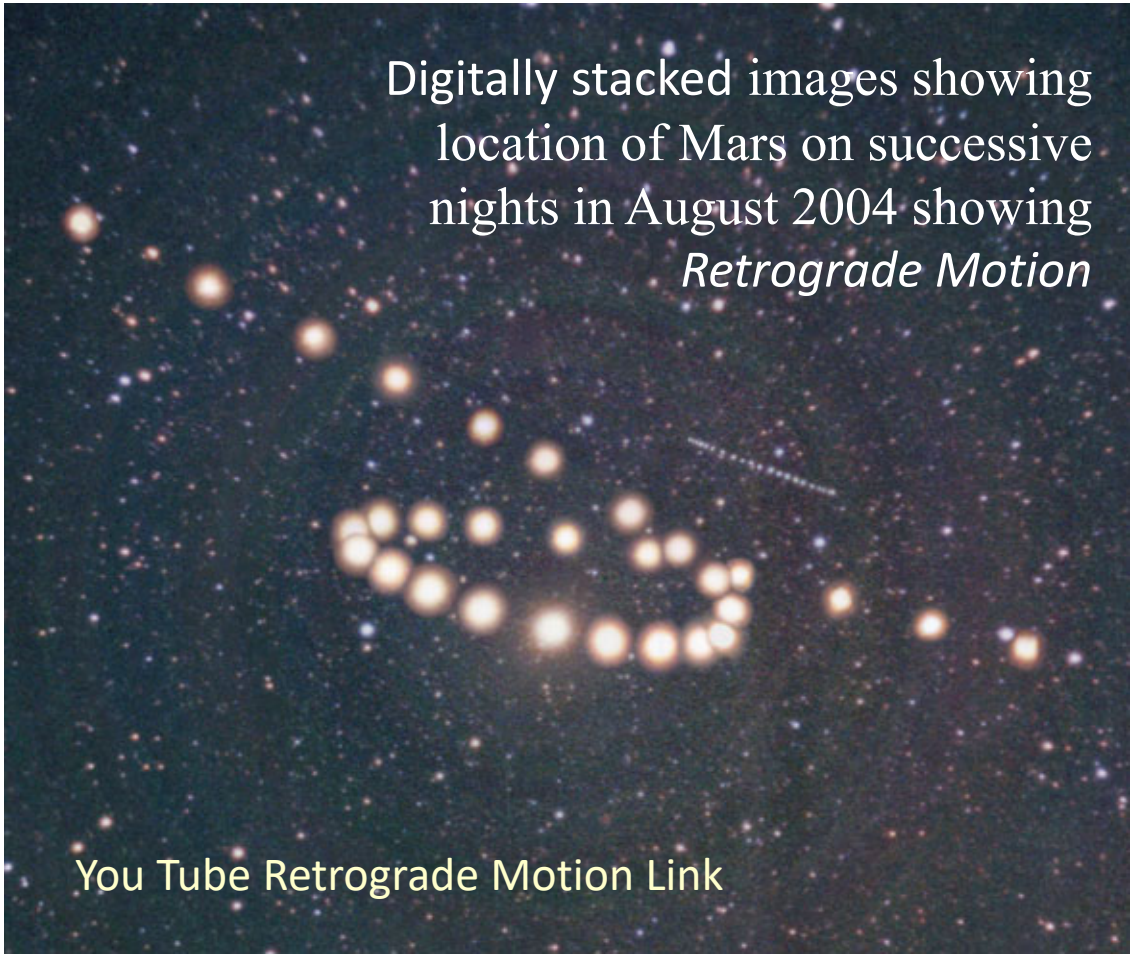
$$x = 250{,}000 \text{ stadia}$$

250,000 stadia × 0.1572 km/stadium = 39,300 km (or, 24,421 miles)

40,008 km (or, 24,865 miles)

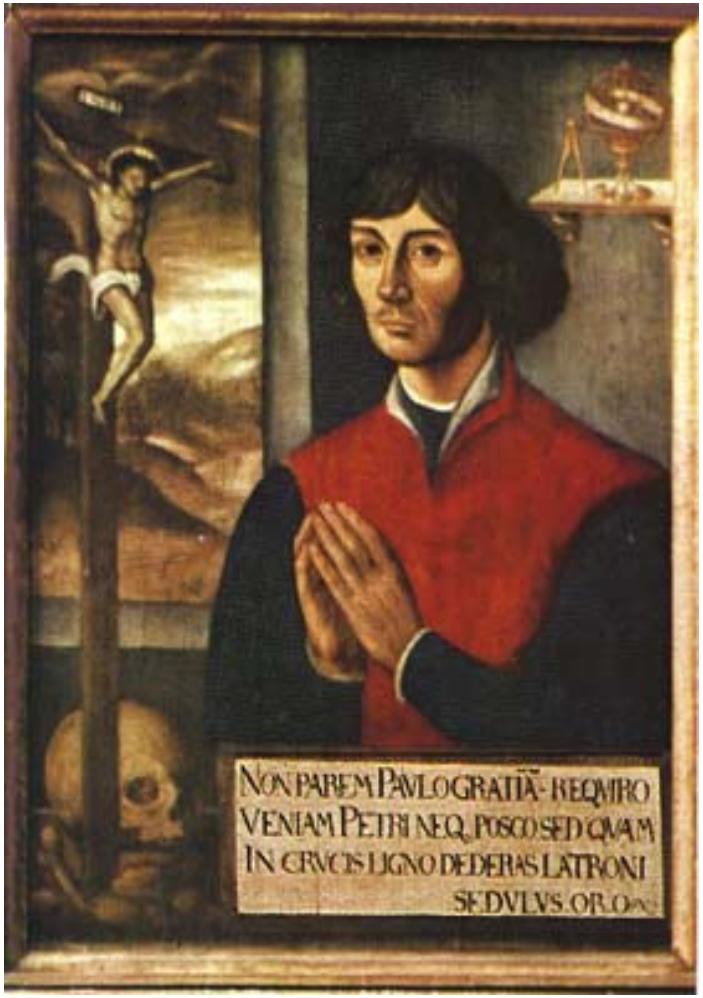
Claudius Ptolemy (87 -150 AD) - astronomer, mathematician and geographer from Alexandria, Egypt believed *geocentric* universe and *circular orbits* but couldn't explain *retrograde motion*

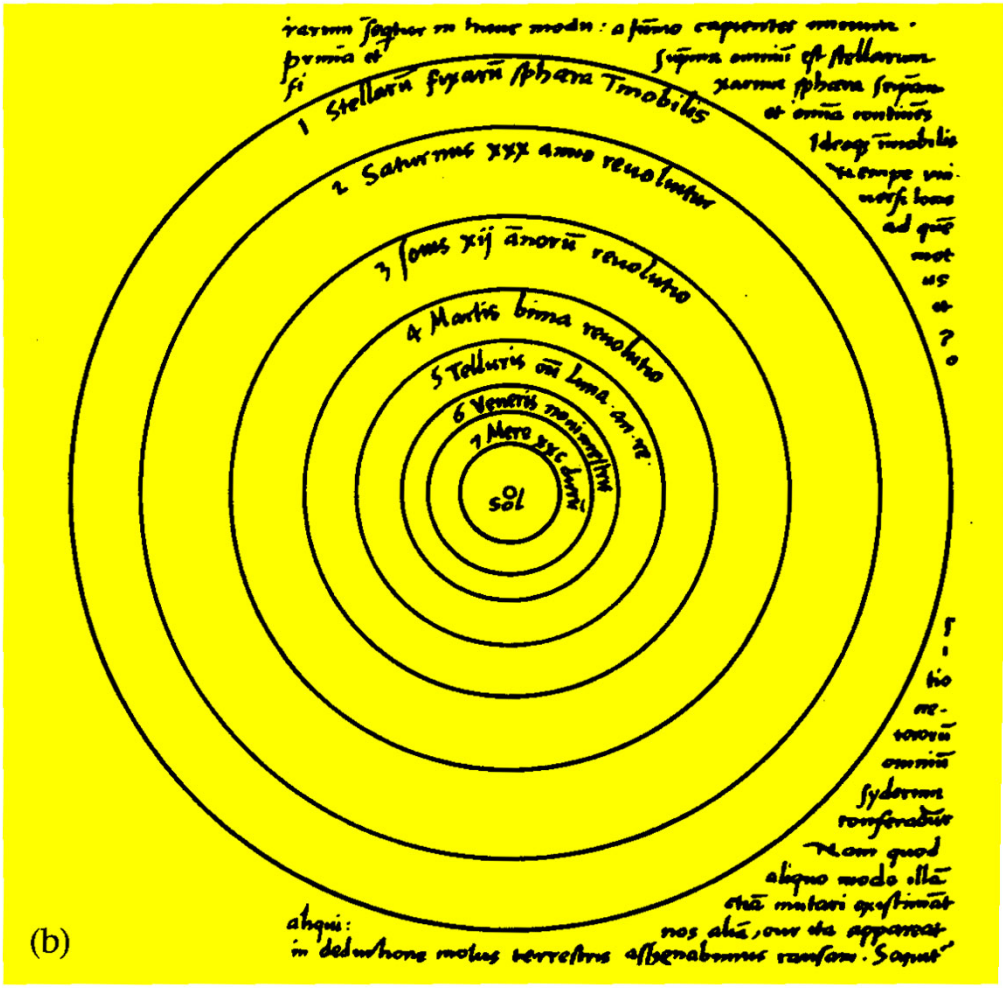
www.campus.pc.edu/faculty/rarts/courses/physics/105/notes/Topic_2_The_Motions_of_the_Planets/Ptolemys_geocentric_universe.jpg



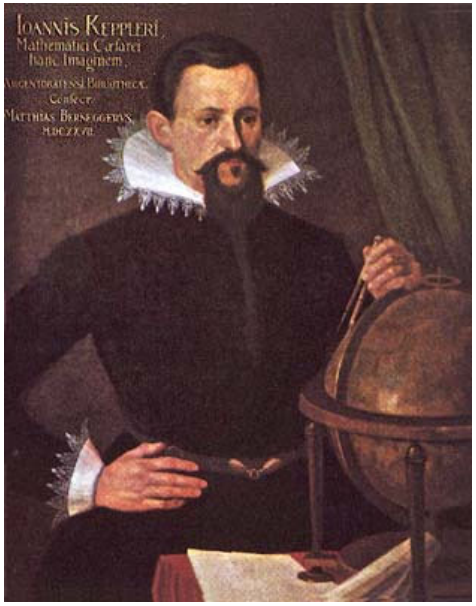
http://alpha.lasalle.edu/~smithsc/Astronomy/retrograd.html

mid 1500's - Copernicus *reintroduces H*eliocentric model of the Universe that explains retrograde motion

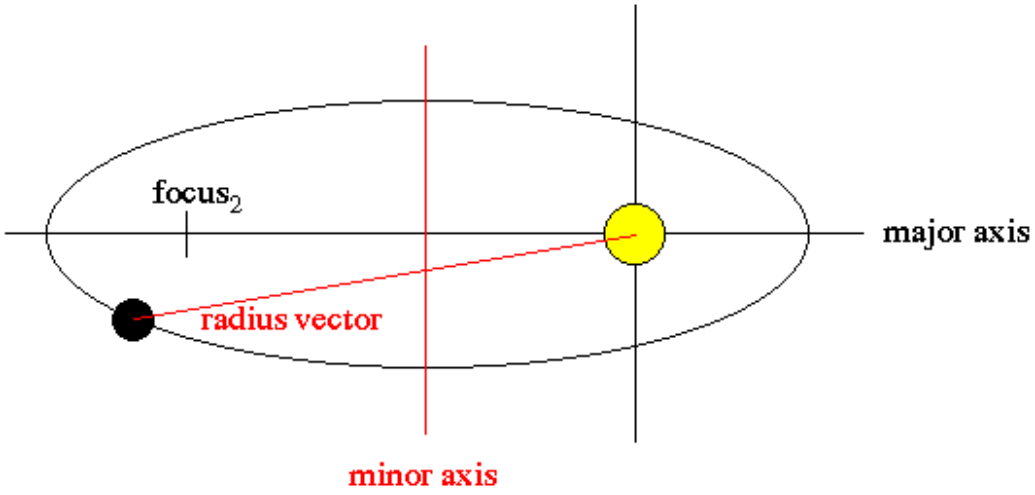




ca 1600 - Kepler shows planets have elliptical orbits, and therefore a basic premise for Ptolemy's calculations for the geocentric hypothesis was wrong



Ellipse = member of a family of mathemathical curves called conic sections



Galileo uses the newly invented telescope to establish conclusively that the planets revolve around the sun

Only 400 years later we now know that galaxies are immense systems of hundreds of billions of clustered stars and there are countless galaxies in the Universe

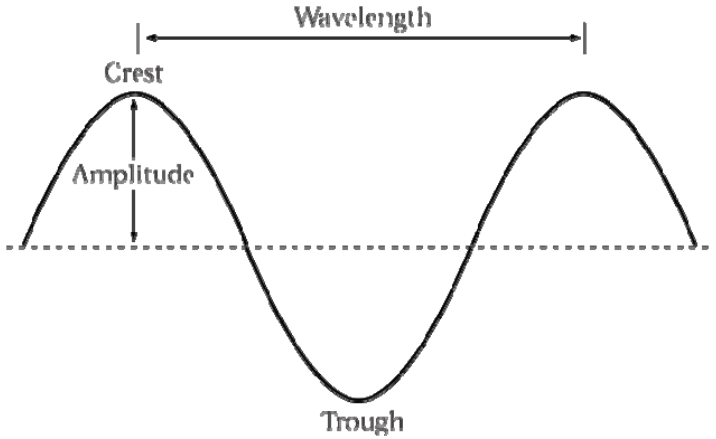
Spiral Galaxy ngc4414

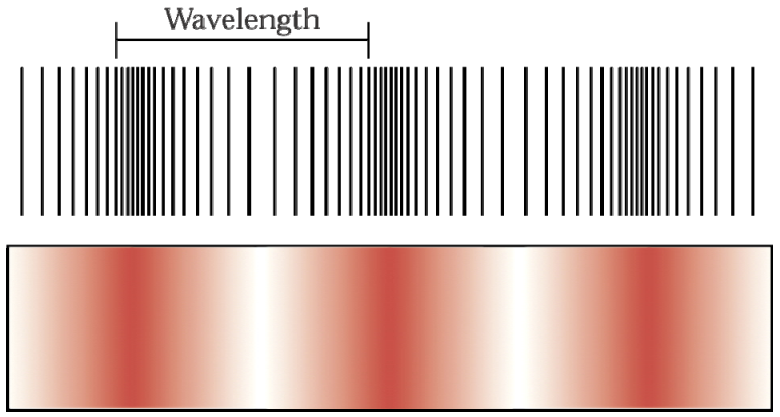
How do galaxies move in relation to each other?

- In order to understand this, we need to understand wave phenomenon and the *Doppler effect*.

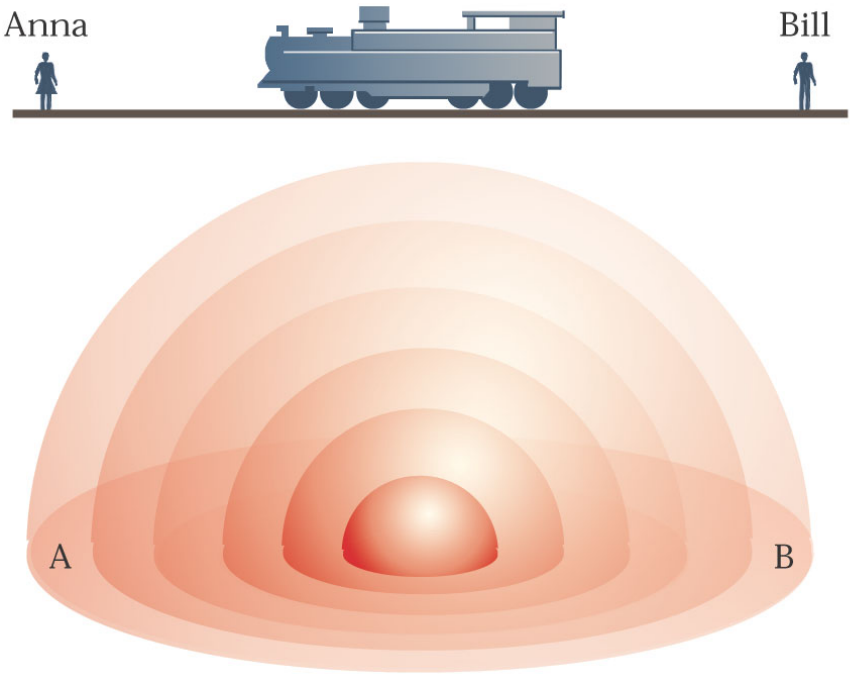
- Sounds are air vibrations having waveforms with varying wavelengths and frequencies, or the number of waves moving past a point in given time.

