

Skylight Astronomical Society

Probes to the Outer Solar System Past, Present and Future

Spotlight on: Pioneer and Voyager

Terry P. Riopka, President of Skylight Astronomical Society - 2018

Probes to the Outer Solar System Past and Present

Launch
Date

1972 — Pioneer 10

1973 — Pioneer 11

1977 — Voyager 2

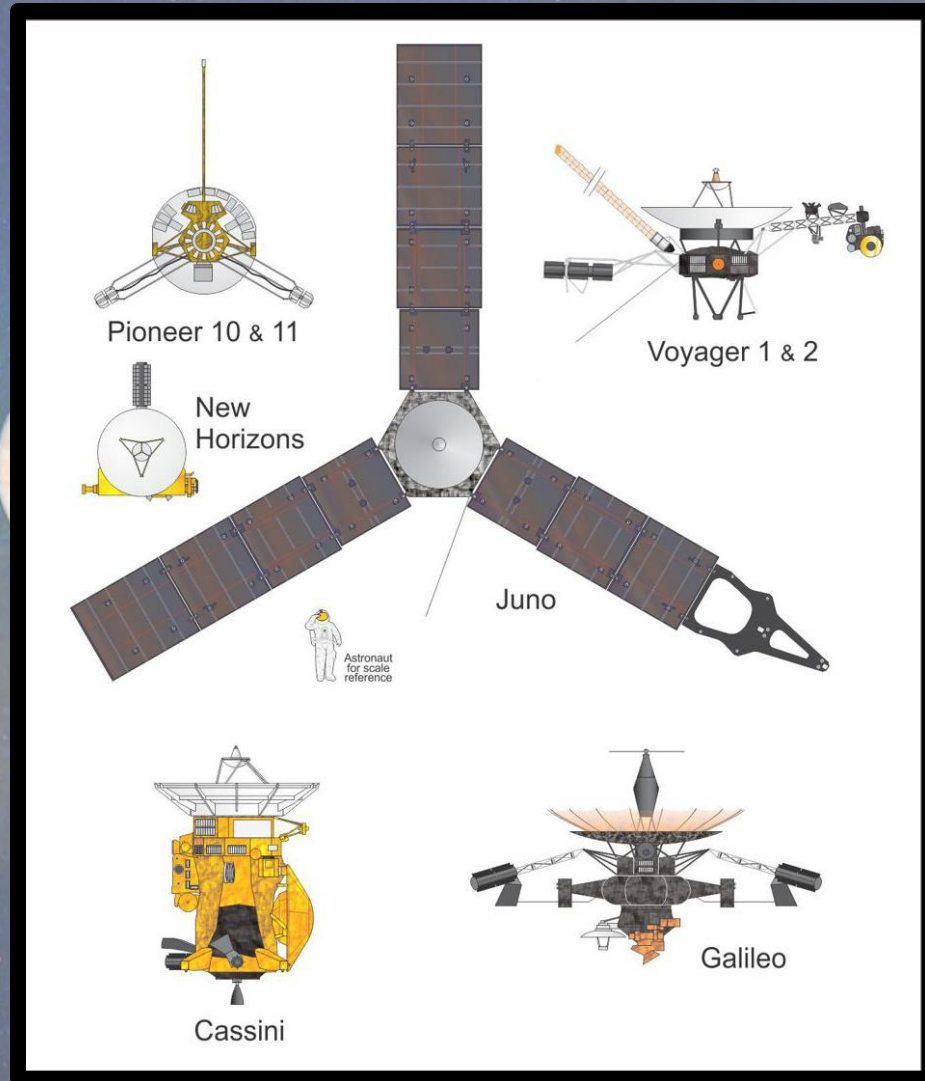
Voyager 1

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Probes to the Outer Solar System

Pioneer 10 @ Jupiter

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First mission to the outer planets

First spacecraft to fly through the asteroid belt

➡ Rate of puncturing impacts averaged at about 15 per month even inside the asteroid belt

