Our "Environment" (the big picture)

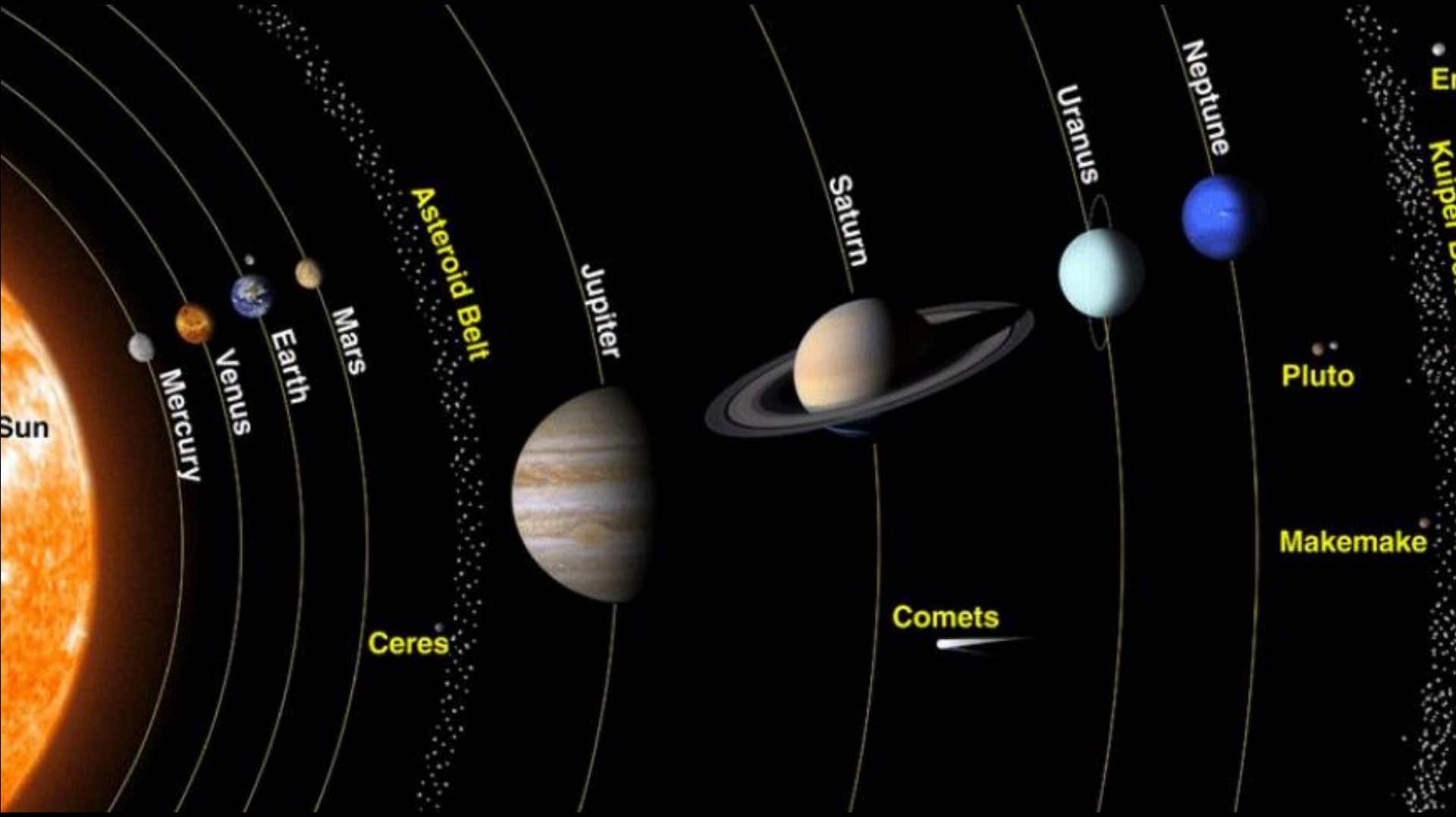


Image from http://a57.foxnews.com/global.fncstatic.com/static/managed/img/Scitech/876/493/solar%20system%20nasa.jpg?ve=1&tl=1

Universe born 14 billion years ago

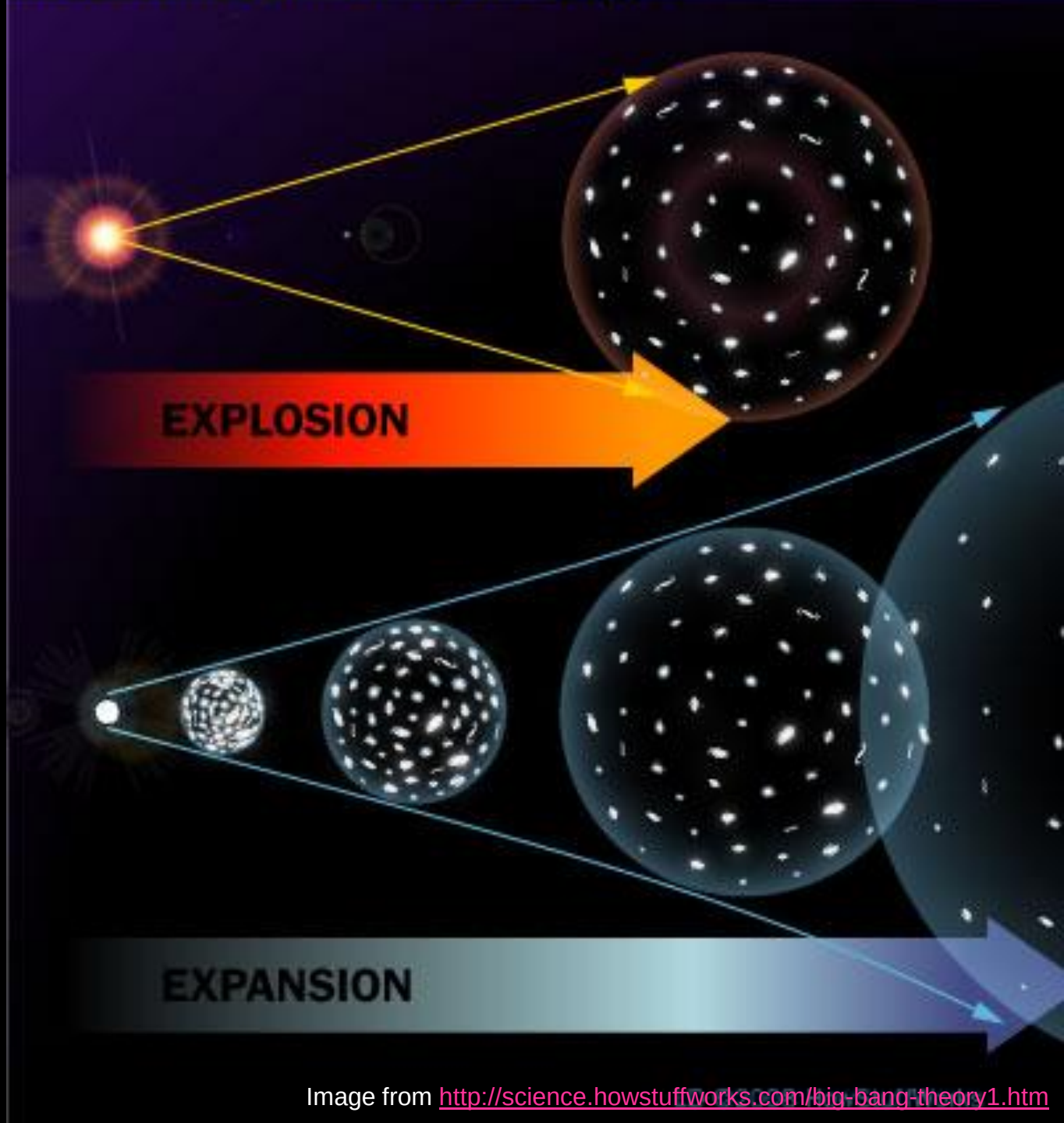


Image from http://science.howstuffworks.com/big-bang-theory1.htm

Galaxies formed 1 billion years after Big Bang

- Galaxies contain billions of stars
  - Our sun is a star
- We live in the Milky Way galaxy
- There are billions of known galaxies