- Sound *pitch* is a measure of the wavelength or frequency variation as perceived by our sense of hearing.

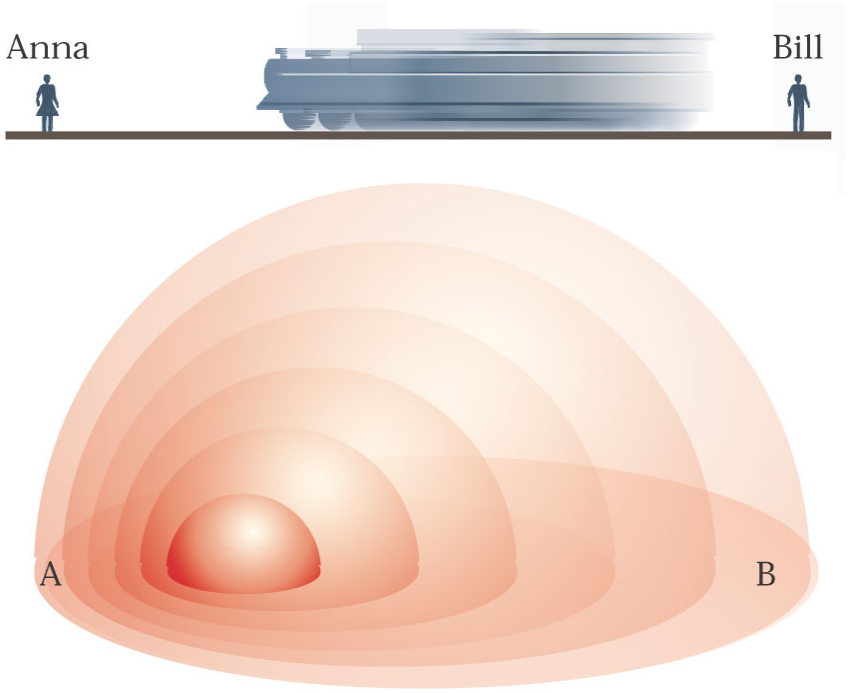




THE DOPPLER EFFECT is hearing different sound waves at different pitches caused by moving objects.

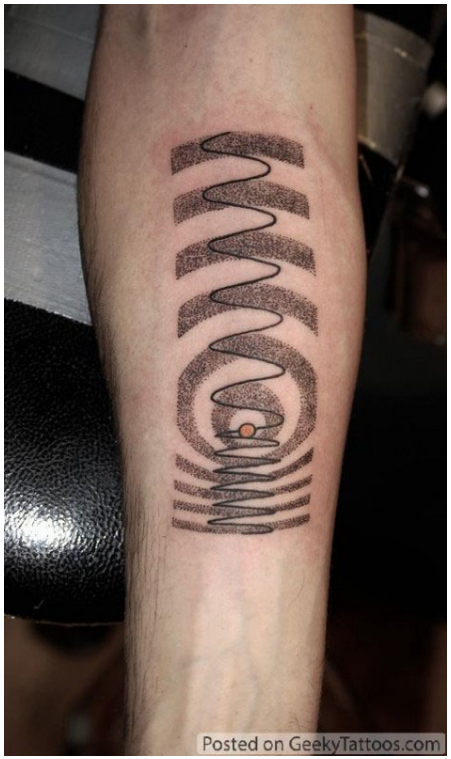


Train is stationary, both Anna and Bill hear the same pitched whistle.



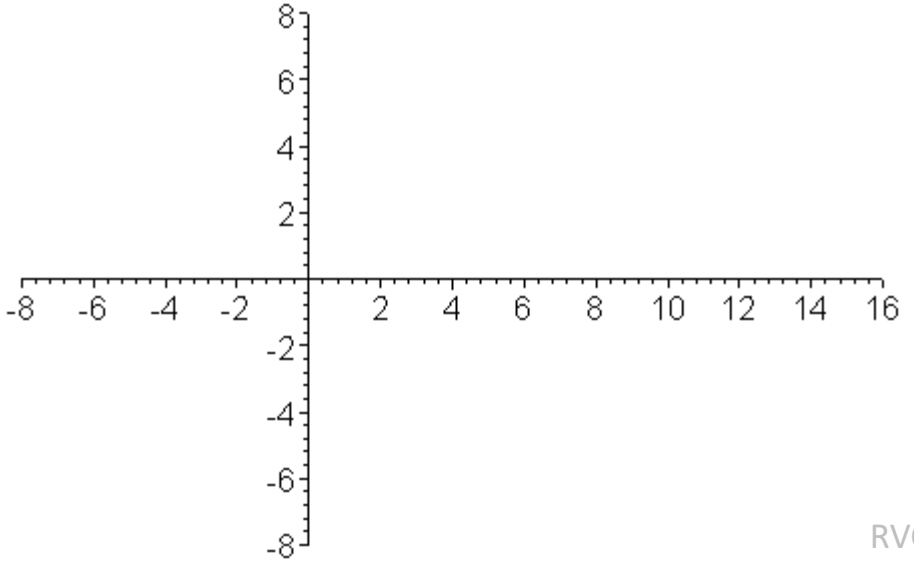
With the train moving towards Anna, the motion compresses sound waves reaching Anna who hears higher pitch versus Joe, where noise waves are stretched out and have lower pitch.

Stationary source



Moving source

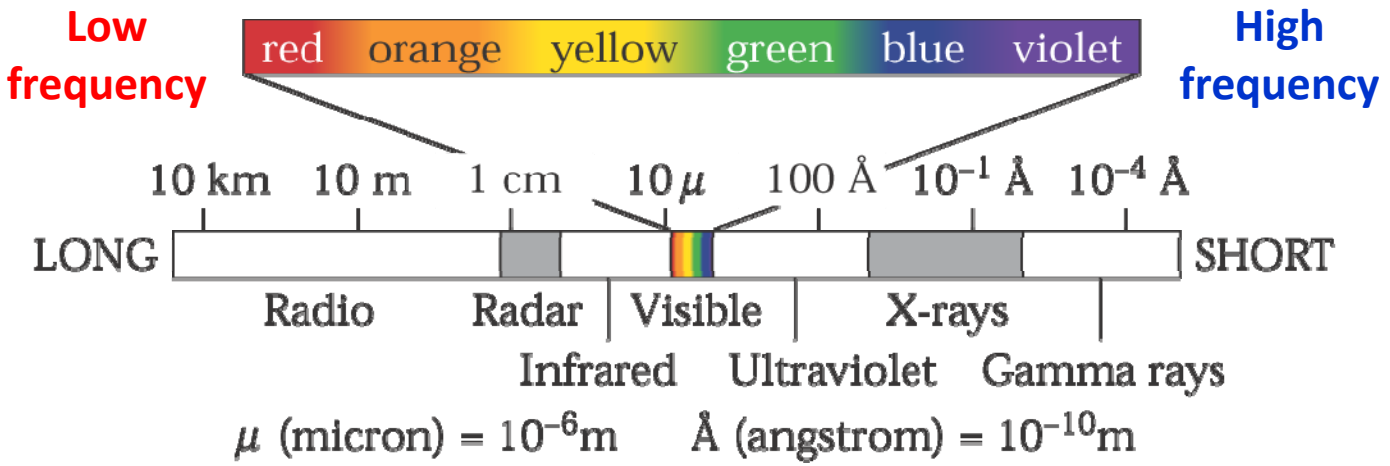
Red shift



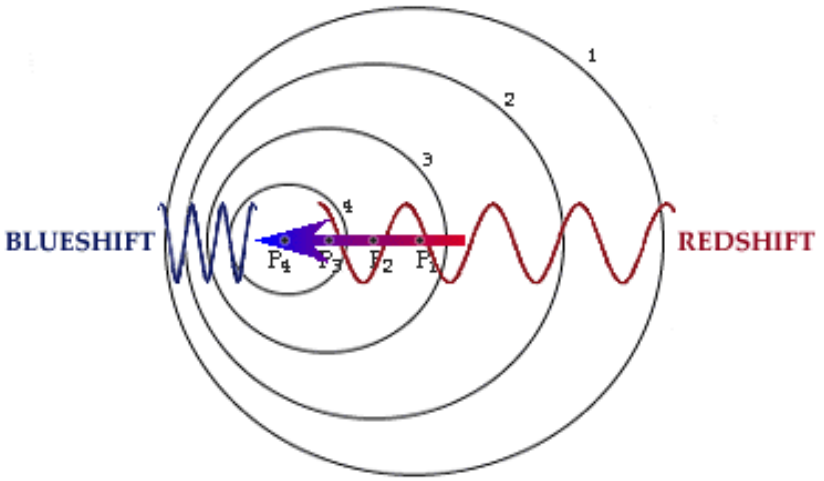
Blue shift

Light is electromagnetic radiation consisting of *photon particles moving in waves* of fixed wavelengths or frequencies.

The combination of all colors within the visible light spectrum is perceived by humans as white light

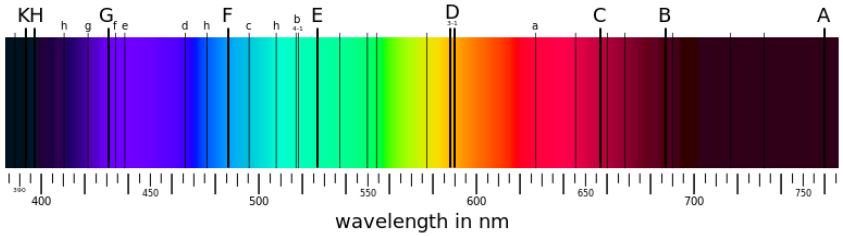


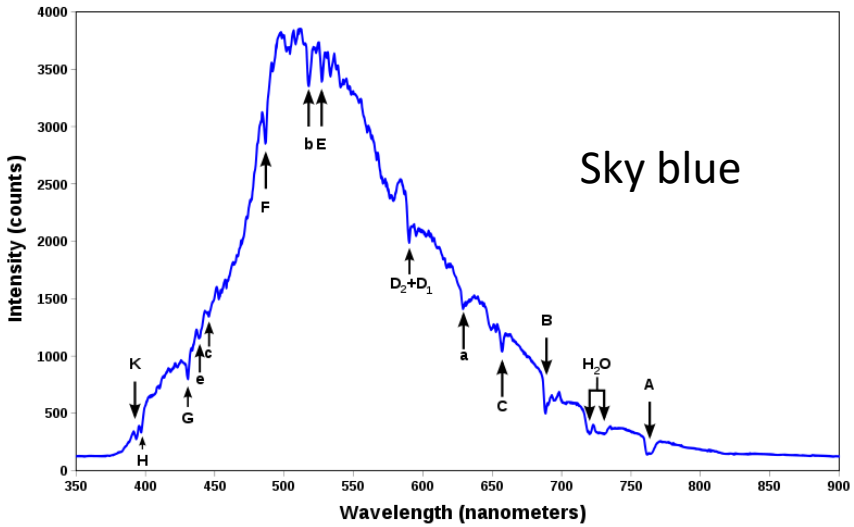
Because light, like sound moves in waves the Doppler effect also applies to starlight seen on Earth



- **1802** - English chemist William Wollaston was the first person to note the appearance of a number of dark features in the solar spectrum received at Earth's surface.

- **1814** - German physicist Joseph von Fraunhofer independently rediscovered the lines and began a systematic study measuring the wavelength of these features.





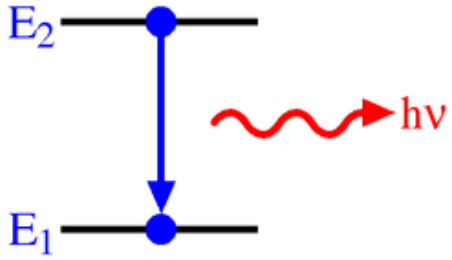
In all, he mapped over 570 lines that are referred to now as 'Fraunhofer' or 'spectral absorption lines'.

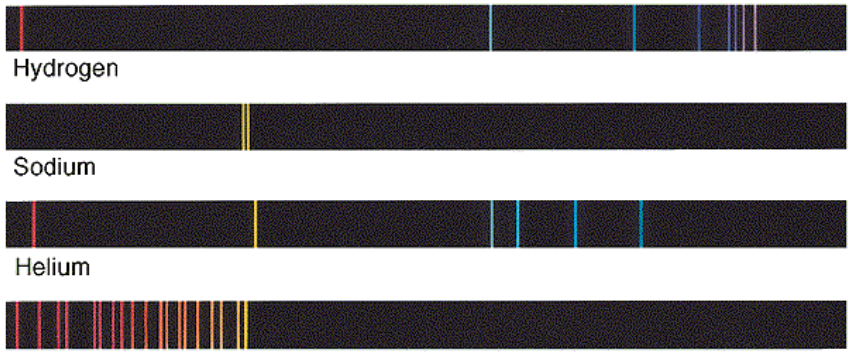
The dark lines are produced whenever a cold gas, lying between a broad spectrum photon source and the detector, absorbs and disperses certain wavelengths of the visible-light spectrum.

The lines are an indication of the elemental composition of the atmospheric gas. For Earth, this is mostly Nitrogen (N), Oxygen (O), and Argon (Ar).

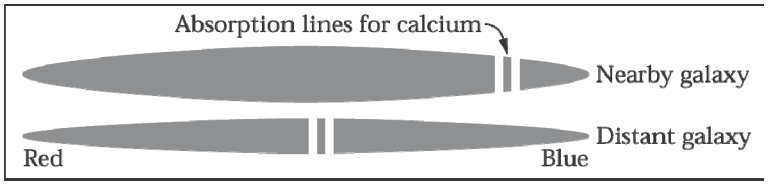
Mid 1800's - Swedish physicist **Anders Jonas Ångström** helped develop the science of *spectroscopy, the study of the interaction between matter and radiated energy.*

Emission spectroscopy is a spectroscopic technique which examines the wavelengths of photons emitted by atoms or molecules during their transition from an excited state to a lower energy state.