First spacecraft to use all nuclear-electrical power (two plutonium-238 thermoelectric generators)

By launch, 15 million man hours had been spent
21 month travel time, took about 500 photos



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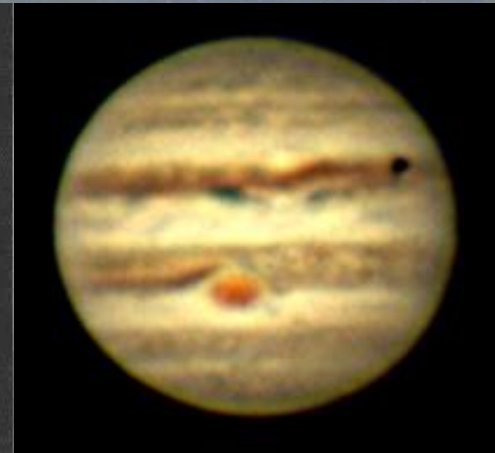
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Image Quality ➡ comparable to quality of today's mediocre amateur astroimages



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Europa



Ganymede



Data transmission rate: 256 bits/s, max on board storage of 6144 bytes, two color channels

Heading in the direction of Aldebaran, in the Taurus constellation which it is expected to reach in about two million years

Last communication in 2003 due to loss of power

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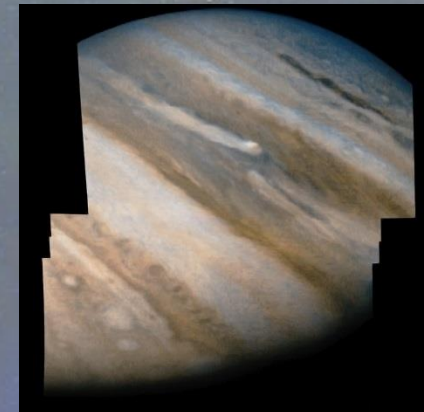
2006 — New Horizons

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Came much closer to Jupiter's surface - 0.60 vs. 1.82 Jovian radii