Image from http://photojournal.jpl.nasa.gov/gallery/universe?start=0

Our Galaxy

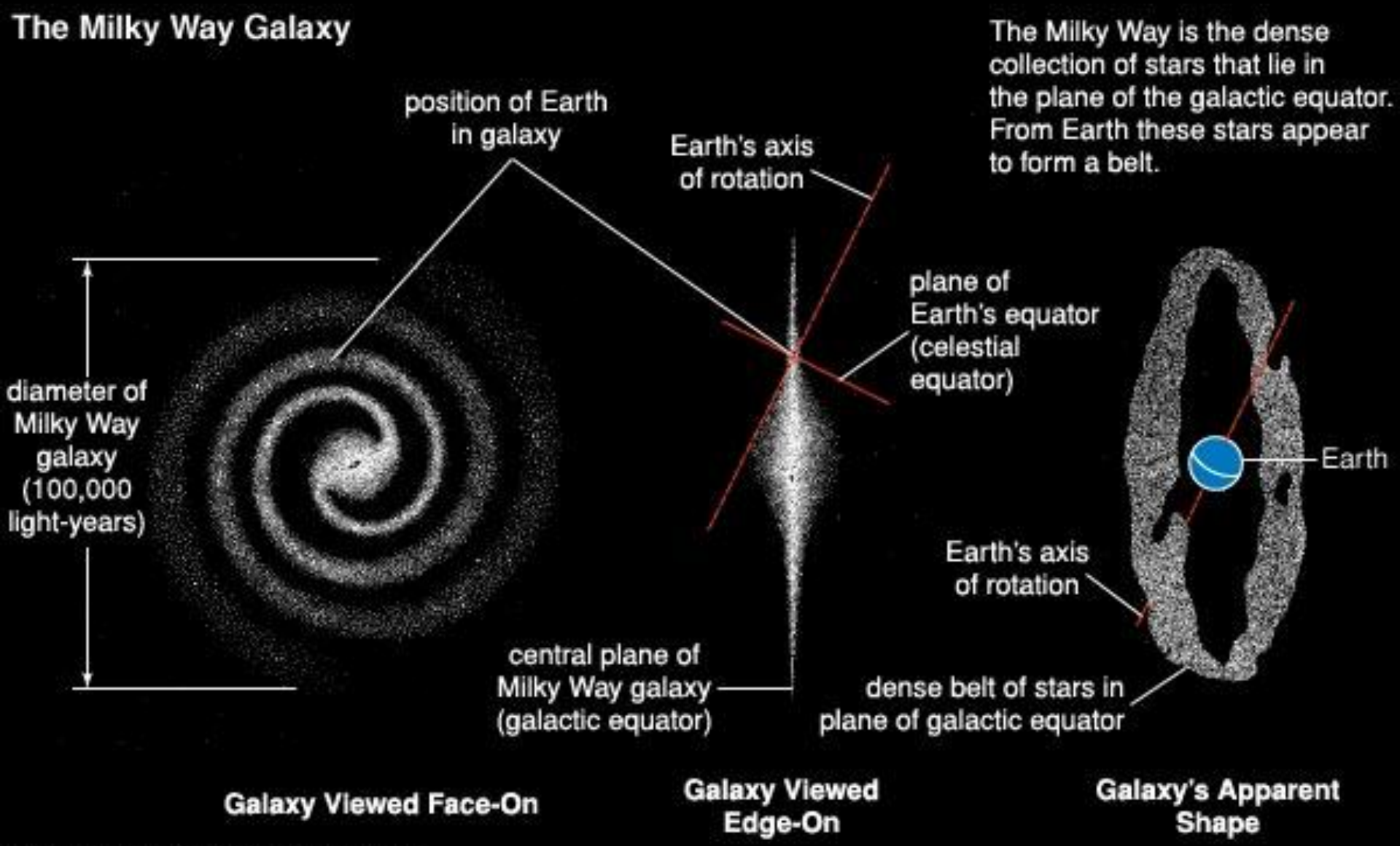


Image from http://student.britannica.com/comptons/art-90853/The-name-of-Earths-galaxy-comes-from-the-visual-phenomenon

How we see our galaxy from earth

Image from http://www.visitandlearn.co.uk/TopicalFactfiles/TheSeasons/TheEarthSunandMoon/tabid/176/Default.aspx

Solar systems began forming 3 billion years after Big Bang

Stars form in Nebulae

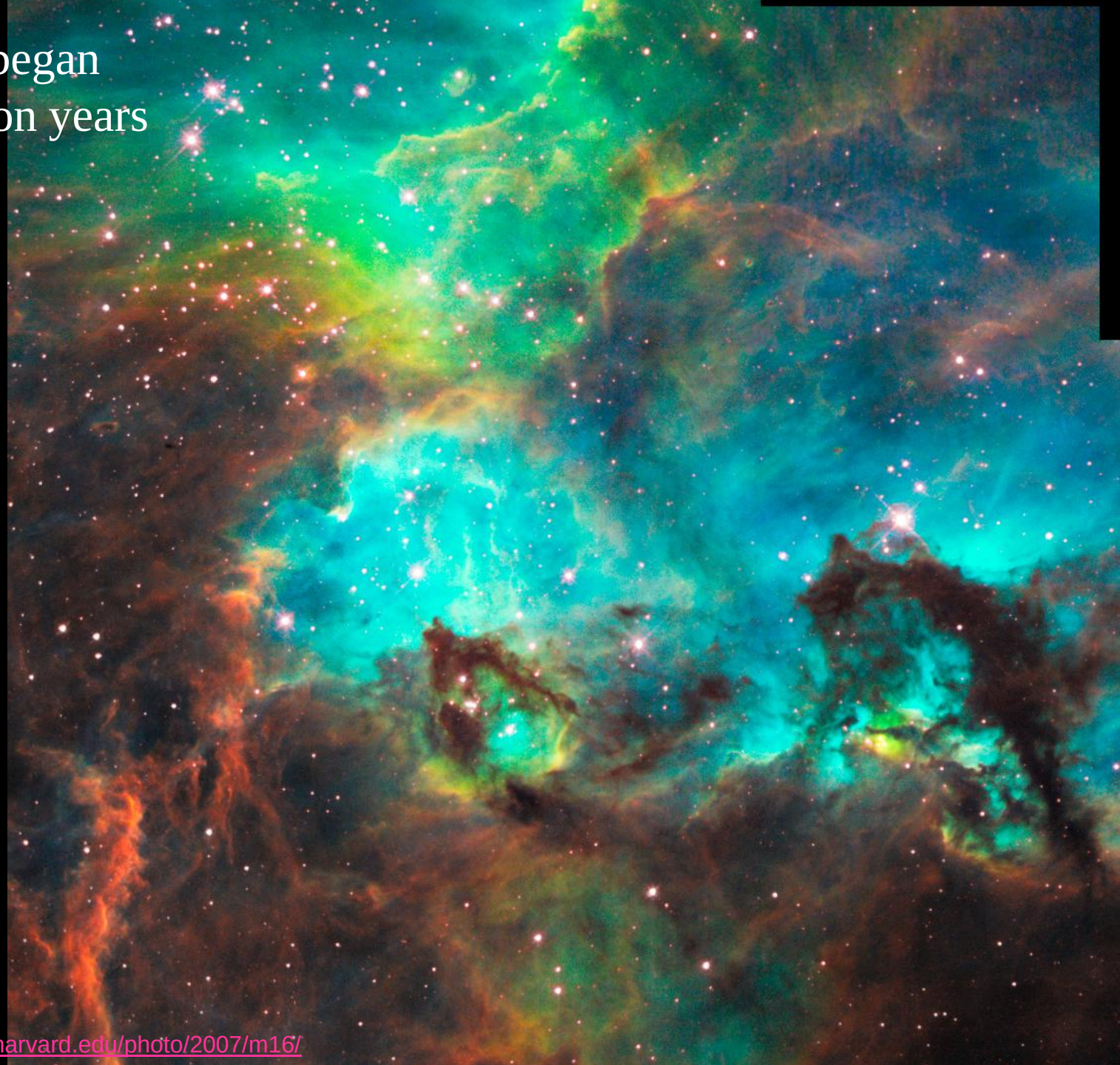


Image from http://chandra.harvard.edu/photo/2007/m16/

Star formation

“Eagle” Nebula

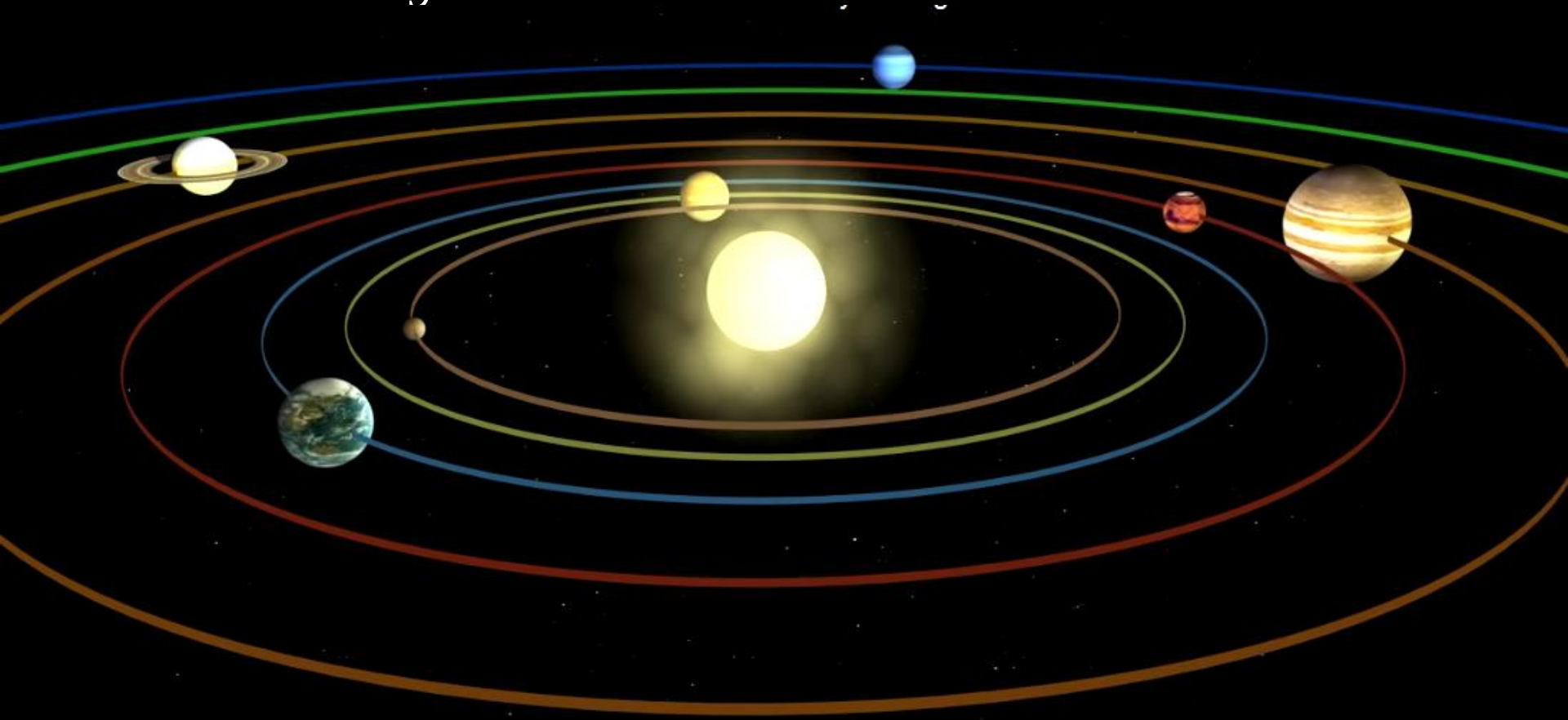
Image from http://www.nasa.gov/mission_pages/hubble/news/hst_100k_orbit_prt.htm