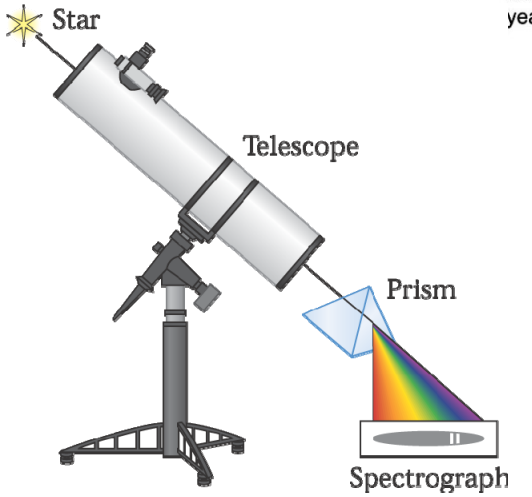


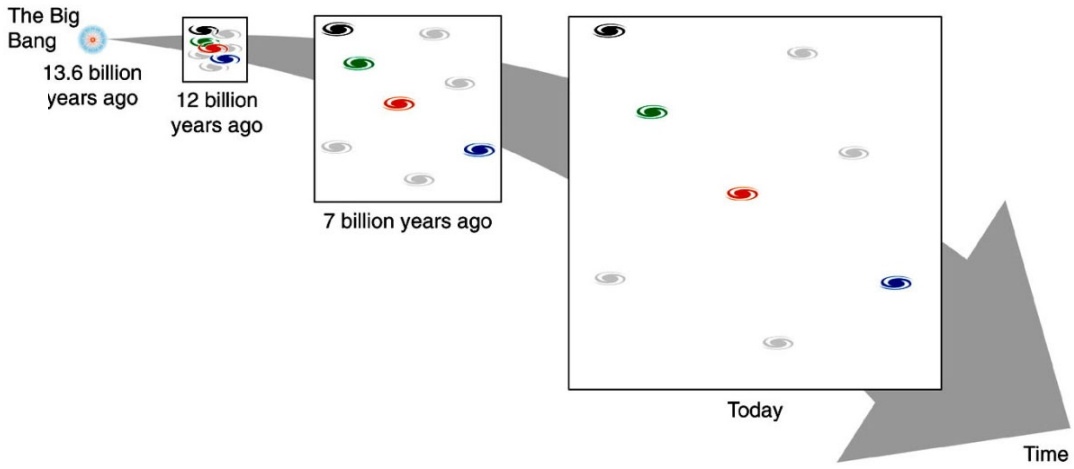
1929 - Because light is selectively absorbed and emitted, and that motion influences how light is perceived, American astronomer **Edwin Hubble** shows that absorption lines for photon sources at increasing distances outside our galaxy are consistently shifted towards RED, that is, *every photon source outside our galaxy is moving away from Earth at very high velocity*, or in other words, ***the Universe is expanding***



Big Bang proposed in the late 1920s

1990 Hubble telescope deployed

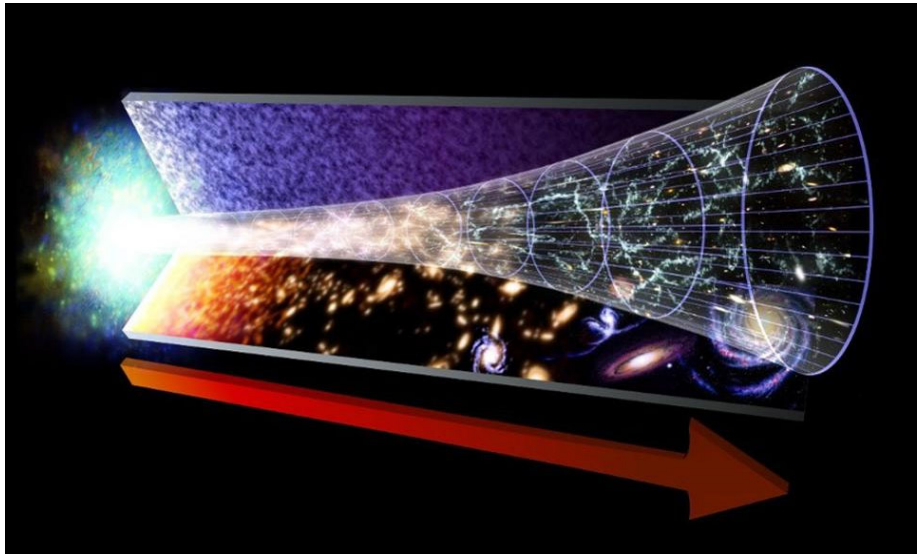




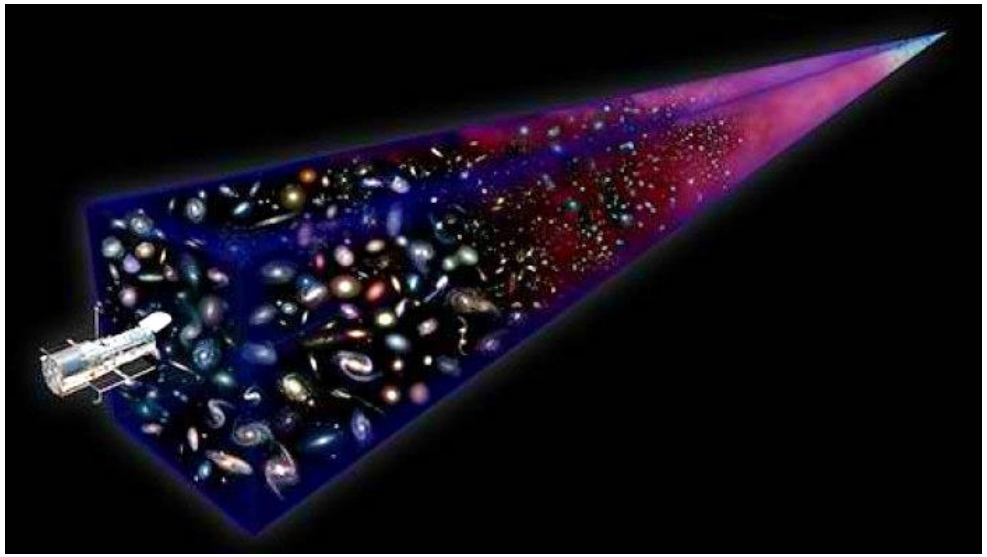
How do we know the age of the universe?

- We now know from using the Hubble telescope and similar instrumentation that the universe is expanding.

- And from measuring the relative brightness's, sizes, and distances of stars, galaxies and supernovae astrophysicists construct cosmic distance ladders.



https://www.forbes.com/sites/startswithabang/2016/04/29/how-do-we-know-the-age-of-the-universe/#74dc072c6155



https://medium.com/starts-with-a-bang/what-the-hell-are-baryon-acoustic-oscillations-cfee6d726538

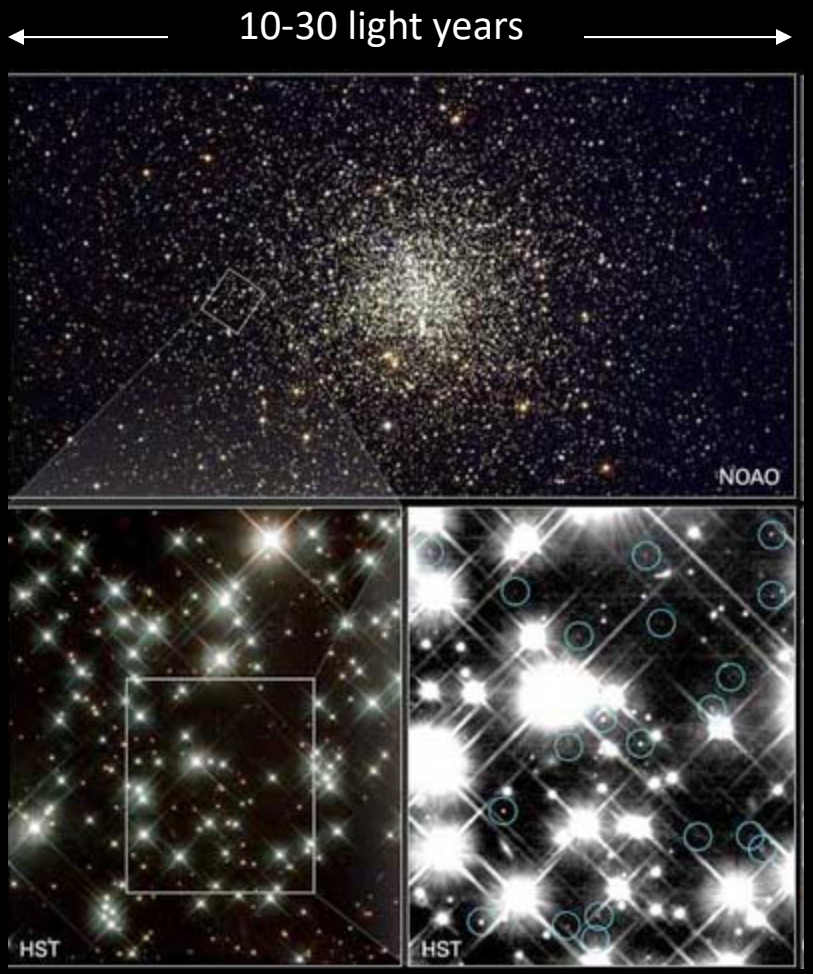
How do we know the age of the universe?

"Conceptually, the new age-dating observation is as elegantly simple as estimating how long ago a campfire was burning by measuring the temperature of the smoldering coals".

For Hubble, the "coals" are white dwarf stars, the burned out remnants of the earliest stars that formed in our galaxy. Hot, dense spheres of carbon "ash" are left behind by the long-dead star's nuclear furnace.

White dwarfs cool down at a predictable rate - the older the dwarf, the cooler it is, making it a perfect "clock" that has been ticking for almost as long as the universe has existed." www.spaceflightnow.com/news/n0204/24hubbleage/

How do we know the age of the universe?



Ancient white dwarfs in globular clusters like M4 are about 12 to 13 billion years old, after accounting for the time it took the cluster to form after the big bang.

In the top panel, a ground-based observatory snapped a panoramic view of the entire cluster, which contains several hundred thousand stars within a volume of 10 to 30 light-years across.

The Hubble telescope studied a small region of the cluster (box in top left).

A detailed view of the small region shown at bottom right is only about one light-year across.

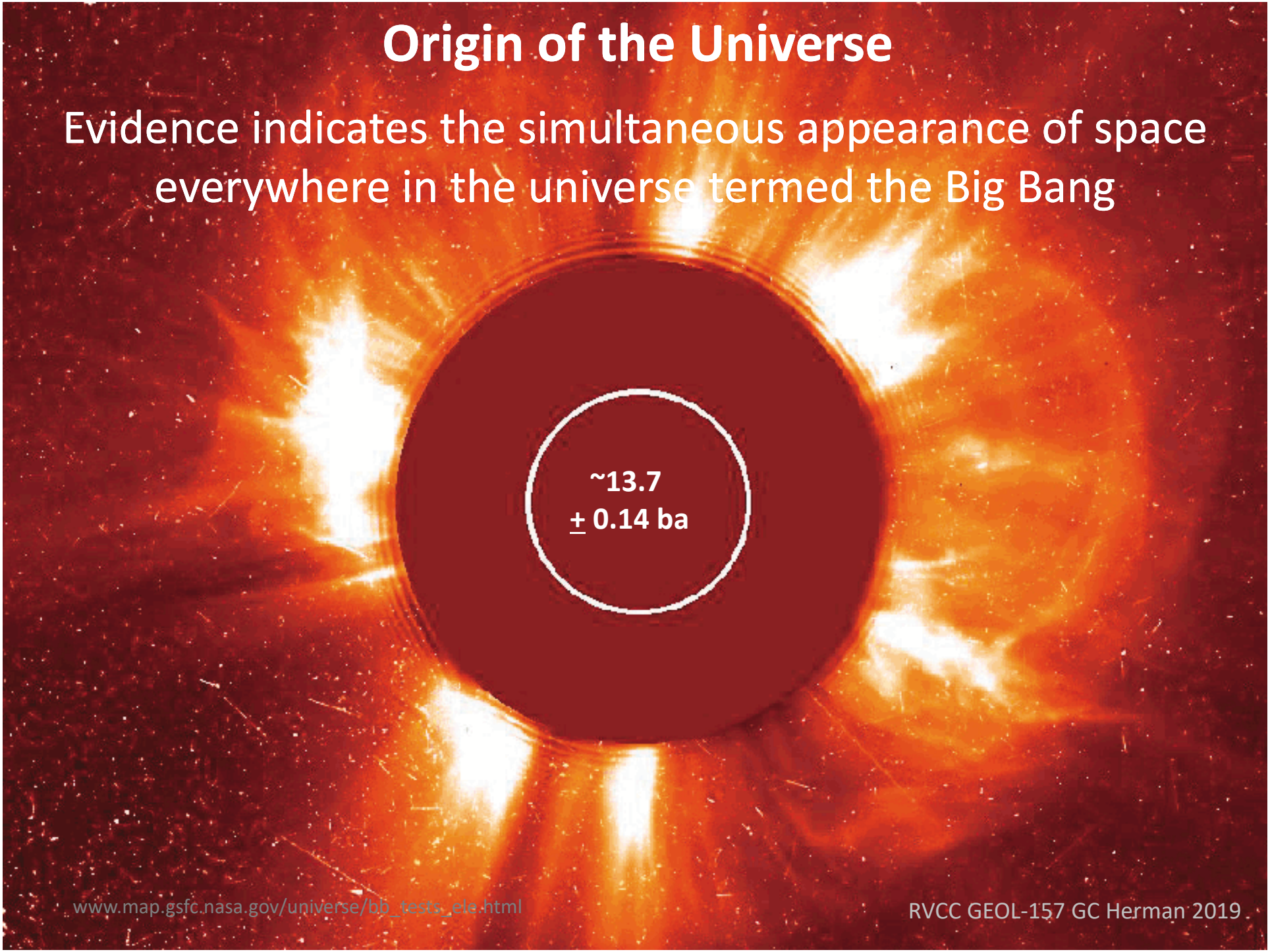
The blue circles pinpoint the faint white dwarfs seen by the Hubble telescope. It took nearly eight days of exposure time over a 67-day period to find these extremely faint stars.

www.spaceflightnow.com/news/n0204/24hubbleage/

Credit for Hubble telescope photos: NASA and H. Richer (University of British Columbia); Credit for ground-based photo: NOAO/AURA/NSF "

Origin of the Universe

Evidence indicates the simultaneous appearance of space everywhere in the universe termed the Big Bang

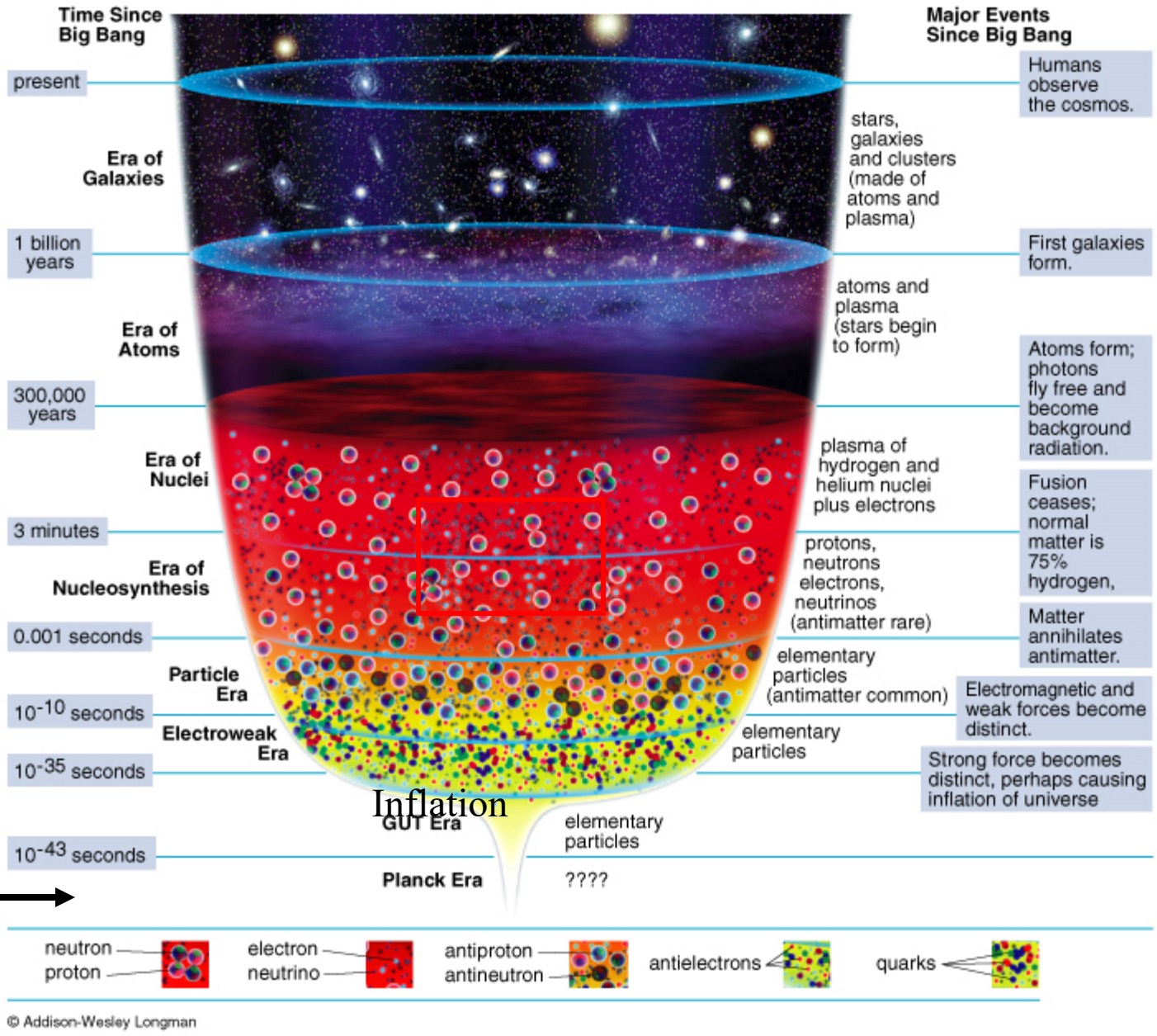


www.map.gsfc.nasa.gov/universe/bb_tests_ele.html

Modern Big Bang theory holds that space and time came into being simultaneously with matter and energy.