Approached from south of the equator to take images of the pole

20 month travel time, took about 460 Jupiter photos



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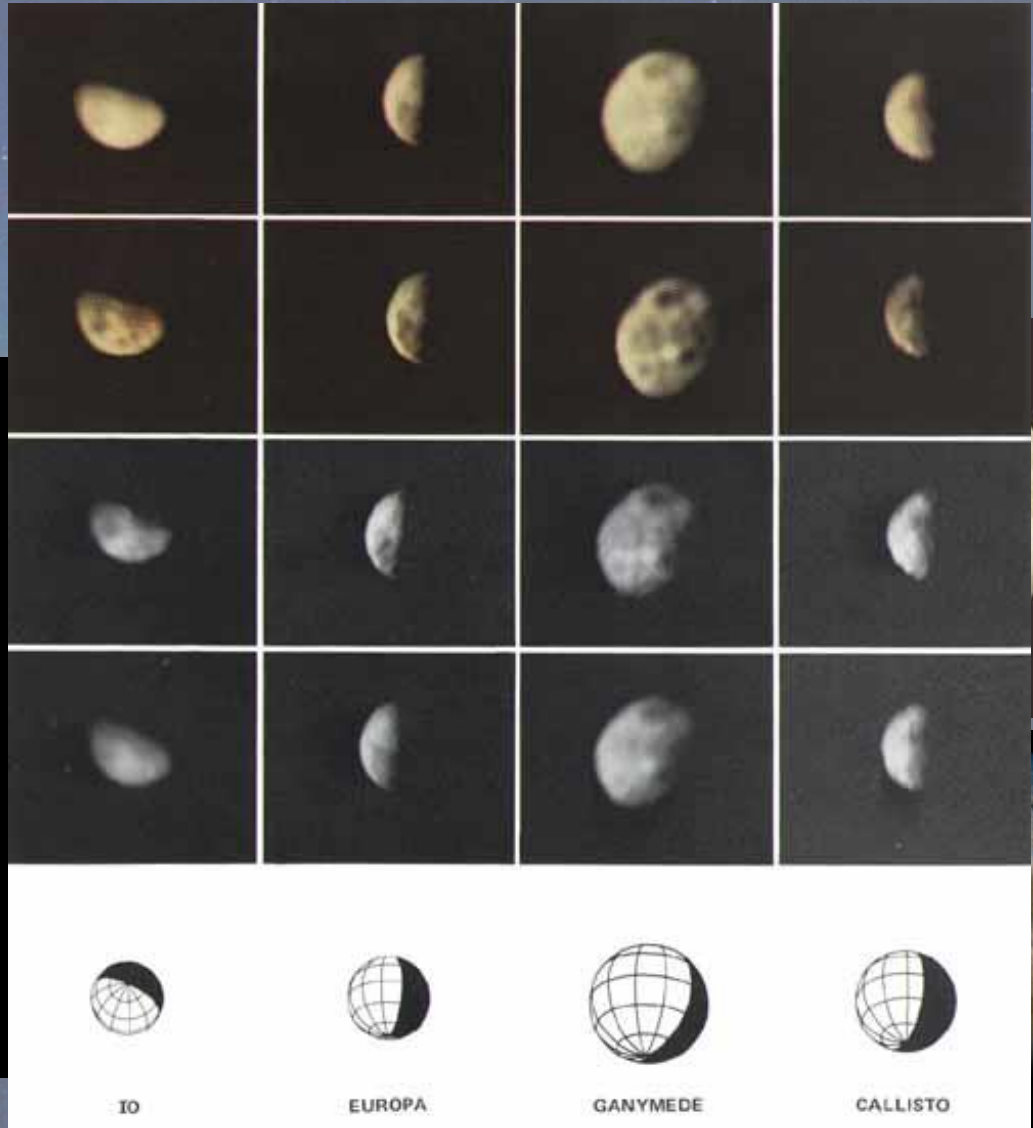
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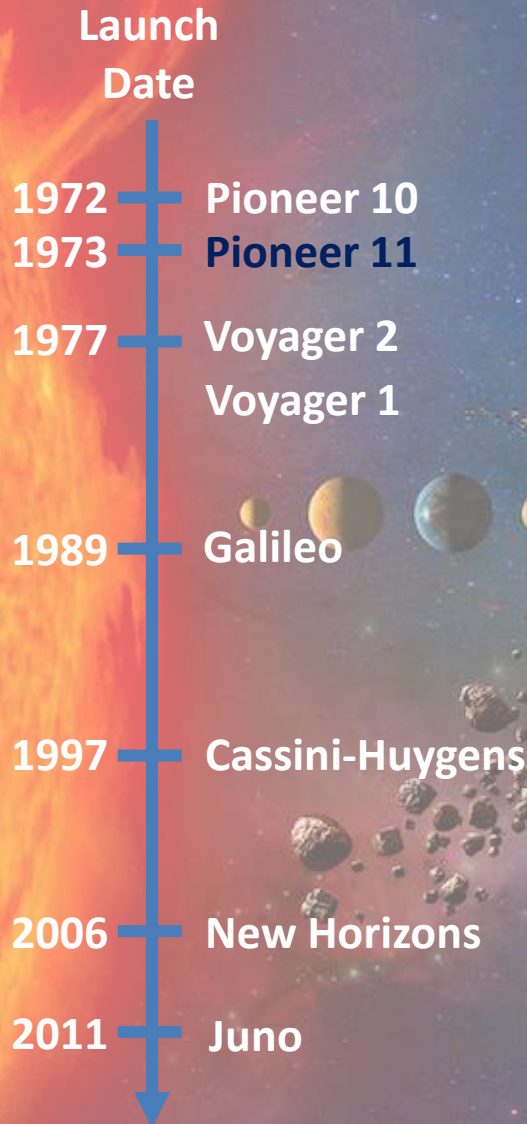
Probes to the Outer Solar System

Pioneer 11 @ Saturn

Arrived at Saturn in 1979

Tested route through ring plane to prepare for Voyagers

First imaged and nearly collided with the small moon Epimetheus, passing at a distance of less than 2,500 mi.