Solar system formation

“ …. a disk of dust and gas surrounding a newborn star becomes flatter and denser, allowing matter in the disk to clump together into planetary building blocks.”

From : http://www.nasa.gov/vision/universe/newworlds/0112_missing_link.html

Traditional view of planetary motion within our Solar System



WATCH VIDEO
https://www.youtube.com/watch?v=z8aBZZnv6y8

However our entire Solar System is moving

- Our sun (a star) is orbiting the center of our galaxy
- Therefore our Solar System's planets actually have **helical orbits**

WATCH VIDEO https://www.youtube.com/watch?v=0jHsq36_NTU

Our exploration limits

- Our galaxy has 400 billion stars and is 200,000 light-years wide
- One light-year = distance traveled by light in one year
  = 300,000,000 meters per second (1 Billion KPH)
- Fastest space travel presently 20,000 times slower (60,000KPH)
- Alpha Centauri (closest star *other than ours*) is 4 light-years away
- Therefore our fastest spacecraft would take 65,000 years to get there
- And the next closest galaxy is 80,000 light years away, so it would take 1 billion years to get there with our present technology

Our exploration limits

- Although we can listen for signals from outside our solar system (since radio signals are encoded forms of electromagnetic radiation – moving at the speed of light) . . . .

Image from http://abscicon.seti.org/index.php

like with the SETI project (Search for Extra-Terrestrial Life)…….

Image from http://abscicon.seti.org/index.php

Our Solar System is most likely all we will ever explore with spacecraft

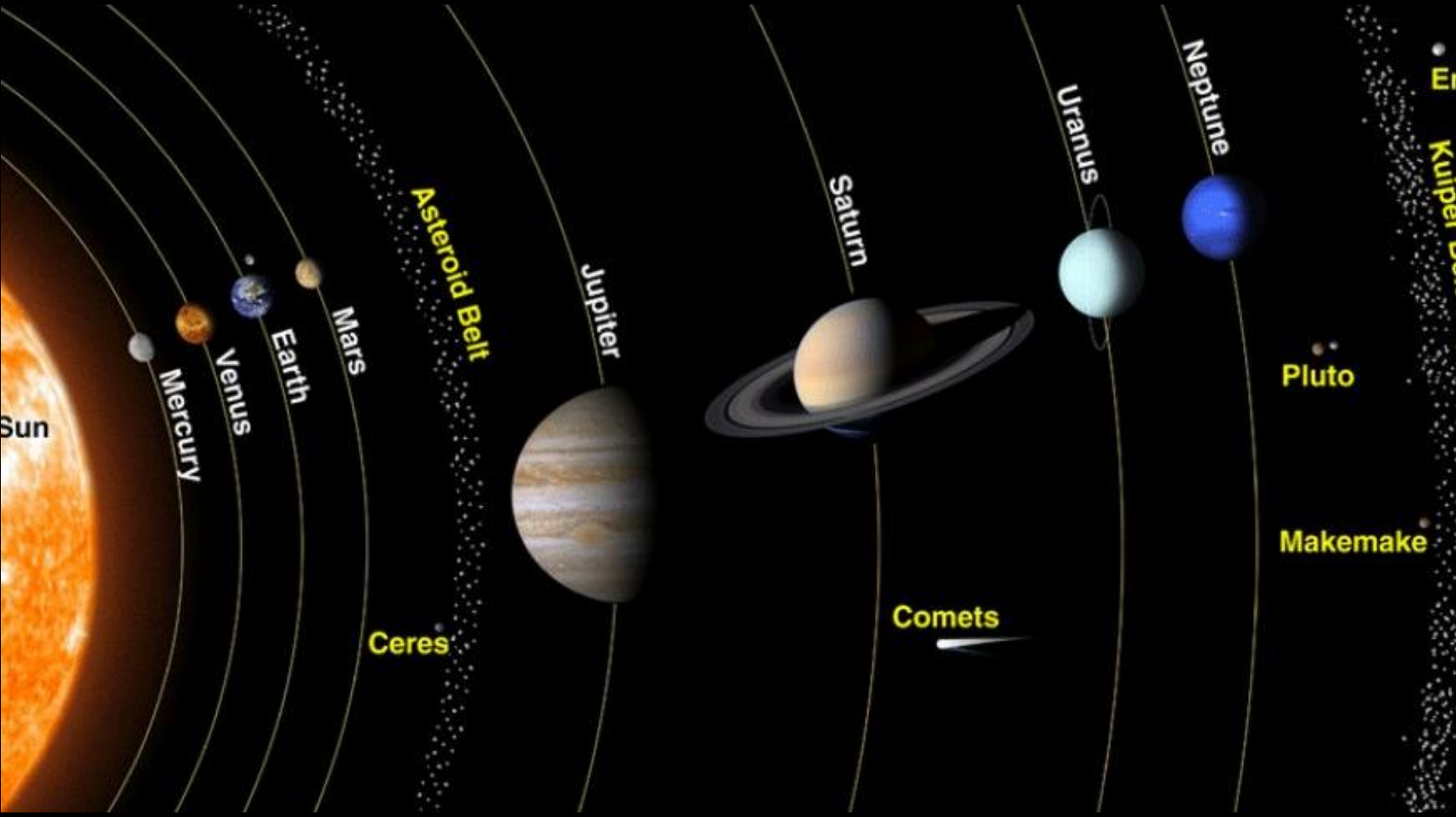


Image from http://a57.foxnews.com/global.fncstatic.com/static/managed/img/Scitech/876/493/solar%20system%20nasa.jpg?ve=1&tl=1

Approximate present-day locations of our most distant spacecrafts

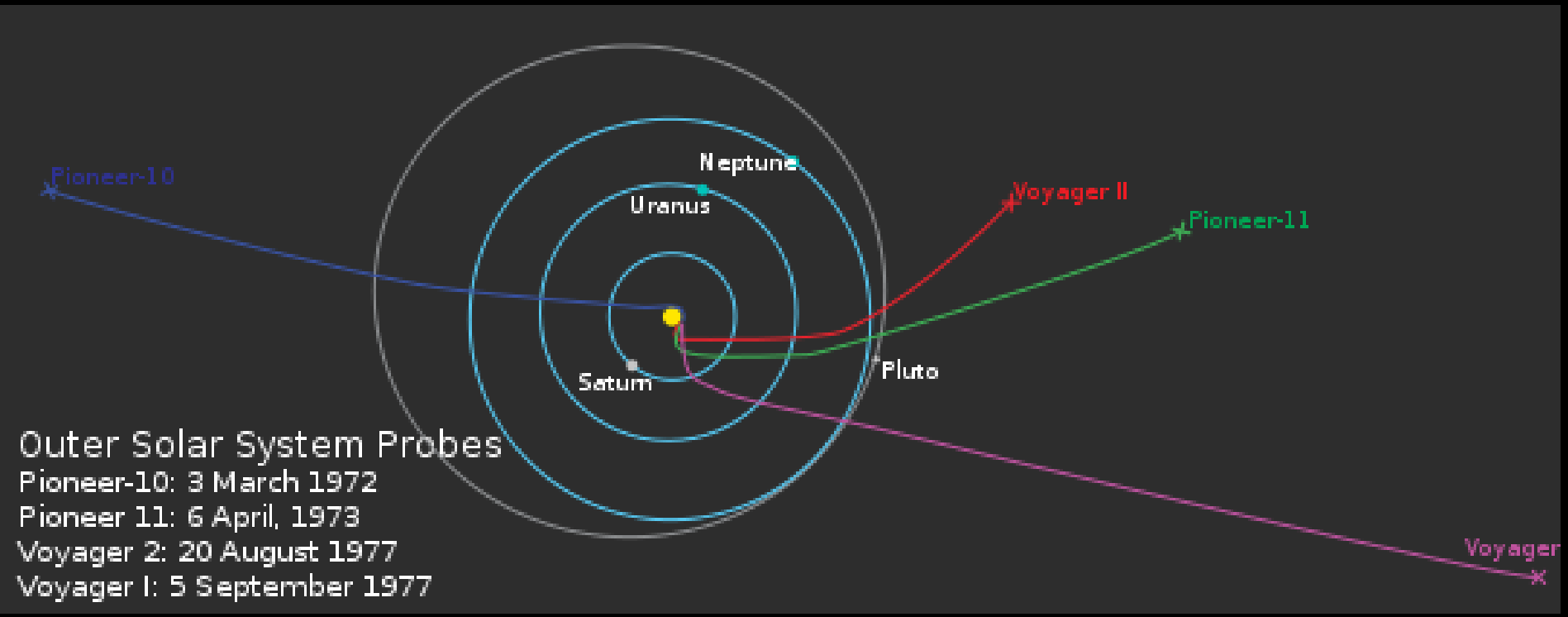


Image from: http://en.wikipedia.org/wiki/Voyager_1

Our Terrestrial Planets

Image from http://www.eso.org/public/outreach/eduoff/vt-2004/Background/Infol2/EIS-D4_pf.html