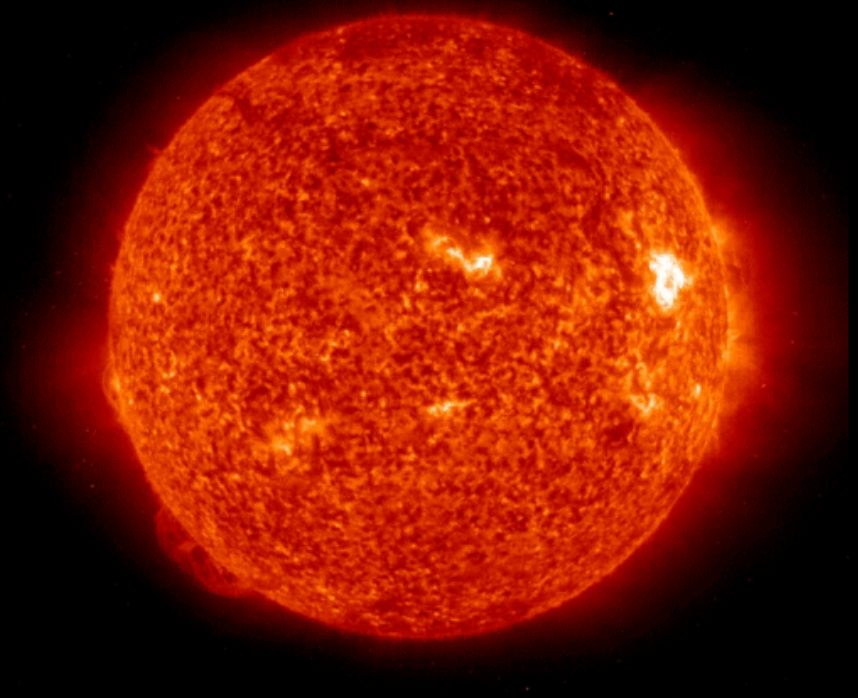
Fusion →

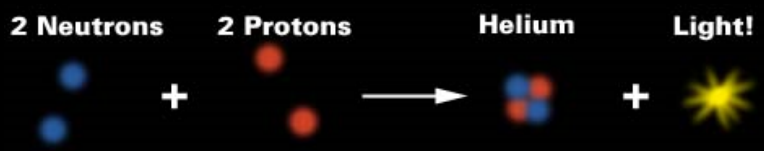
Thought to be 100 million trillion times smaller than a proton →



Gravity causes largest nebular cores to become very dense; H and He collide & **FUSE** forming more complex elements, up to Fe (#26 of 92 naturally occurring elements)

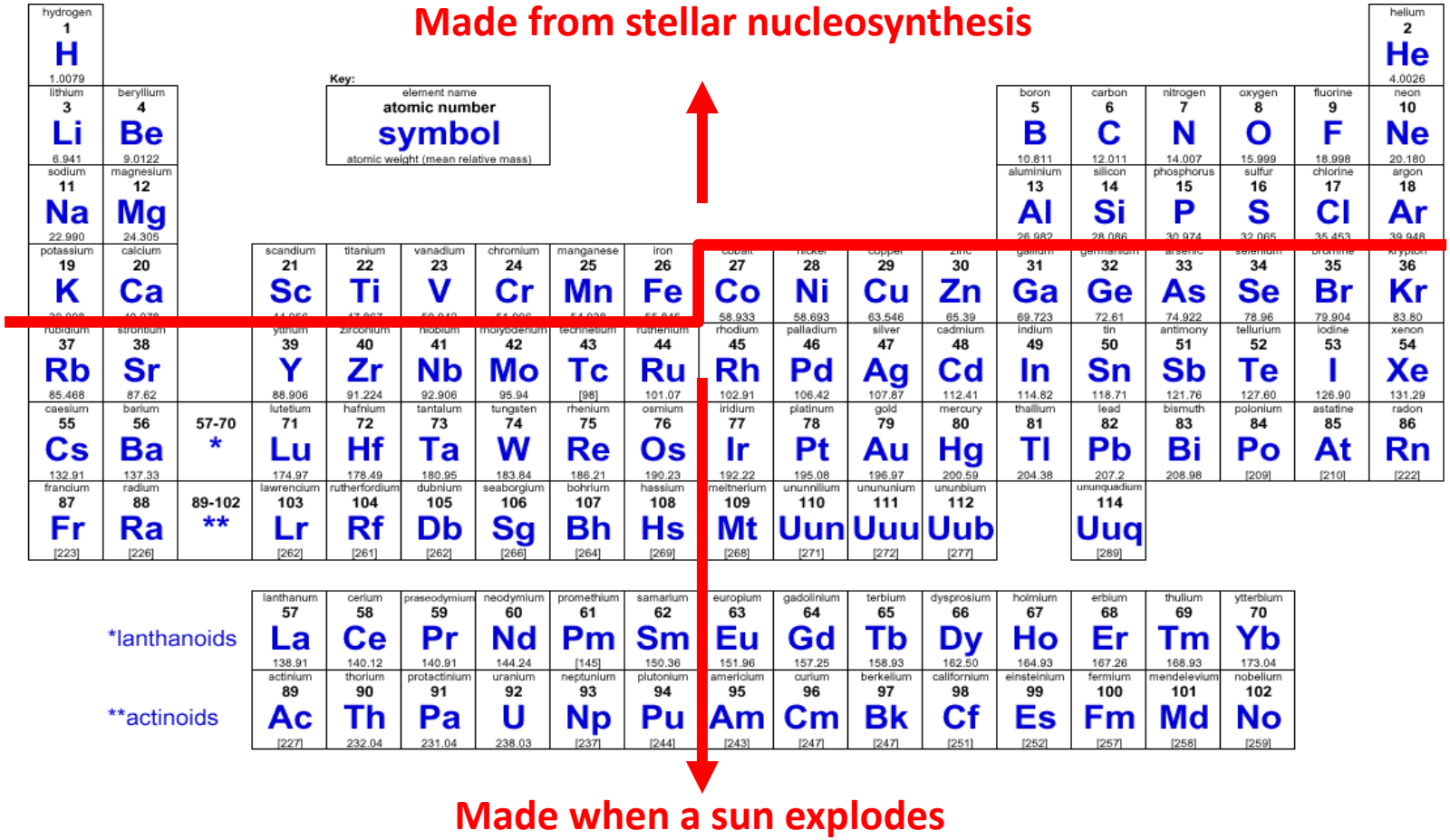
first stars formed 100's of millions of years after the Big Bang





Enormous amounts of energy are released during nuclear-fusion reactions

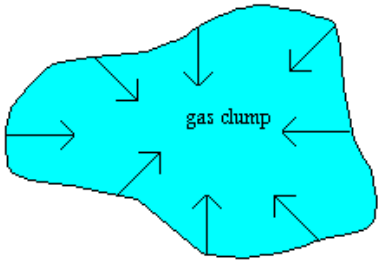
Elements number 1 (Hydrogen) to 26 (Iron) form inside stars by *fusion* during nucleosynthesis



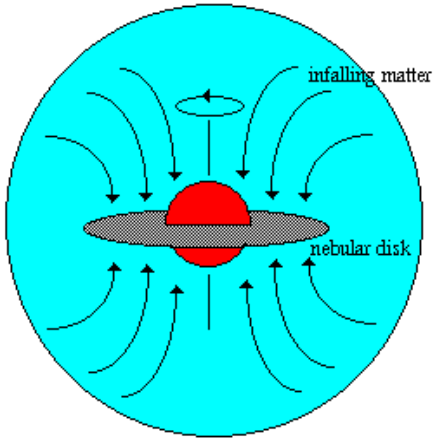
When a start's H & He fuel is used up, the star enters the **SUPERNOVA** stage when they expand, explode and scatter mass into space and forming elements 27 (Cobalt) to 92 (Uranium) in the process

NEBULAR CLOUDS AND PROTOSTAR FORMATION

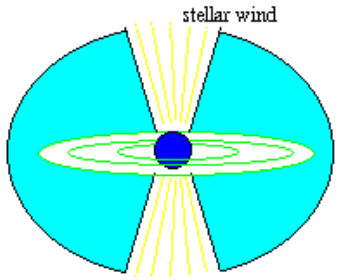
abyss.uoregon.edu/~js/ast122/lectures/lec13.html



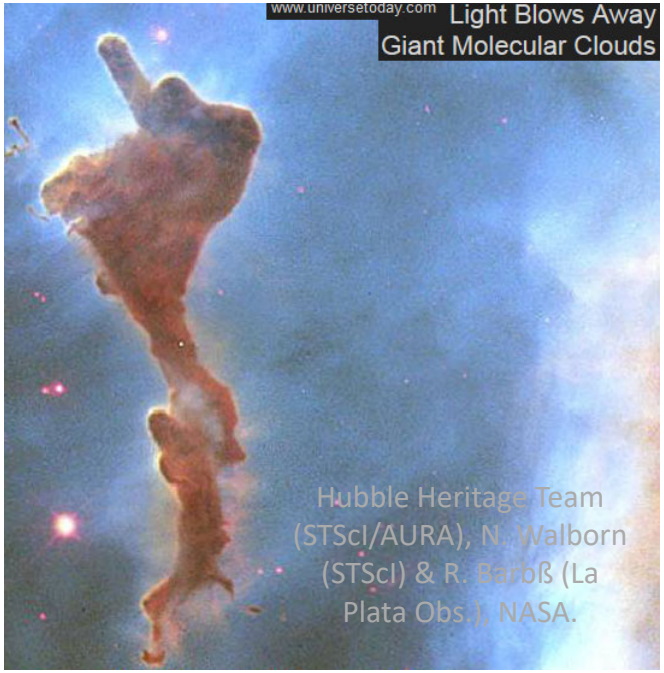
A dense gas clump breaks off from molecular cloud and collapses Angular momentum turns the irregular clump into a rotating disk



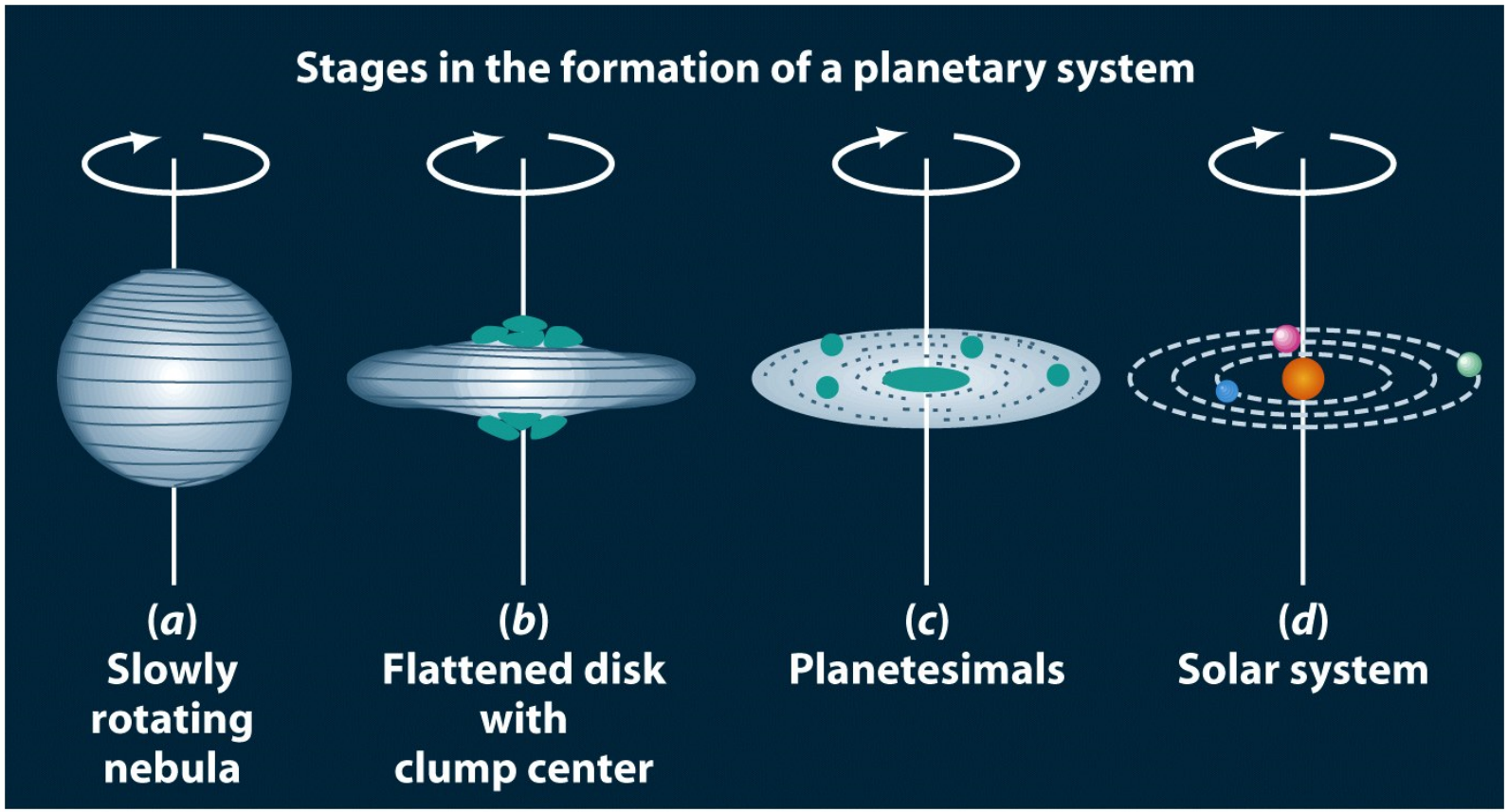
The central region is denser and forms into a protostar, the nebular disk forms slower to become a planetary system. Infalling matter increases the size of the protostar by a factor of 100



Infall is stopped when the protostar begins thermonuclear fusion and produces a strong stellar wind



This cloud of gas and dust is being deleted. Likely, within a few million years, the intense light from bright stars will have boiled it away completely. The cloud has broken off of part of the Carina Nebula, a star forming region about 8000 light years away.



Gas-rich disks surround stars between 1 and 3 million years old (Ma).