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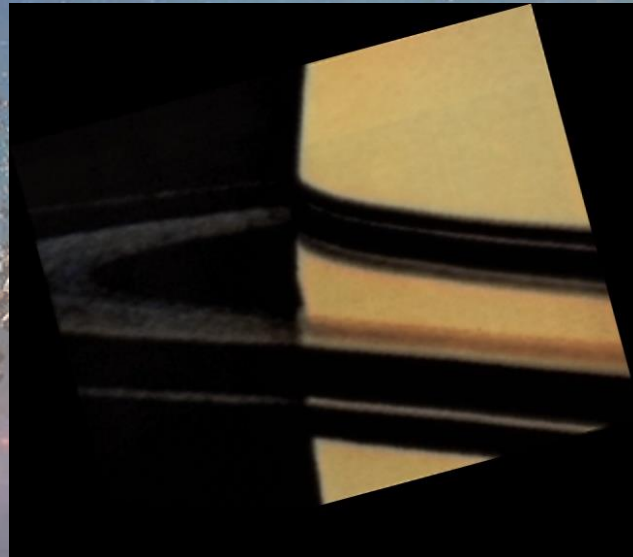
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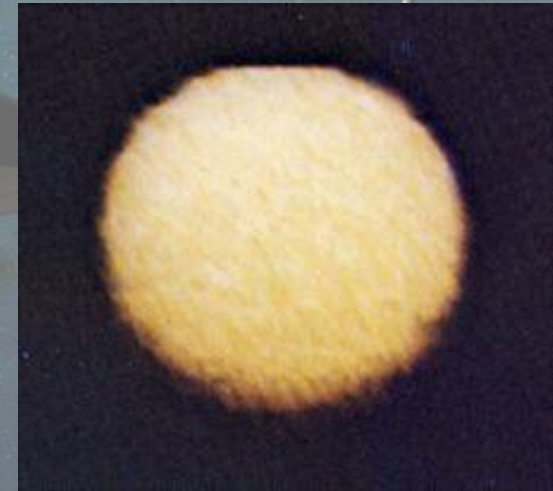
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Close-up of Rings



Titan

Now headed out of our solar system in the direction of Sagittarius – last communication was Nov. 1995

Probes to the Outer Solar System

Pioneer 10/11

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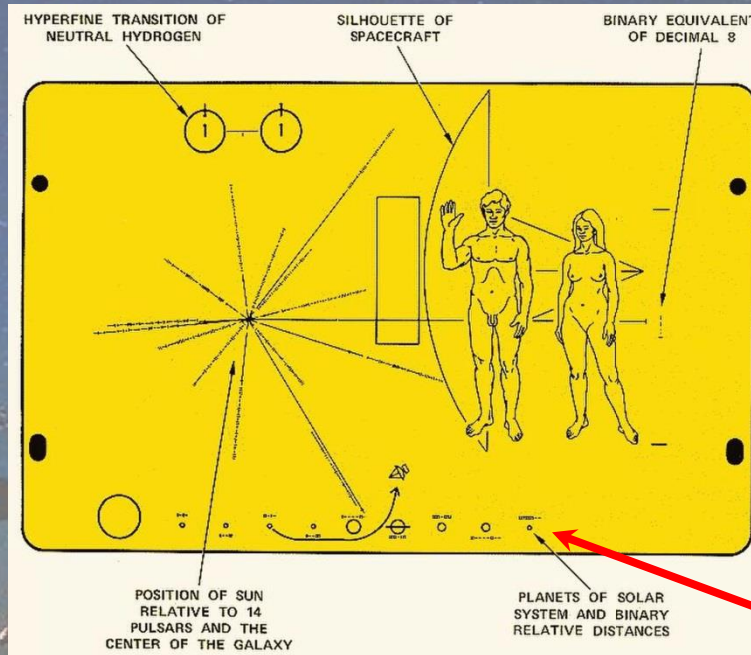
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- original idea by Eric Burgess (journalist and friend of Arthur C. Clarke)
- designed by Carl Sagan and founder of SETI Frank Drake