Our Gaseous Planets ("Giants")

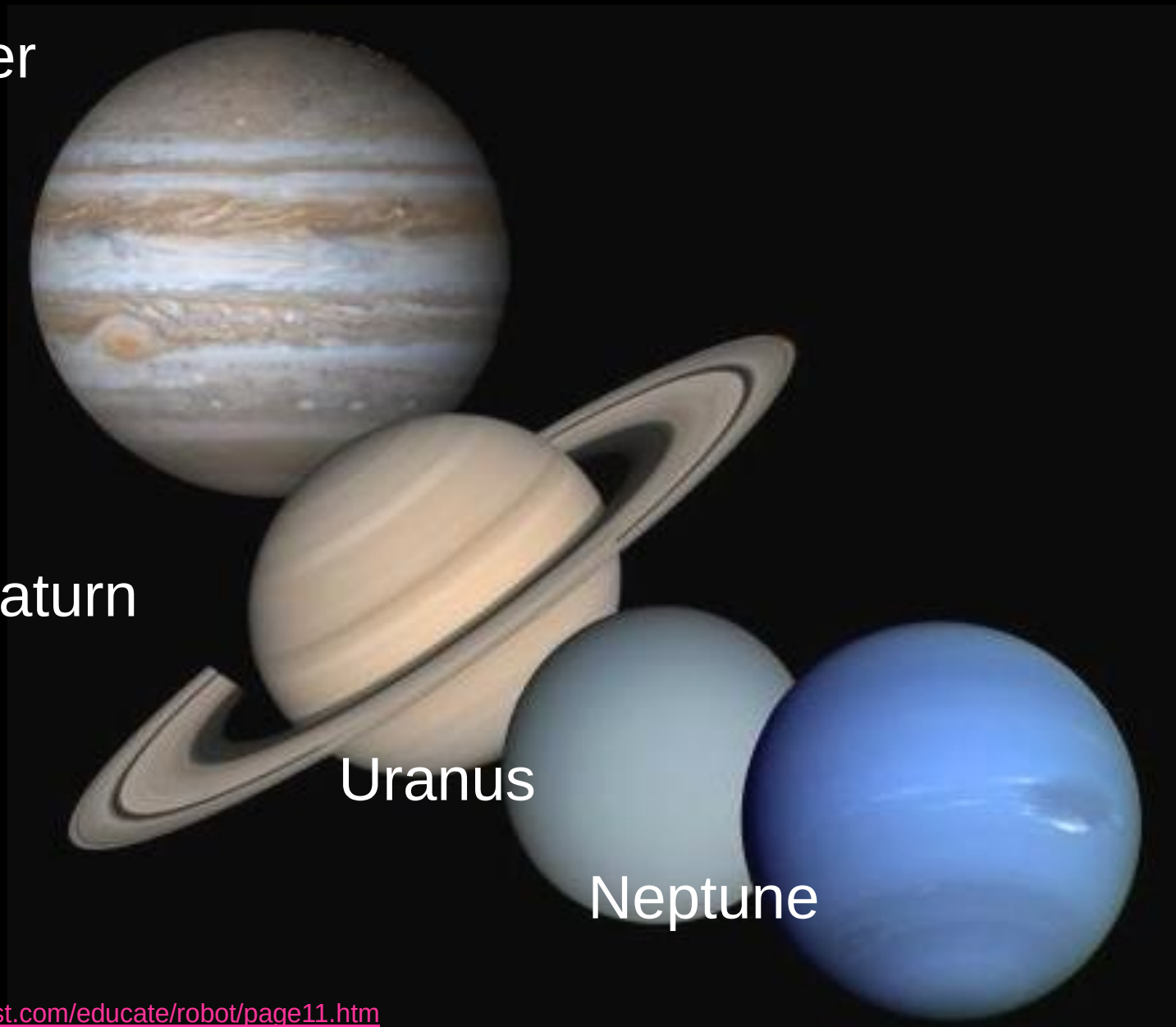


Image from http://astrophys-assist.com/educate/robot/page11.htm

We also have many moons to explore ……..