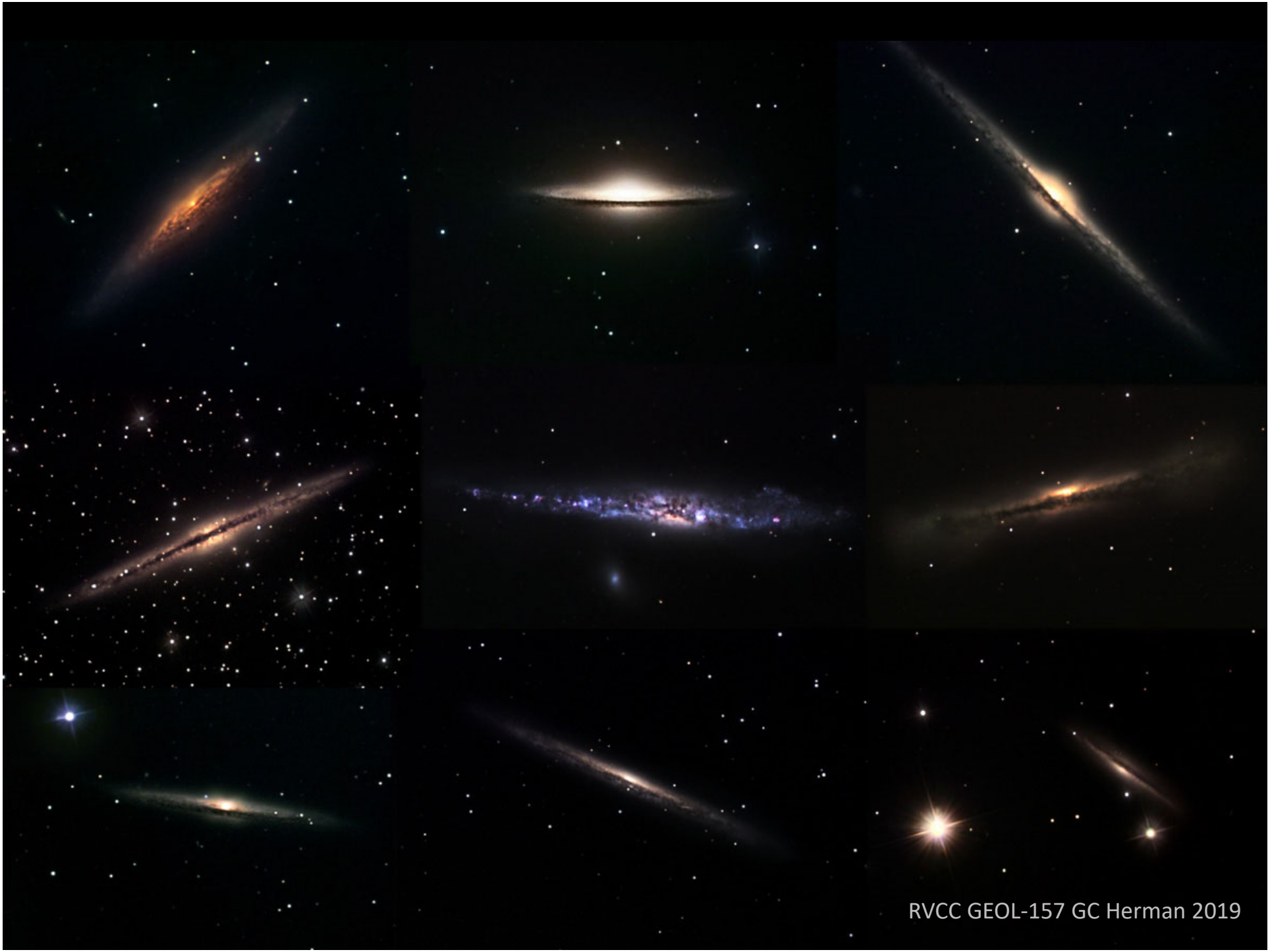
Stars older than 10 million years have gas-poor disks,
the gas having been blown away by solar wind during fusion from the star.

Therefore planet formation occurs within 10 myr.

Nebular hypothesis: formation of our solar system

A 2nd- or 3rd-generation nebula formed from ~80% H, 15% He, and 5% heavier elements produced by fusion reactions in stars and supernovae explosion.

The nebula condensed into a swirling, *accretionary disk*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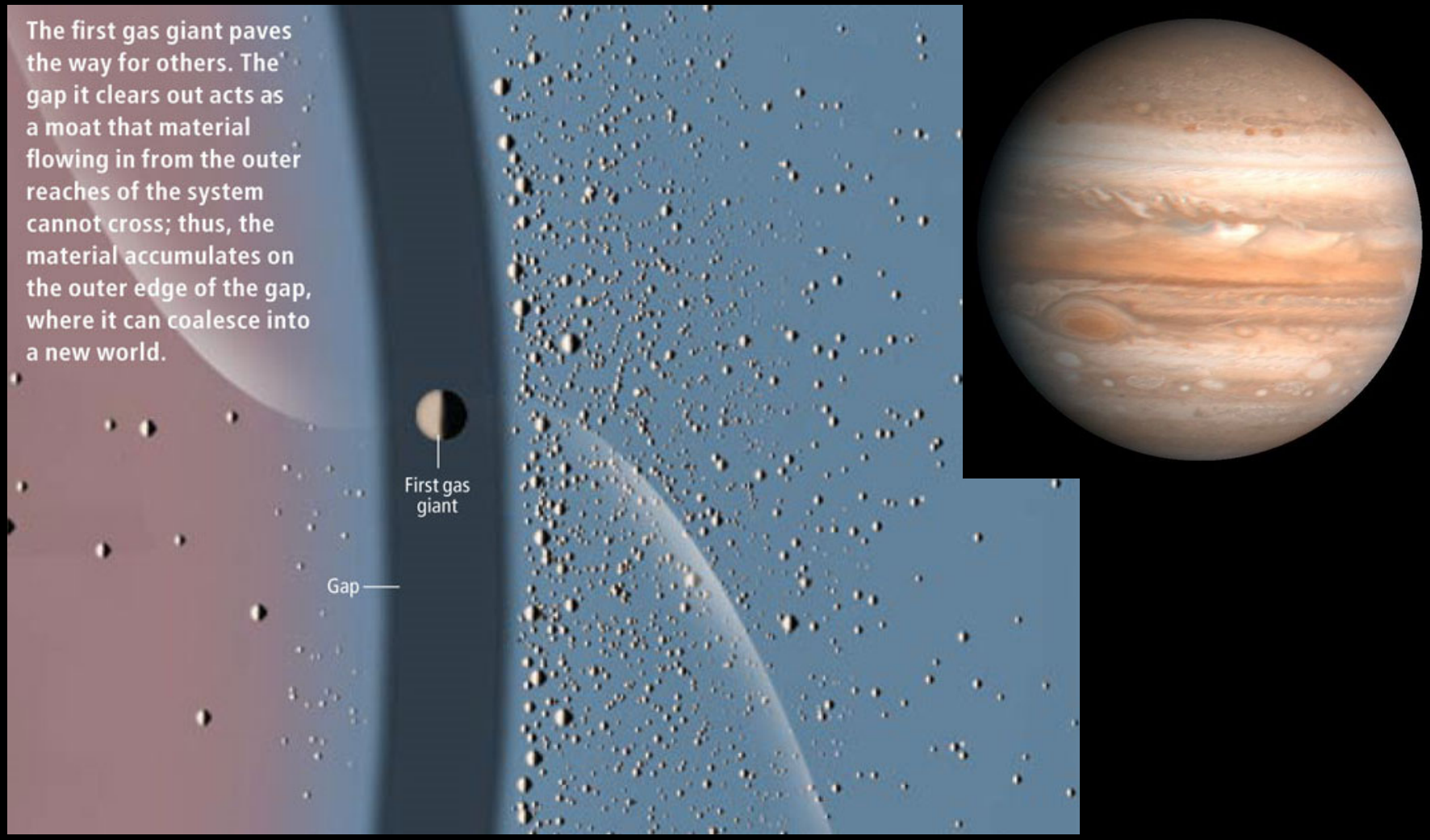
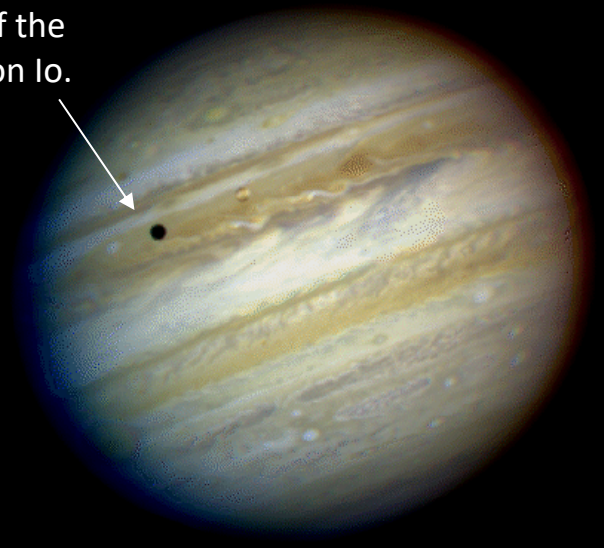
Enlarging the family through accretion

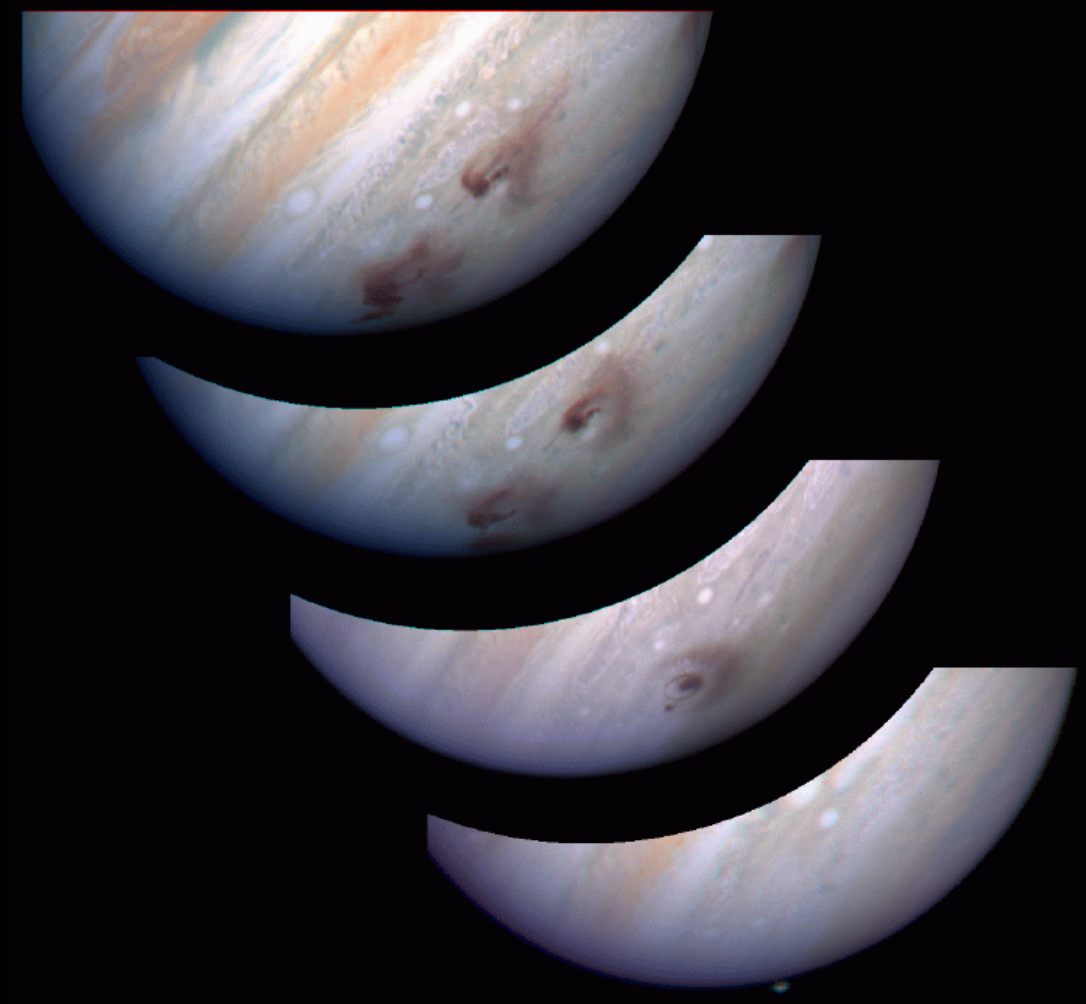


Comet P/Shoemaker-Levy 9 impacts Jupiter in 1994

The dark spot on the disk of Jupiter is the shadow of the inner moon Io.



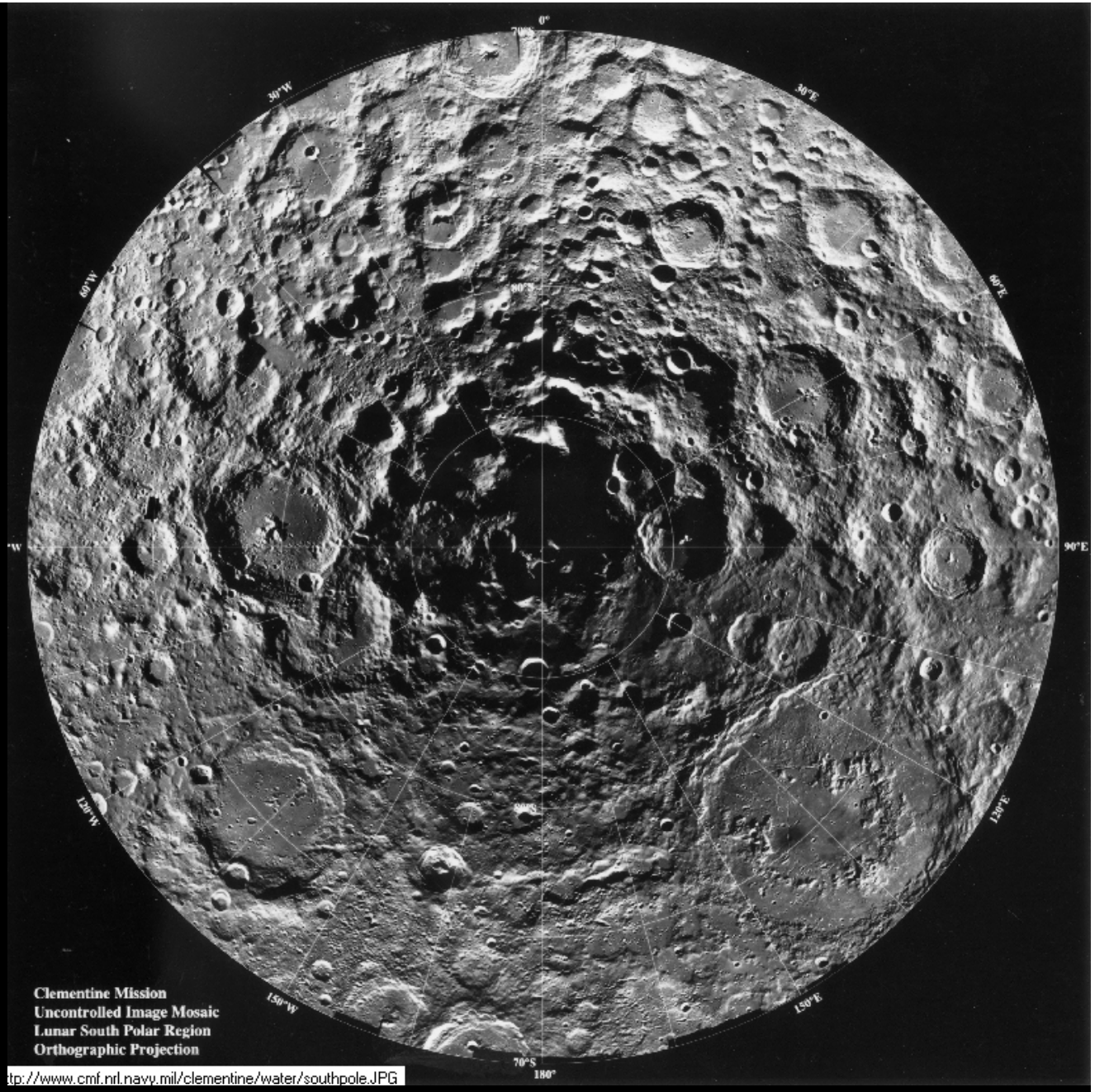
When the comet was observed on May 17, its train of 21 icy fragments stretched across 1.1 million km of space, or 3 times the distance between Earth and the Moon.