Pluto immortalized as ninth planet!

Pioneer Anomaly



fell behind 3000 miles each year in their projected travel

- spawned close to 1000 academic papers proposing new theories of gravity and dark matter
- mystery finally “solved” in 2012 - due to unbalanced thermal radiative heat

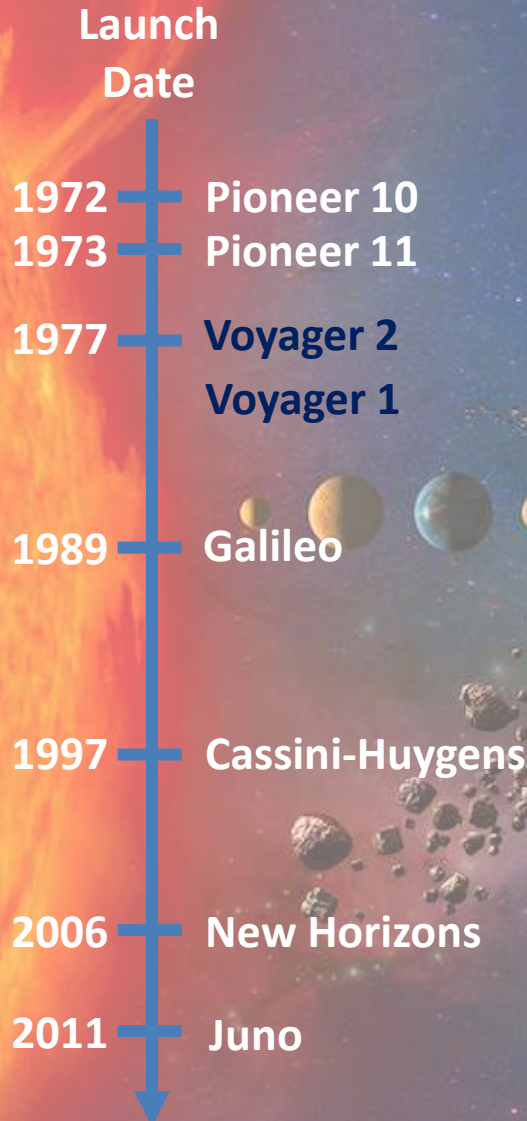
Probes to the Outer Solar System

Voyager 1 and 2

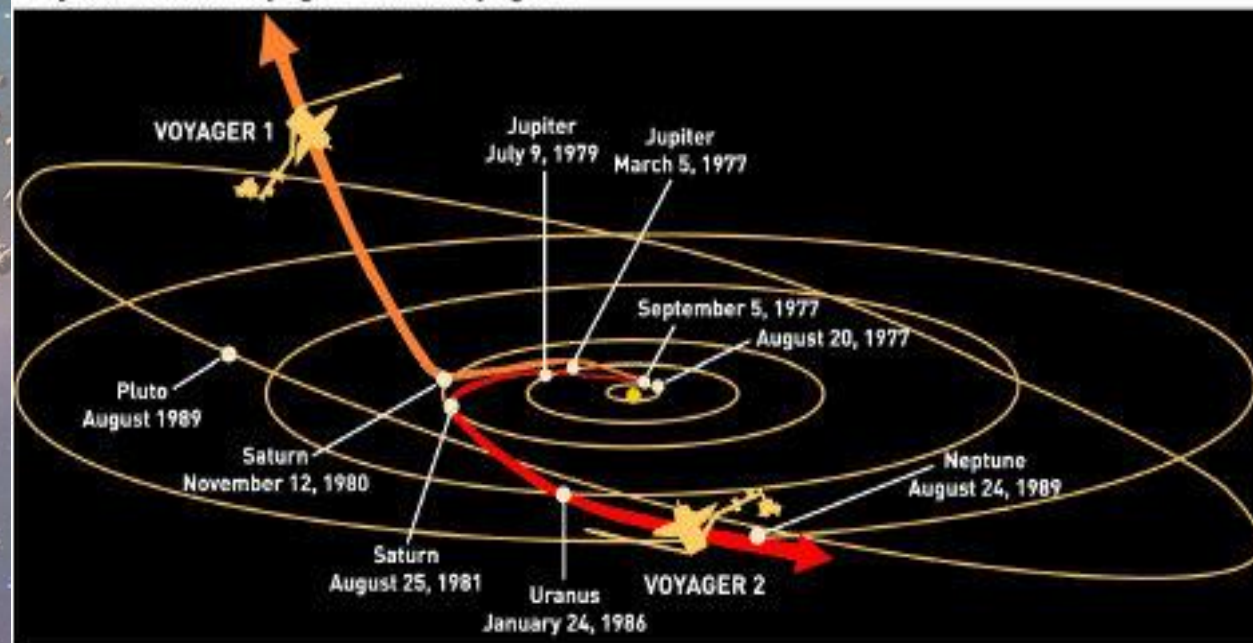
Originally funded to study Jupiter, Saturn and moons

Voyager 1 faster trajectory designed for optimal flyby of Saturn's moon Titan – could also (instead) have gone to Pluto