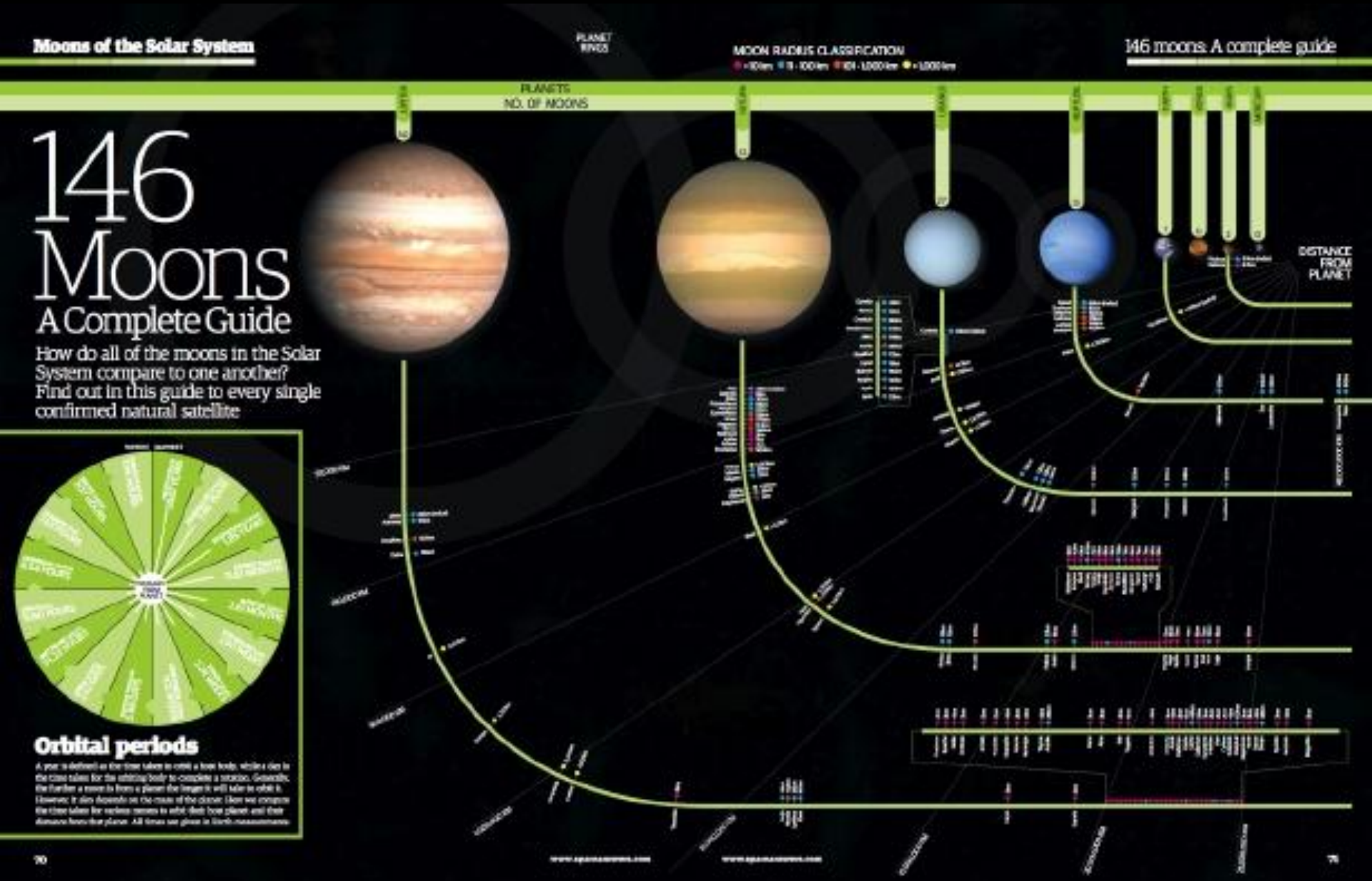


Image from http://www.spaceanswers.com/wp-content/uploads/2012/08/Moons.jpg

Selected Moons of the Solar System, with Earth for Scale

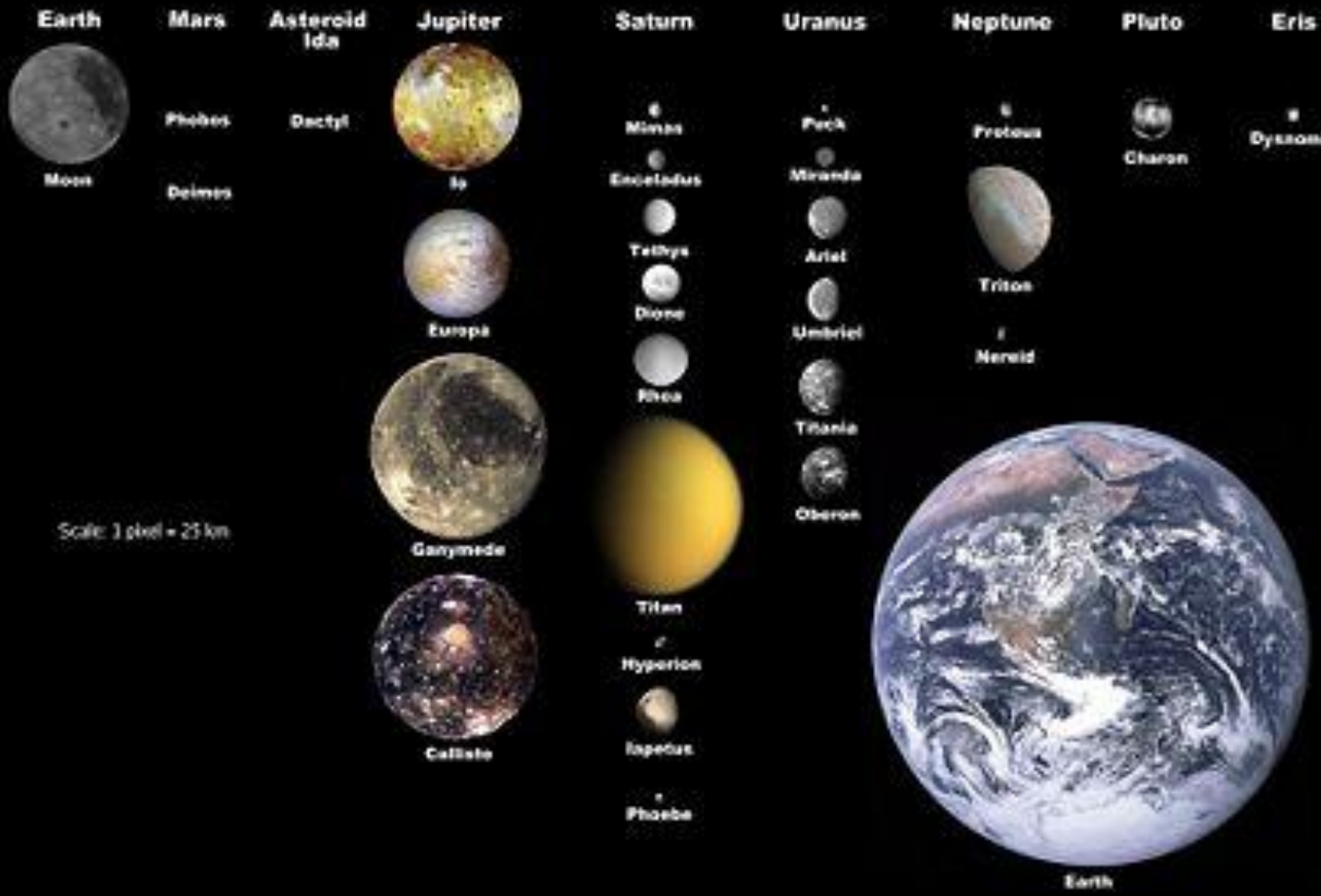


Image from http://www.factmonster.com/spot/solar-system.html

Jupiter's Galilean moons

Image from: http://wgbis.ces.iisc.ernet.in/envis/Remote/section1917.htm

Jupiter's Galilean moons

Ganymede and Europa have sub-surface oceans

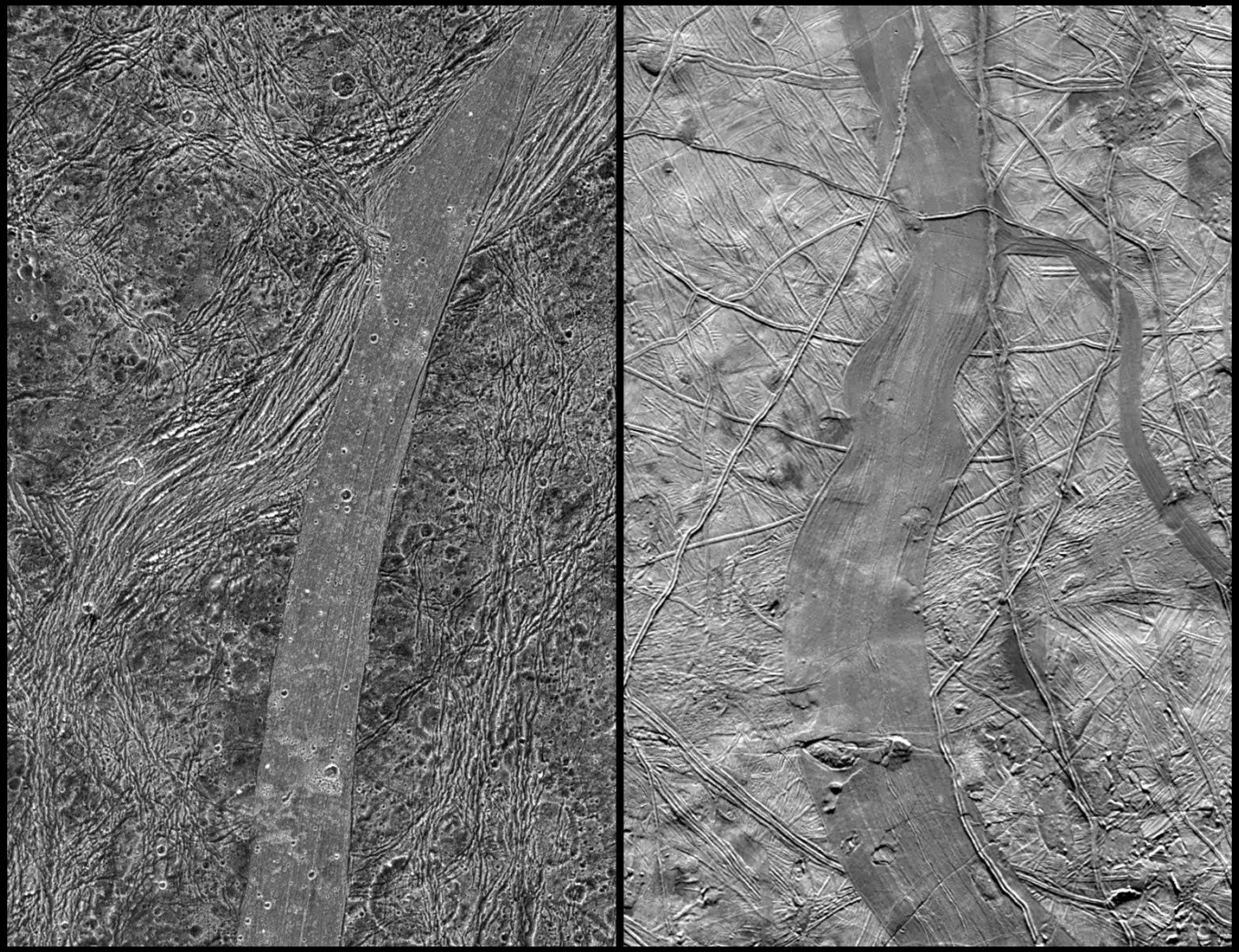


Image from: http://www.nasaimages.org/luna/servlet/detail/NVA2~14~14~24939~124662:Comparison-of-Ganymede-and-Europa-f