images showing evolution the impact sites

The Moon shows numerous impacts,

Especially on the southern hemisphere



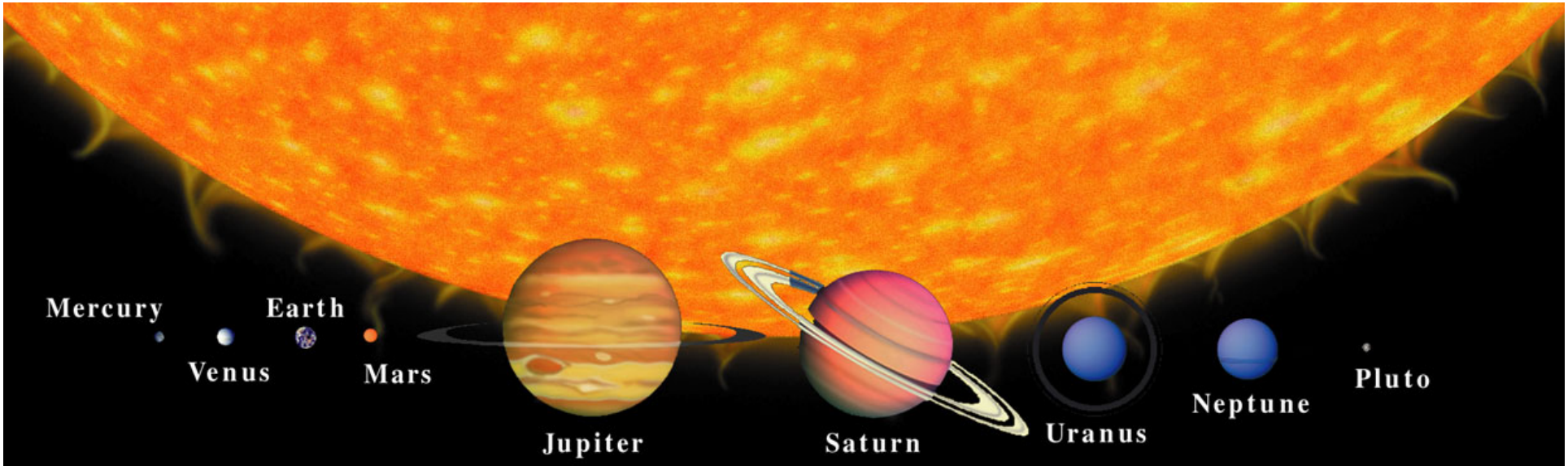
What is a planet?

The 2006 redefinition of planet by the International Astronomical Union (IAU) states that, in the solar system, a planet is a celestial body that:

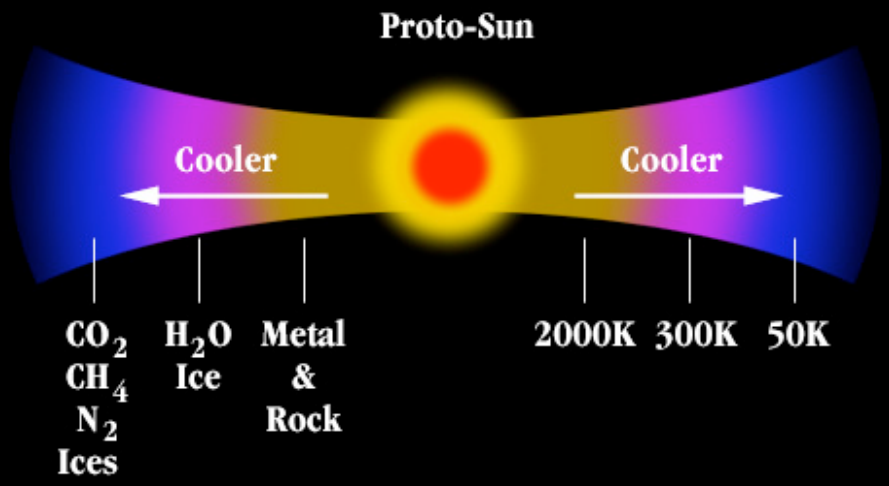
Orbits around the Sun, has sufficient mass to assume a nearly round shape (hydrostatic equilibrium), and has "cleared the neighborhood" around its orbit.

A non-satellite body meeting only the first two criteria is classified as a "dwarf planet“

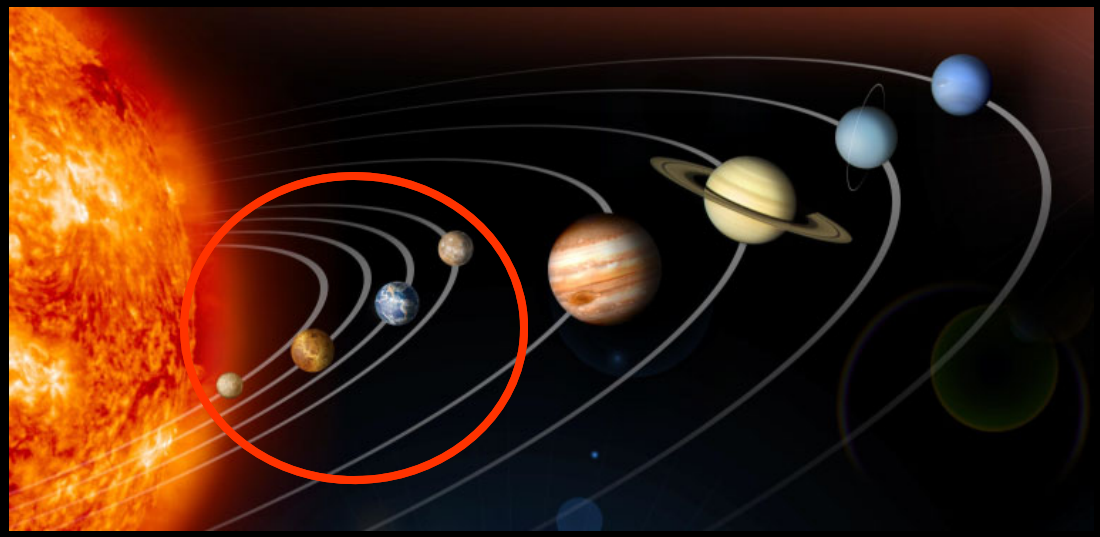
A non-satellite body meeting only the first criterion is a "small solar system body" (SSSB). The redefinition has been criticized and remains controversial.



Relative size of planets



Terrestrial Planets



Mercury
88-day orbit

4879 km, core 75%
H and He atmosphere
427°C to -170°C

Venus
225 days

12,104 km, core 25-50%
CO_2, N, and H_2O
127°C to -170°C

Earth
365 days

12,756 km, core 55%
N, O, and Ar
average 8°C

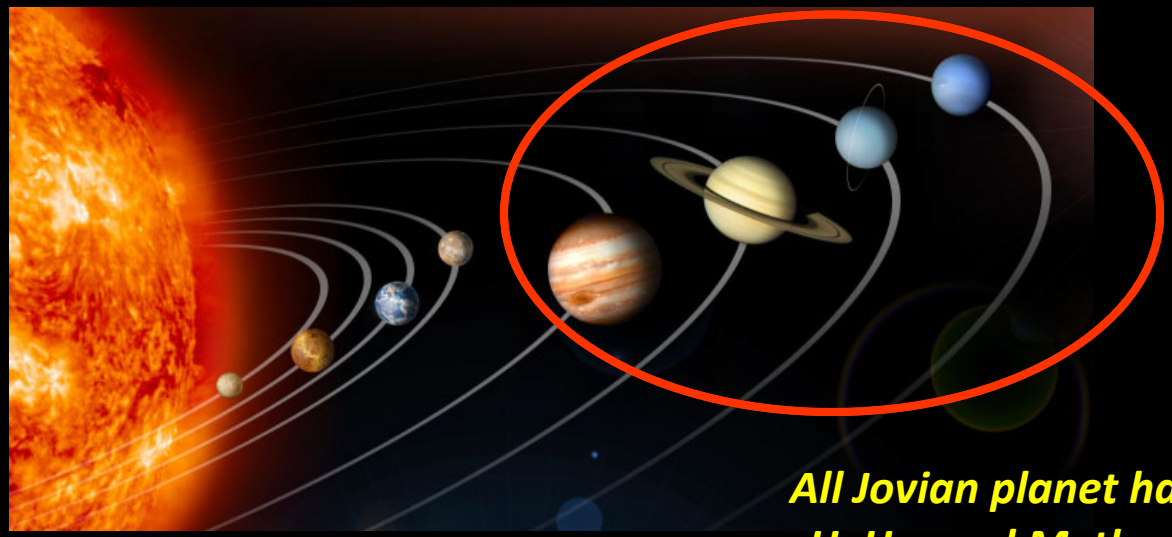
Mars
687 days

2 moons

12,756 km, core 50%
CO_2 , N, and Ar
average 8°C

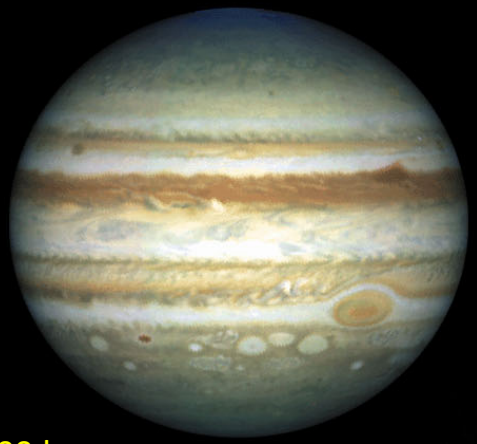
http://sse.jpl.nasa.gov/planets/profile.cfm?Object=Mercury&Display=Overview

Gas Giants or Jovian Planets



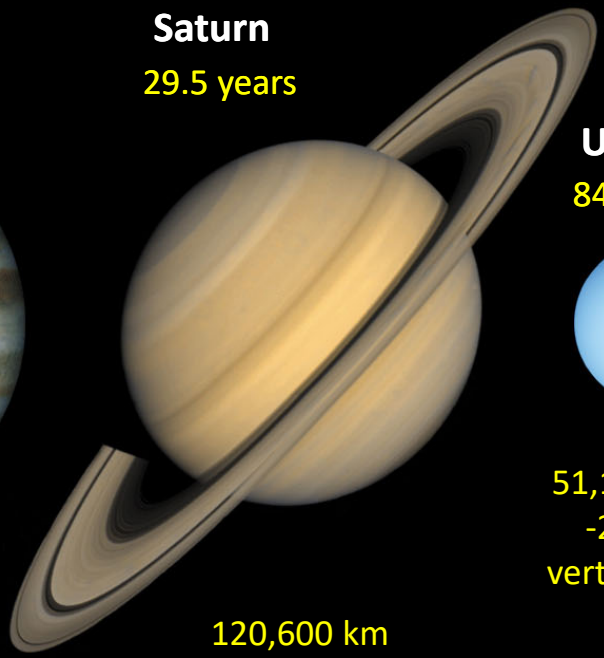
All Jovian planet have H, He, and Methane atmospheres