Voyager 2 trajectory designed to continue to Uranus and Neptune – in case of Voyager 1 failure, could have been diverted to Saturn's moon Titan



Trajectories of Voyager 1 and Voyager 2



Probes to the Outer Solar System

Voyager 1 and 2 @ Jupiter

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Voyager 1

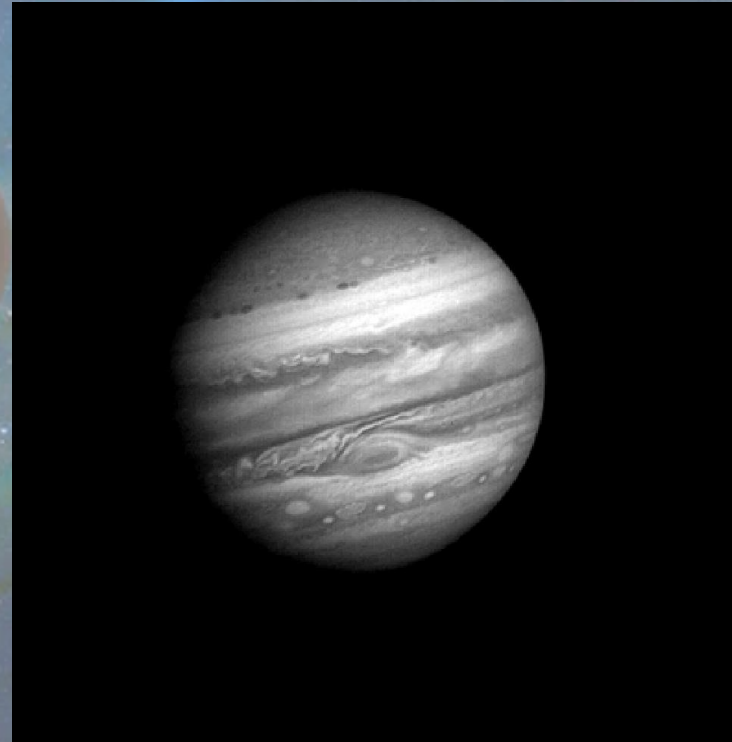
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Hardware: Powered by three Pu-238 thermoelectric generators
More advanced imaging system – two cameras, wide + narrow angle lens, 8-Filter color wheel