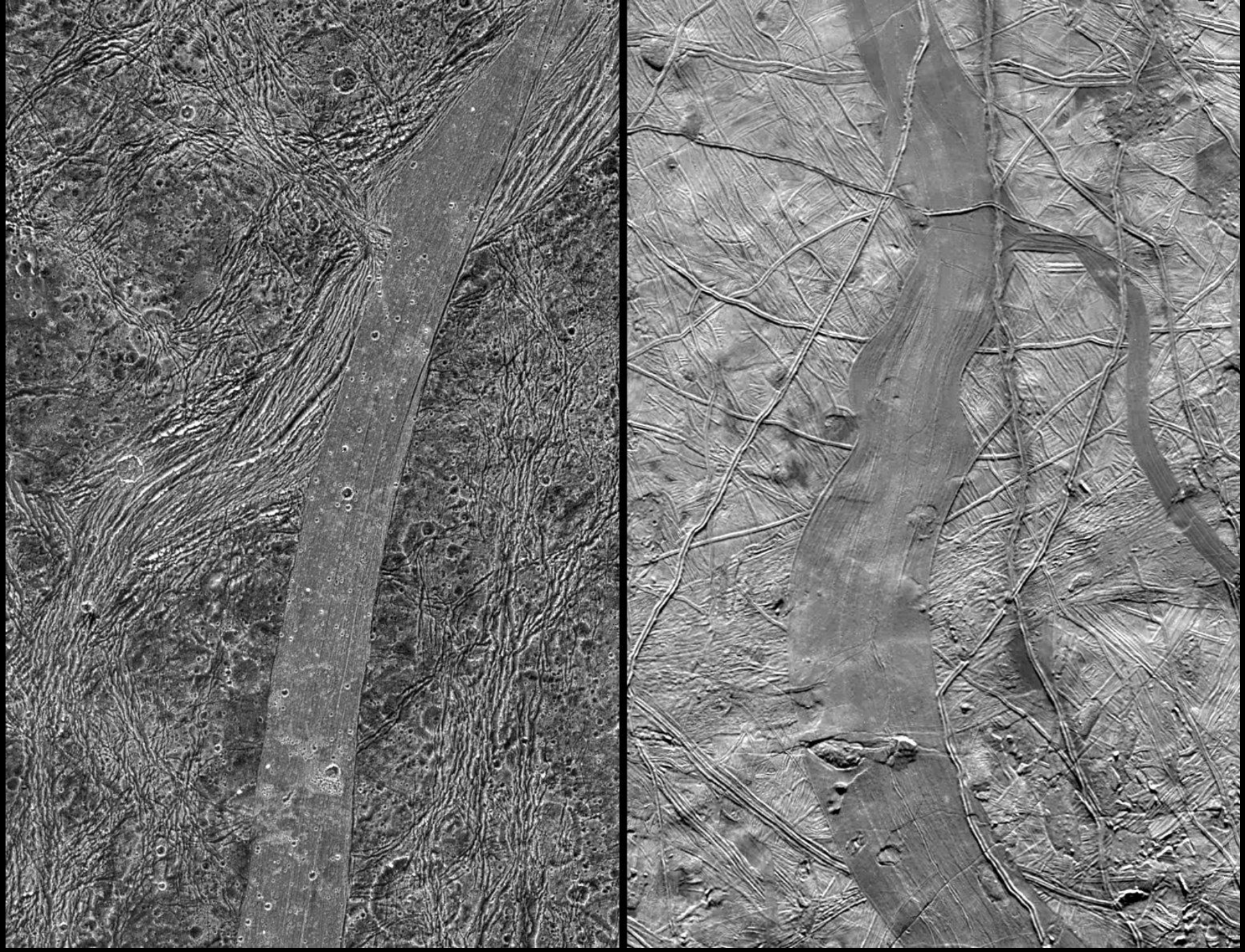


Image from: http://www.nasaimages.org/luna/servlet/detail/NVA2~14~14~24939~124662:Comparison-of-Ganymede-and-Europa-f

This course is focused on three places for deploying rovers

1) **Moon**
2) **Mars**
3) **Jupiter's moon Europa**

Image from http://www.mapsharing.org/MS-maps/map-pages-space-map/2-solar-system-planets-map.html

Distances to Planets (from Earth and Sun)

Distance from Earth effects:

- Travel time for deployment of rovers
- Degree of required rover **Autonomy** since communication delays prevent “tight” tele-operation of vehicles from earth

DISTANCES FROM EARTH:

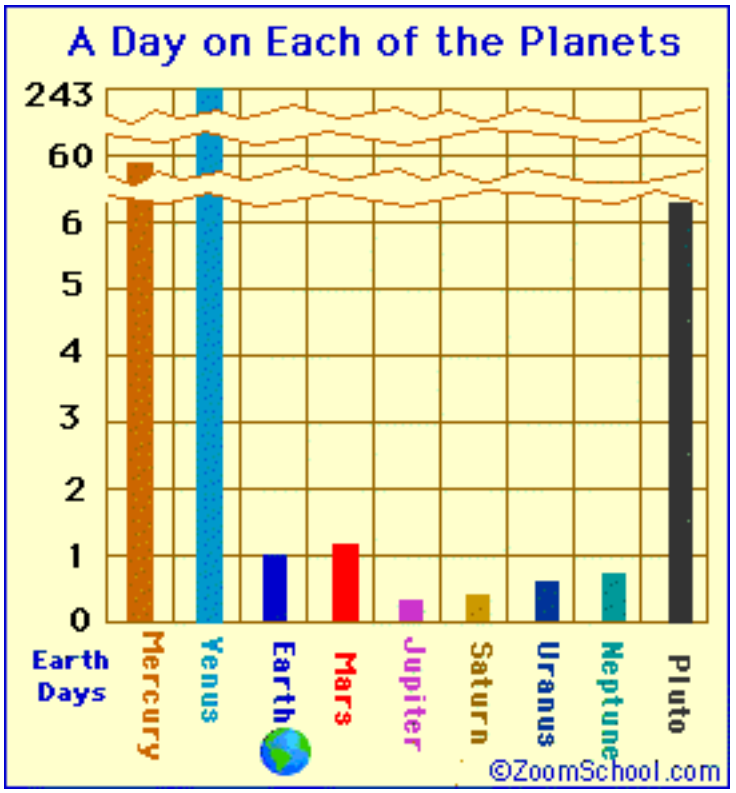
1) Our Moon = 384,403 km
2) Mars = 54,600,000 km (at closest)
3) Europa = 590,629,248 km (at closest)

Distance from Sun effects using solar collection to power rovers

DISTANCES FROM SUN:

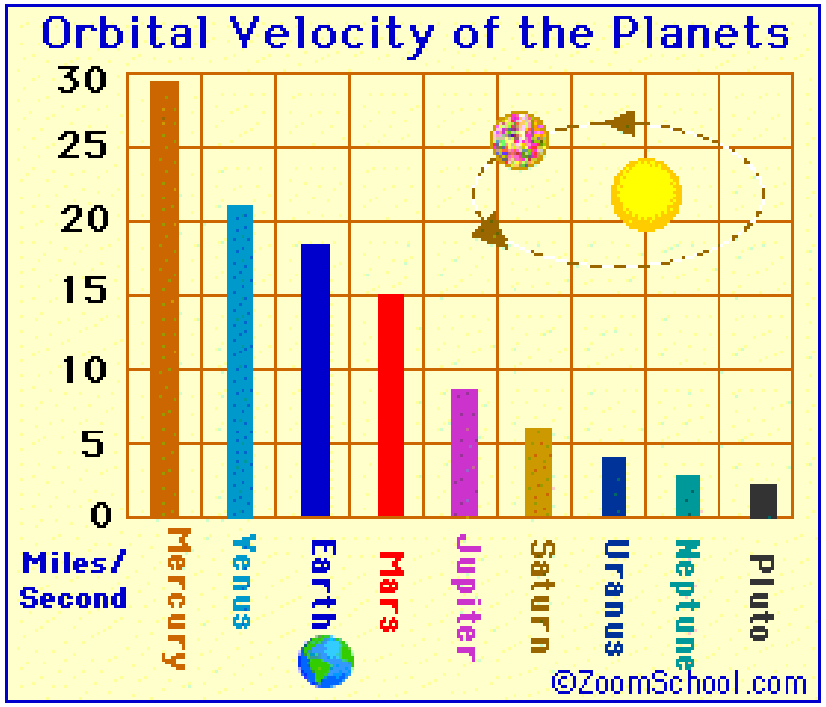
1) To Moon = ~1 AU (Astronomical Unit)
2) To Mars = 1.524 AU
3) To Europa = ~5.203 AU

Length of Day on Planets also effects solar collection



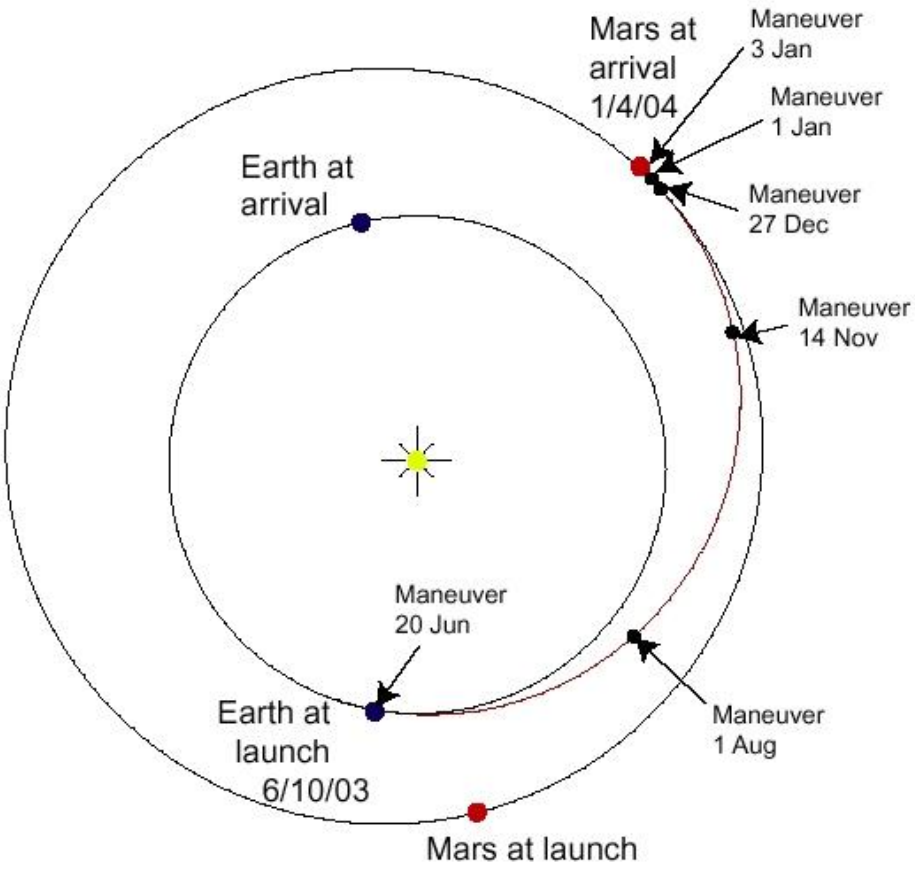
Relative Orbital Velocities effects:

- Travel time for delivery and deployment of rovers
- Degree of required rover **Autonomy** *(i.e., variation in time for signals from earth to reach rovers)*



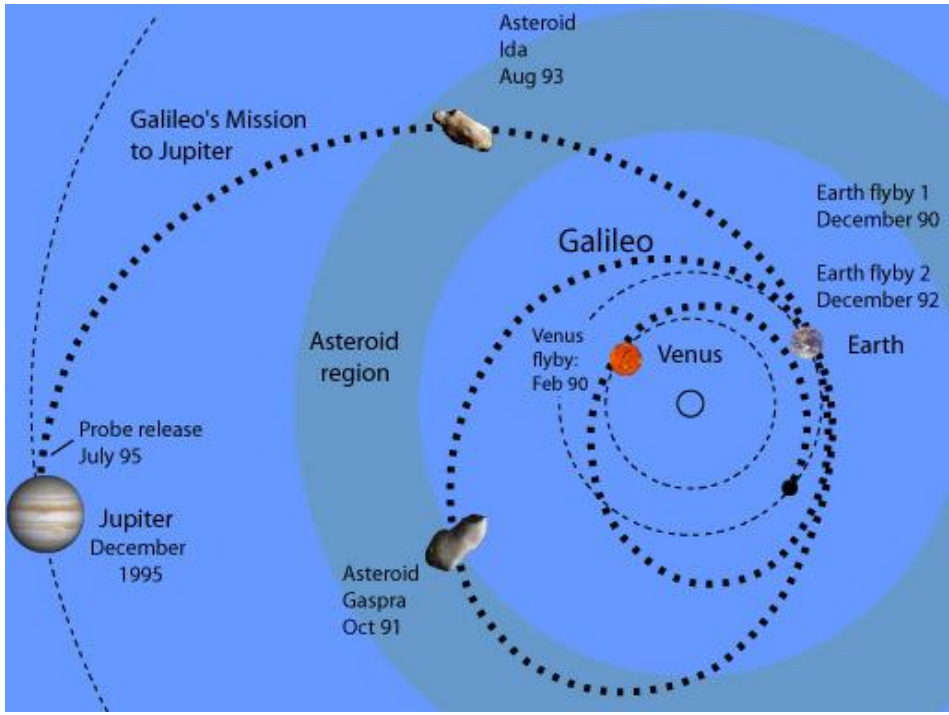
Graph from http://www.enchantedlearning.com/subjects/astronomy/planets/

Relative Orbital Velocities also dictates Launch "Windows"



2004 delivery of Mars rovers "Spirit" and "Opportunity"

Image from: http://www.mars.tv/mer/overview.html

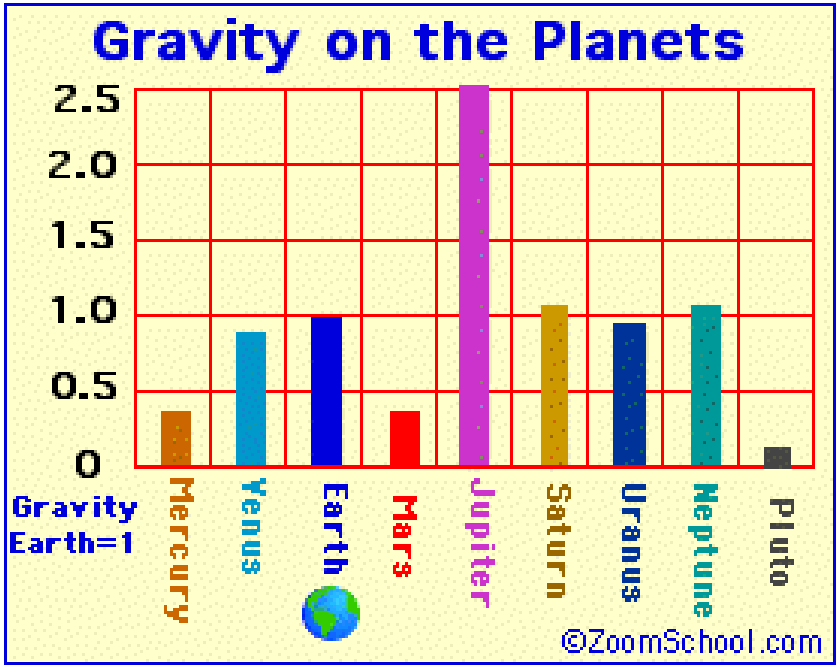


1989 Galileo Mission

Image from: http://hyperphysics.phyastr.gsu.edu/HBASE/solar/galileo.html

Gravity effects the Engineering Mechanics of rover design and deployment

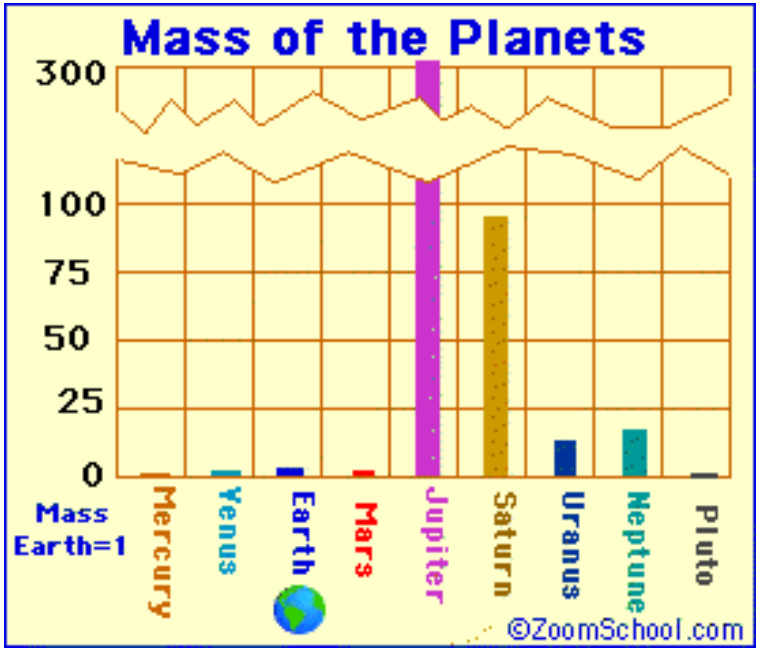
1) Moon = 0.16 g
2) Mars = 0.38 g
3) Europa = 0.13 g



Graph from http://www.enchantedlearning.com/subjects/astronomy/planets/
Image from http://www.mapsharing.org/MS-maps/map-pages-space-map/2-solar-system-planets-map.html

Mass

Jupiter's mass creates strong tidal forces on Europa -- which creates conditions for a subsurface liquid ocean, and potentially life

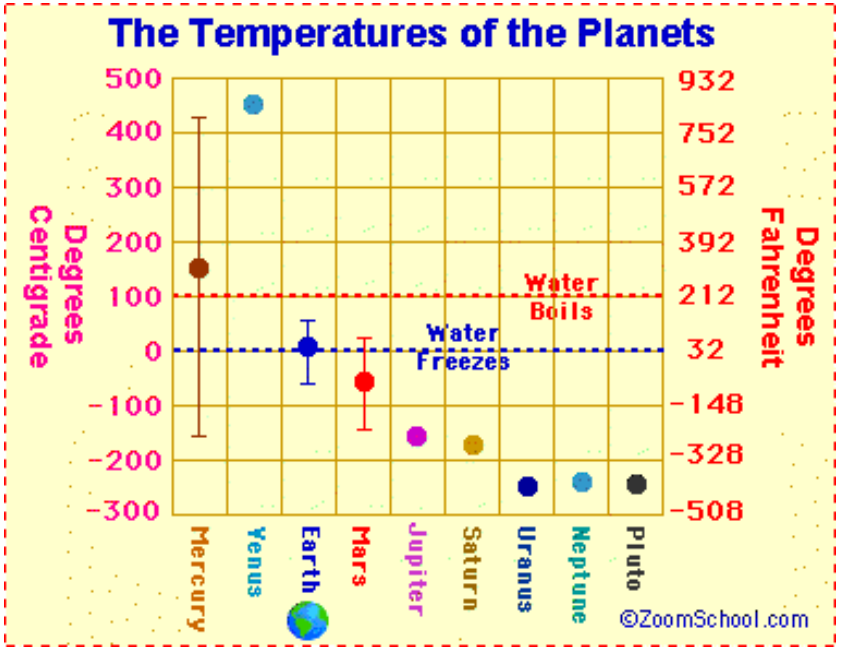


Graph from http://www.enchantedlearning.com/subjects/astronomy/planets/

Image from http://www.mapsharing.org/MS-maps/map-pages-space-map/2-solar-system-planets-map.html