Jupiter
11.9 years



142,800 km
-153°C
18 satellites

Saturn
29.5 years



120,600 km
-185°C
18 satellites

Uranus
84 years

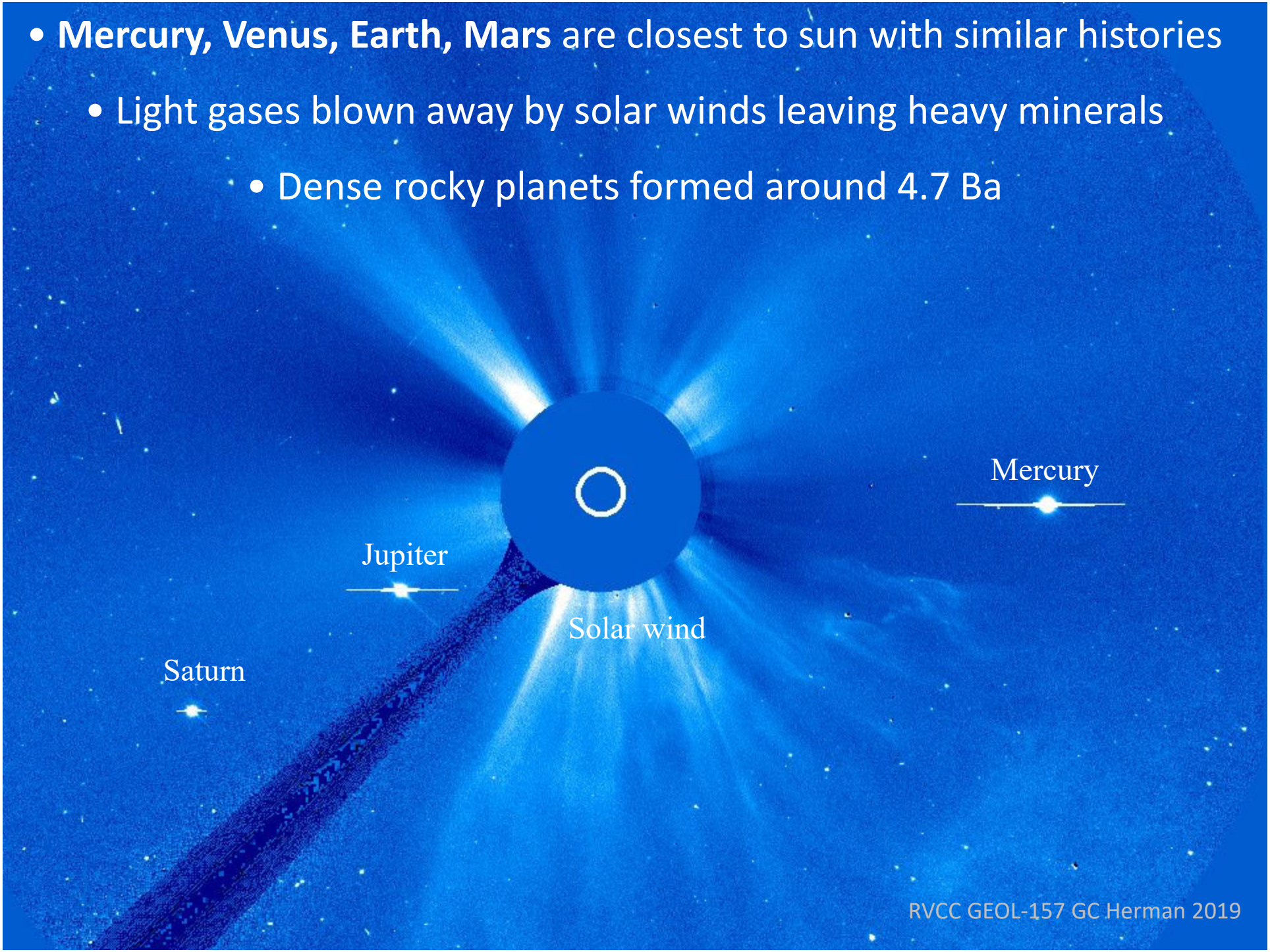
51,118 km,
-214°C
vertical ring

Neptune
165 years

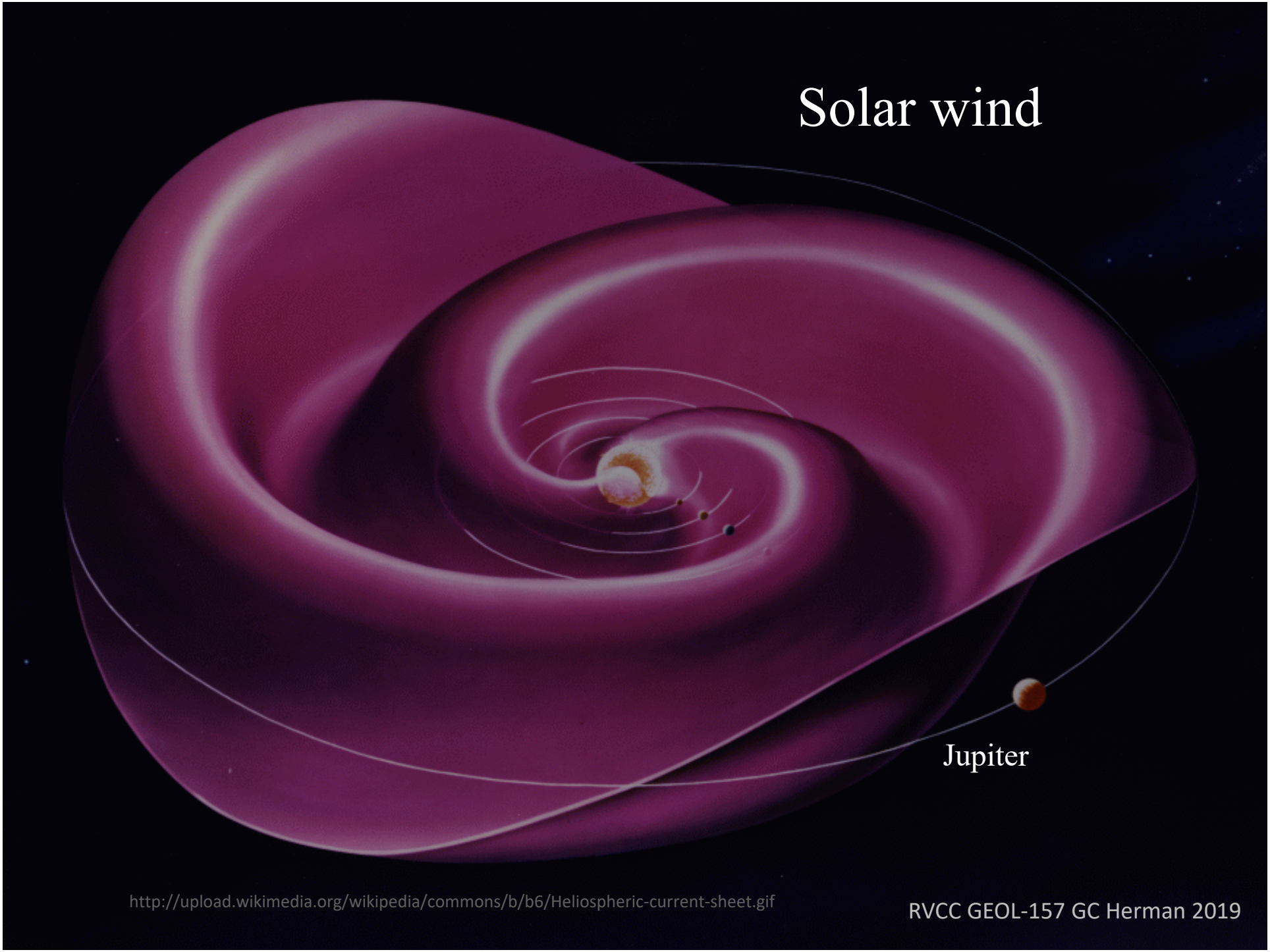
49,528 km
-225°C
narrow rings

http://photojournal.jpl.nasa.gov/catalog/PIA05389

- **Mercury, Venus, Earth, Mars** are closest to sun with similar histories
  - Light gases blown away by solar winds leaving heavy minerals
    - Dense rocky planets formed around 4.7 Ba

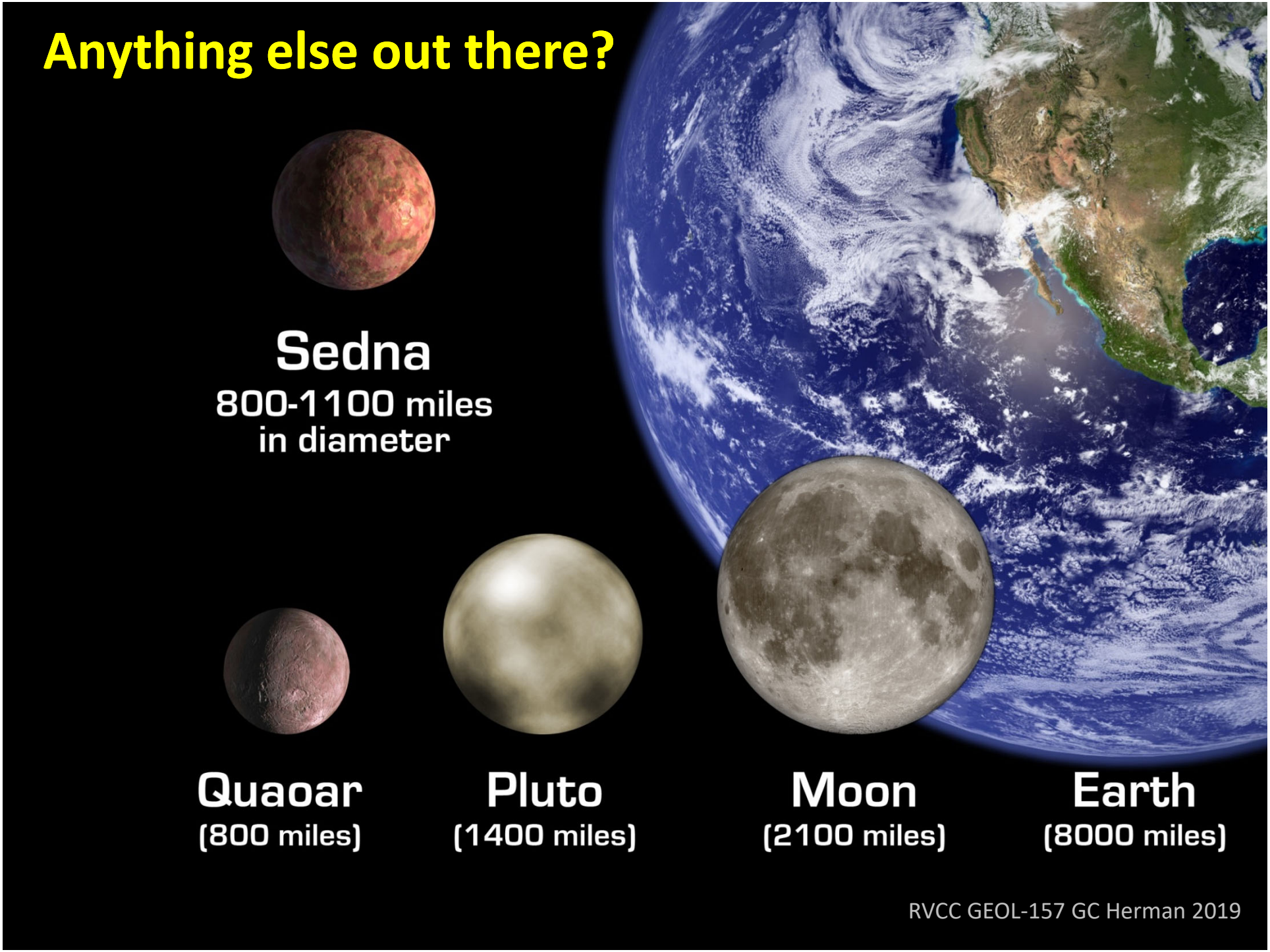


Solar wind



http://upload.wikimedia.org/wikipedia/commons/b/b6/Heliospheric-current-sheet.gif

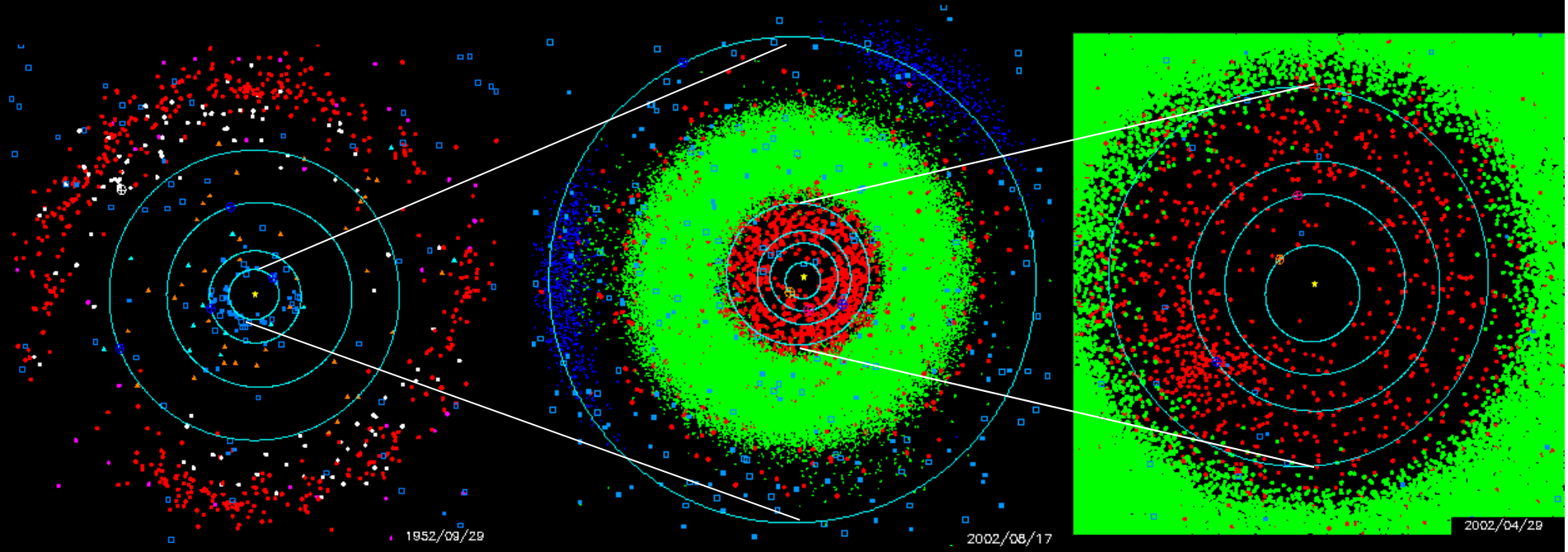
Anything else out there?



Outer solar system

Middle solar system

Inner solar system



Objects in the outer solar system, beyond the orbit of Jupiter. The orbits of Jupiter, Saturn, Uranus and Neptune are shown.

Centaurs as orange triangles, Plutinos as white circles, TNOs as red circles and Scattered-Disk Objects as magenta circles.

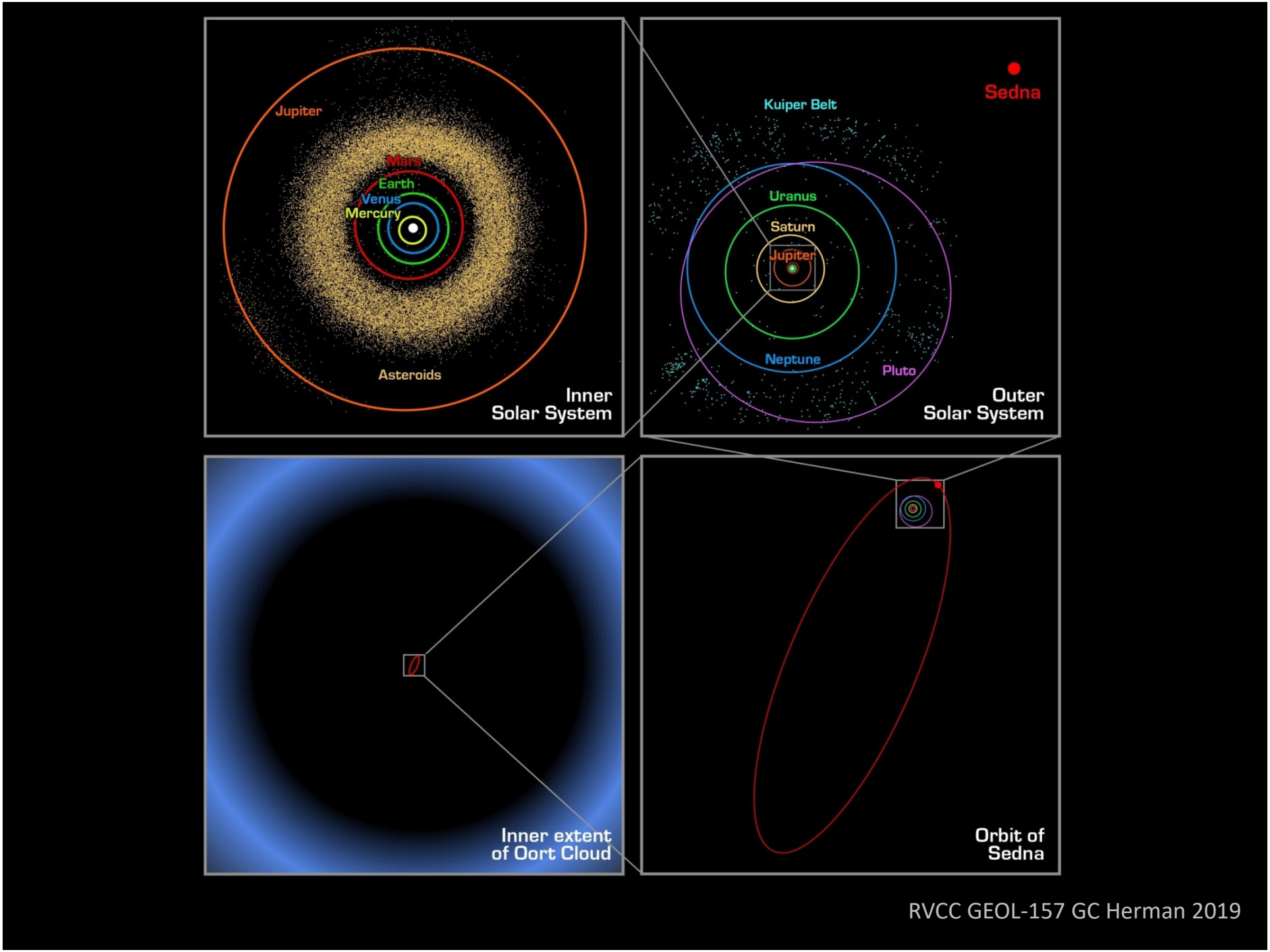
Jupiter's orbit is the outer, light-blue circle. The Jupiter Trojans, which orbit in the same orbit as Jupiter are colored blue.

This shows more than 100000 objects tracked by the Minor Planet Center.

Orbits of Mercury, Venus, Earth and Mars are shown in light blue Main-belt minor planets are shown as green circles

Near-Earth asteroids as red circles.

www.minorplanetcenter.net/iau/Animations/Animations.html



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In astrobiology, the Goldilocks zone refers to the habitable zone around a star for life that we know.

Planet	Diameter km	Distance from the sun 10^6 km	Surface temperature °C	Density g/cm^3	Main atmosphere gases
Sun	**1,392,000**		**5,800**		
Mercury	**4,880**	**58**	**260**	**5.4**	
Venus	**12,112**	**108**	**480**	**5.3**	**CO_2**
Earth	**12,742**	**150**	**15**	**5.5**	**N_2, O_2**
Mars	**6,800**	**228**	**-60**	**3.9**	**CO_2**
Jupiter	**143,000**	**778**	**-110**	**1.3**	**H_2, He**
Saturn	**121,000**	**1,427**	**-190**	**0.7**	**H_2, He**
Uranus	**52,800**	**2,869**	**-215**	**1.3**	**H_2, CH_4**
Neptune	**49,000**	**4,498**	**-225**	**1.7**	**H_2, CH_4**
Pluto	**3,100**	**5,900**	**-235**	**?**	**CH_4**

"Not too close to the Sun and not too far away to rule out life"

How do we know about the material in space?

- Meteors – boulder to sand-size solar-system particles and debris

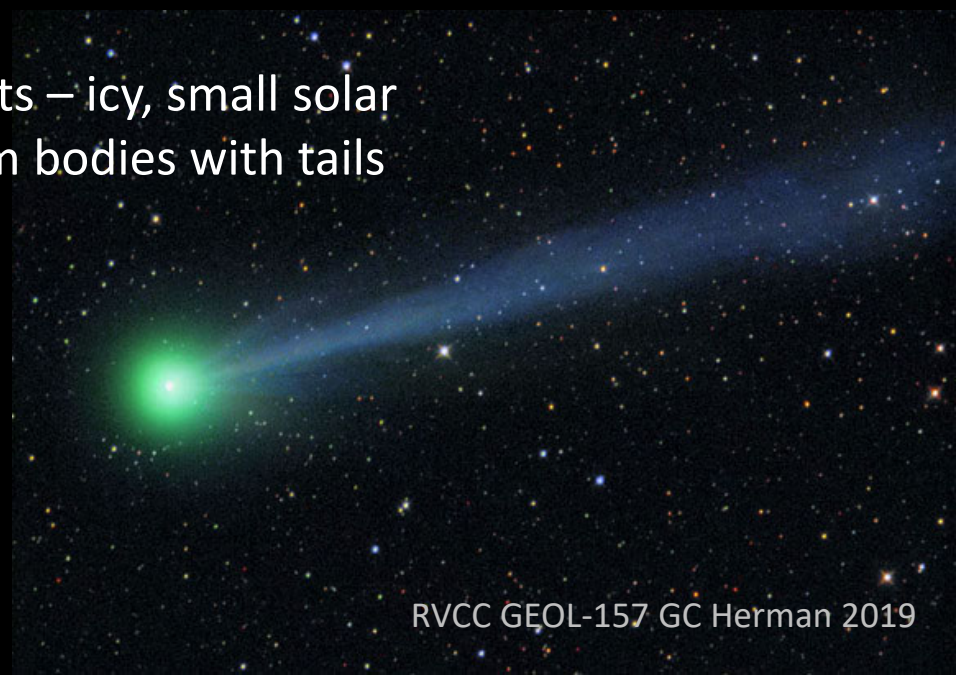
- Asteroids – rocky and metallic objects that orbit the Sun but too small to be considered planets

Meteoroid - space

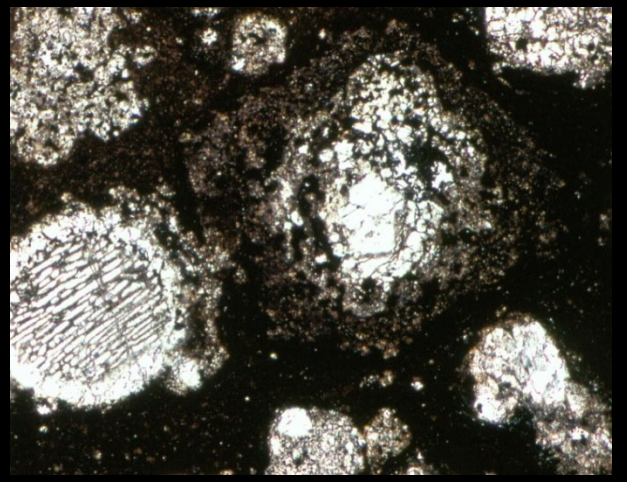
Meteor - atmosphere

Meteorite - ground

Comets – icy, small solar system bodies with tails



Pre-planetary (primitive) and Planetary Meteorites



- Primitive (chondrite) meteorites are stony and not modified due to melting or differentiation of the parent body; rich in Fe and Mg-bearing minerals from > 4.5 billion years ago, formed when primordial dust and grains formed early in a solar system group[together, or 'accrete'.
- Planetary meteorites are composed of materials that we see on Earth, Moon, and Mars.

Meteorites and asteroids provide direct evidence of Planet formation, the composition of the sun and the dust cloud it formed from, and other rare material from other star systems and their environments

Recent meteorite hits home in Freehold, NJ

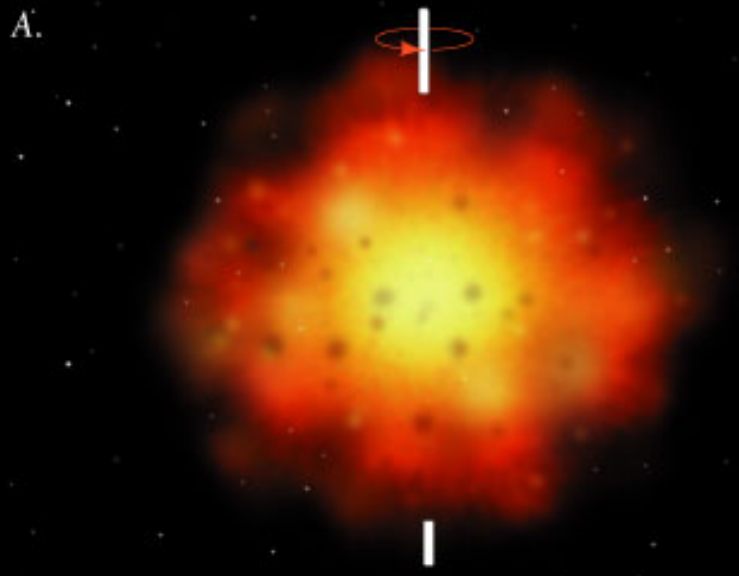
Update – actually space junk

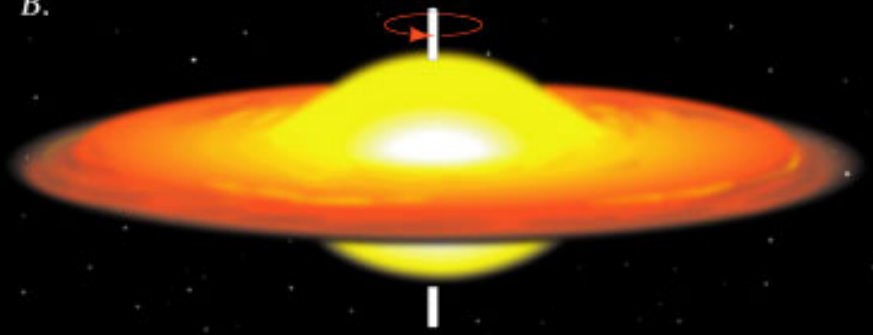
The mass of the Earth increases about 3,000 tons each year because of meteorites and from space.

www.einsteinyear.org/facts/physicsFacts

REVIEW

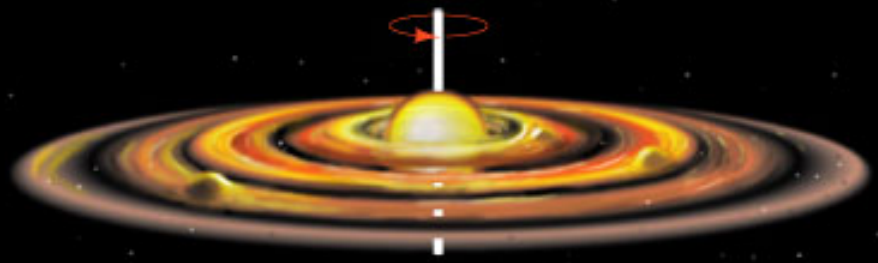
Solar nebula

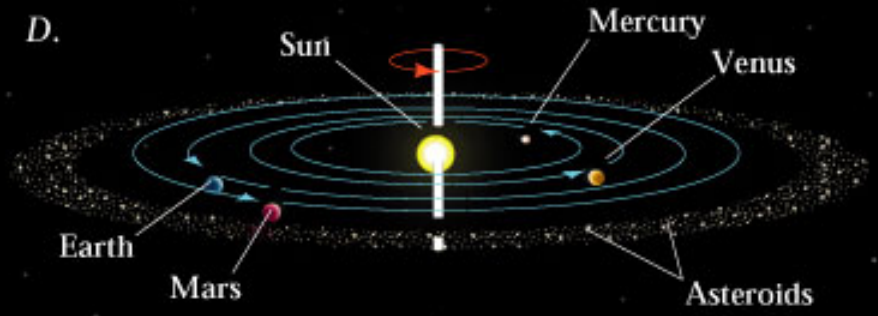




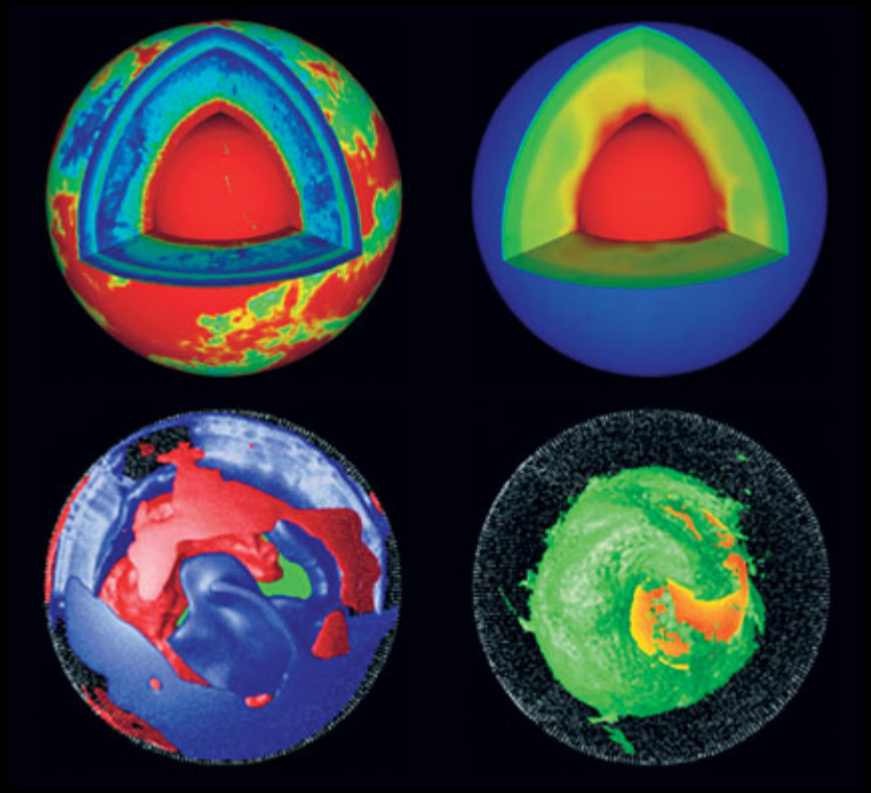
Condensation of protostar

C. Formation of planets





Voila!



Earth as a heat engine

A Spheroid ~ 13,000 km in diameter circulating through the solar system at about 30 km/sec that is also spinning about a wobbly axis at roughly 1 km/sec along it's equator.

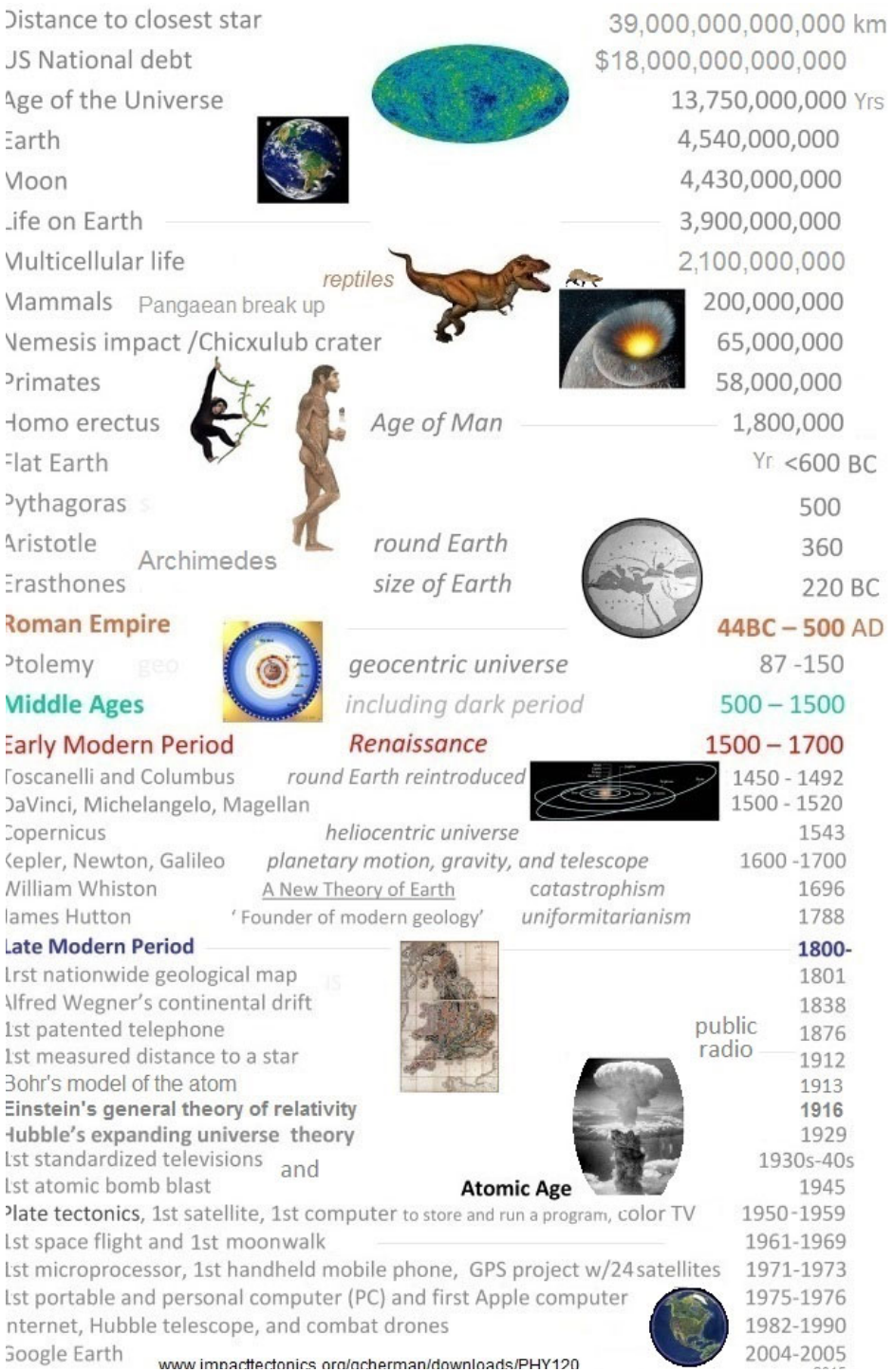
The inner core is solid metal (mostly Fe and less Ni) that's about 1/4 of it's diameter.

The outer core is a layer of viscous fluid that is about 1/4 of it's radius and the entire core is about 1/2 of its diameter. Convective, eddy currents in the outer core probably influence the Earth's magnetic field.

The core is mantled by a plastic and stony layer that is less viscous than the outer core and slowly creeps and periodically belches magma while during slowly cooling .

The internal heat is mostly from original (latent) heating and from radioactive decay (fission 90%), but also from friction and mineral recrystallization as minerals recrystallize at different depths and Iron and Nickel segregate and move to the core.

The escaping heat migrates outward and surface ward. As the stony, plastic rind creeps in response, it pushes and pulls a thin veneer of brittle crust around the sphere's surface.



http://www.impacttectonics.org/GEOL157/LAB1_Time-life-man.jpg

LAB1 Take-home assignment

One-page, handwritten (or printed) essay with your reaction and thoughts to the timeline.