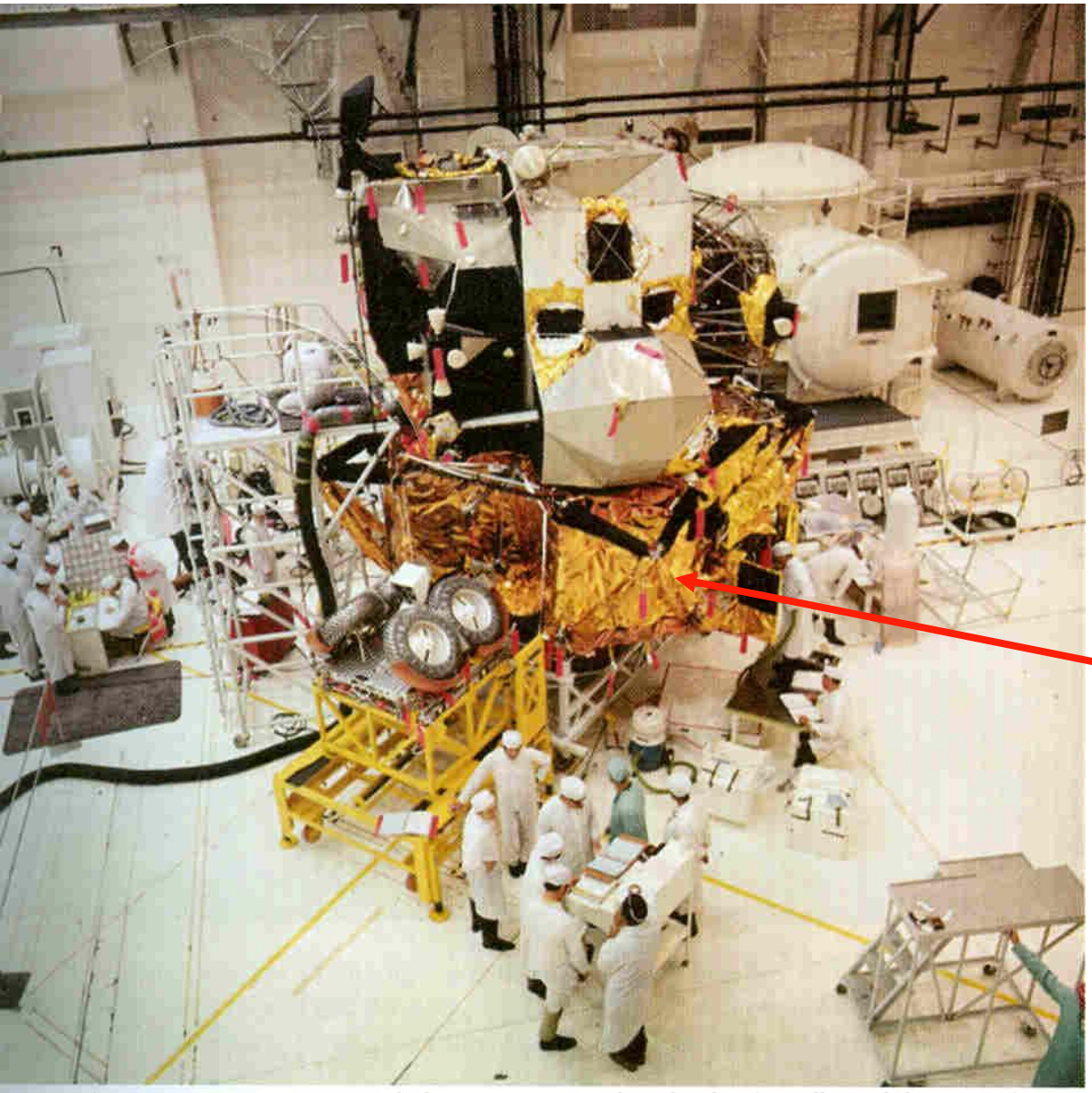
Temperatures can adversely effect rover equipment; especially electronics

Europa has a harsh surface environment:
-143C (-225F) max *at equator*



Graph from http://www.enchantedlearning.com/subjects/astronomy/planets/
Image from http://www.mapsharing.org/MS-maps/map-pages-space-map/2-solar-system-planets-map.html

Radiation can adversely effect equipment -- and can be deadly



***1971 Apollo 15 Lunar Module (Lander) with "Lunar Roving Vehicle"* (LRV) attached to side**

Metalized mylar (gold) reflects 98% of solar energy

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

Could this depiction of Europa be accurate?

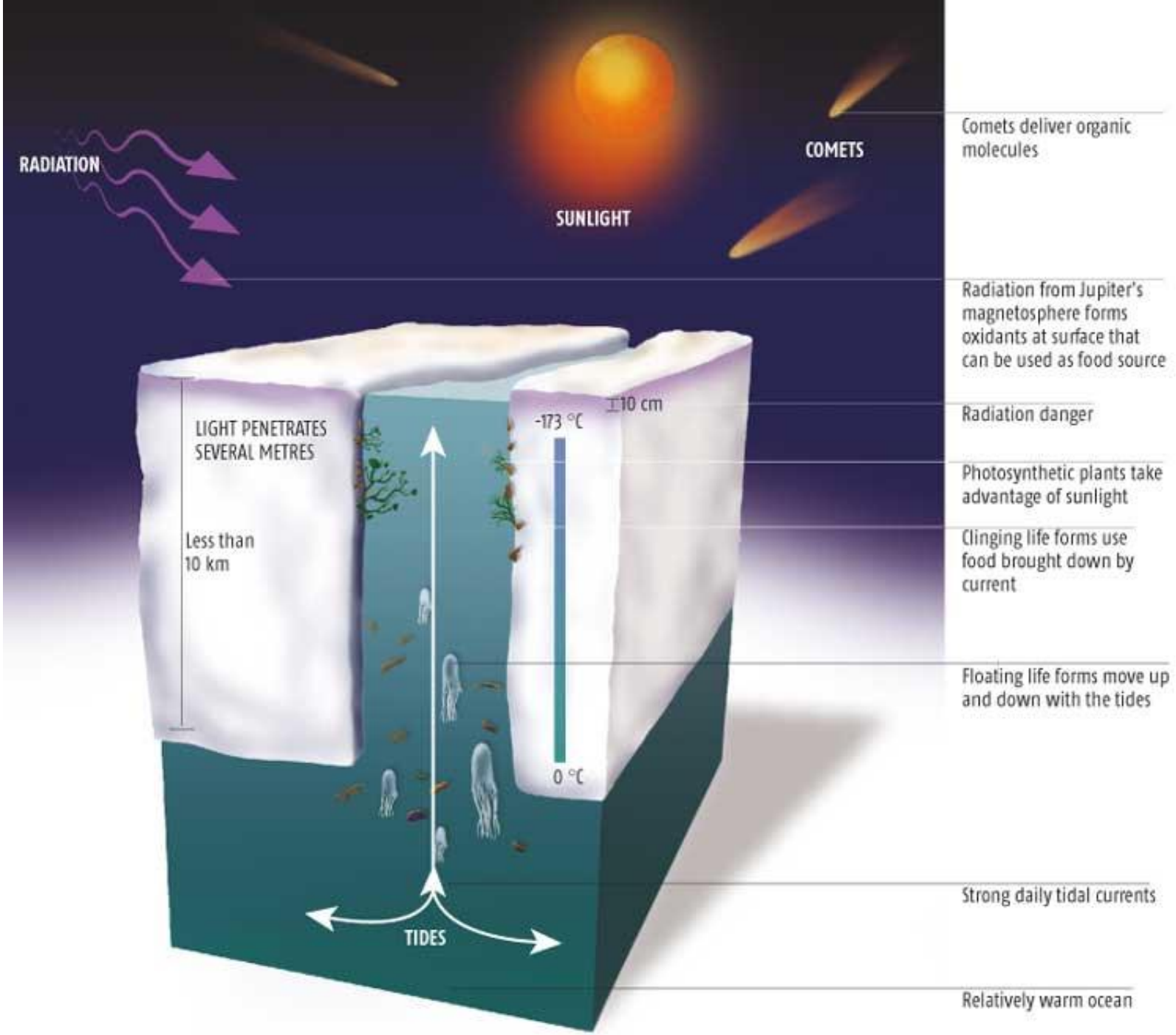


Image from http://www.newscientist.com/article/dn2929-thin-ice-opens-lead-for-life-on-europa.html

More information at:

Planet Data

Planet Images

Exploration History

Google Earth

Image from http://www.mapsharing.org/MS-maps/map-pages-space-map/2-solar-system-planets-map.html

And remember that our exploration of space has always yielded technologies that help us on Earth (i.e., **"Spin-off" Technologies**)

Image from https://www.youtube.com/watch?v=Q3YYwlsMHzw

And remember that our exploration of space has always yielded technologies that helped us on Earth (i.e., **"Spin-off" Technologies**)

WATCH VIDEO https://www.youtube.com/watch?v=Q3YYwIsMHzw