Data transmission rate: 115,000 bits/s, max on board storage of 64 Kbytes

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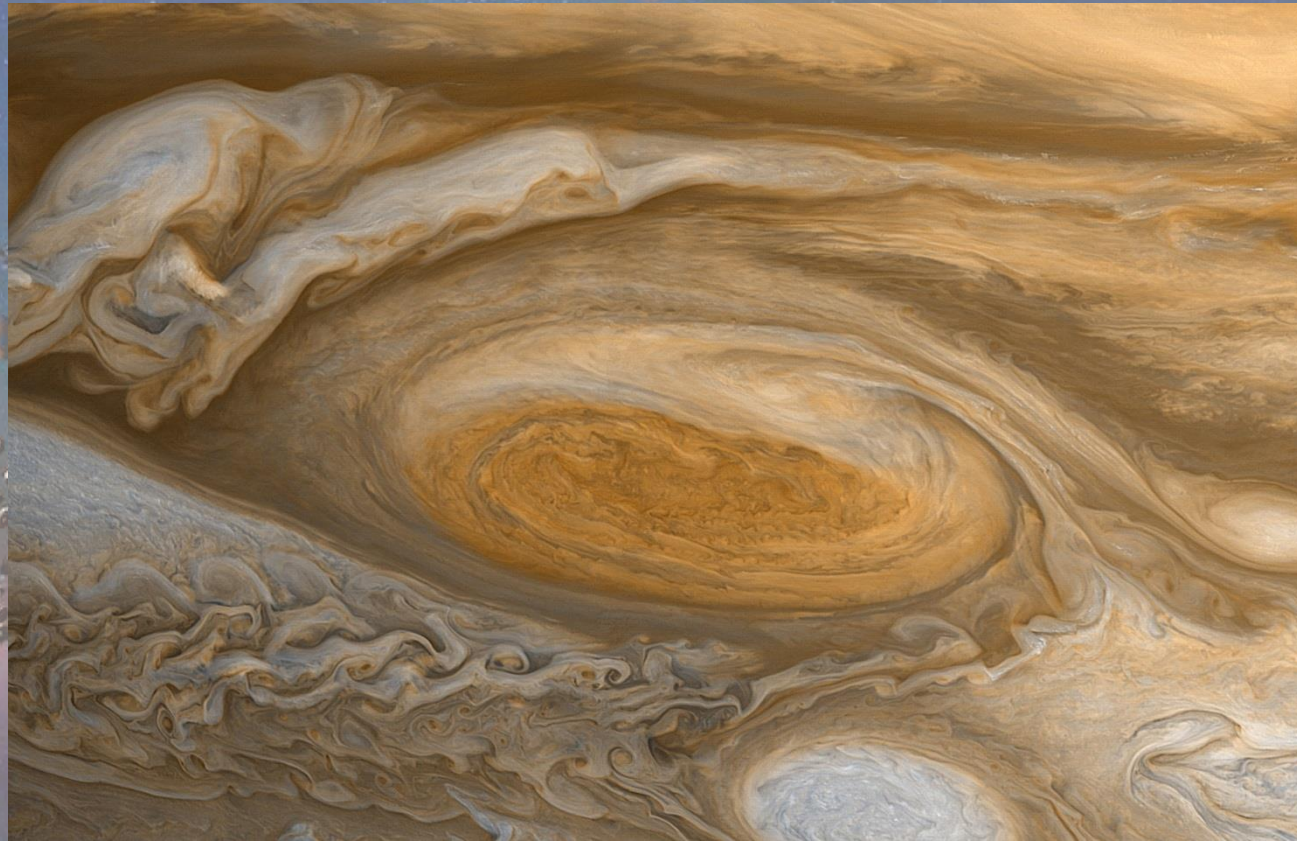
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Red Spot

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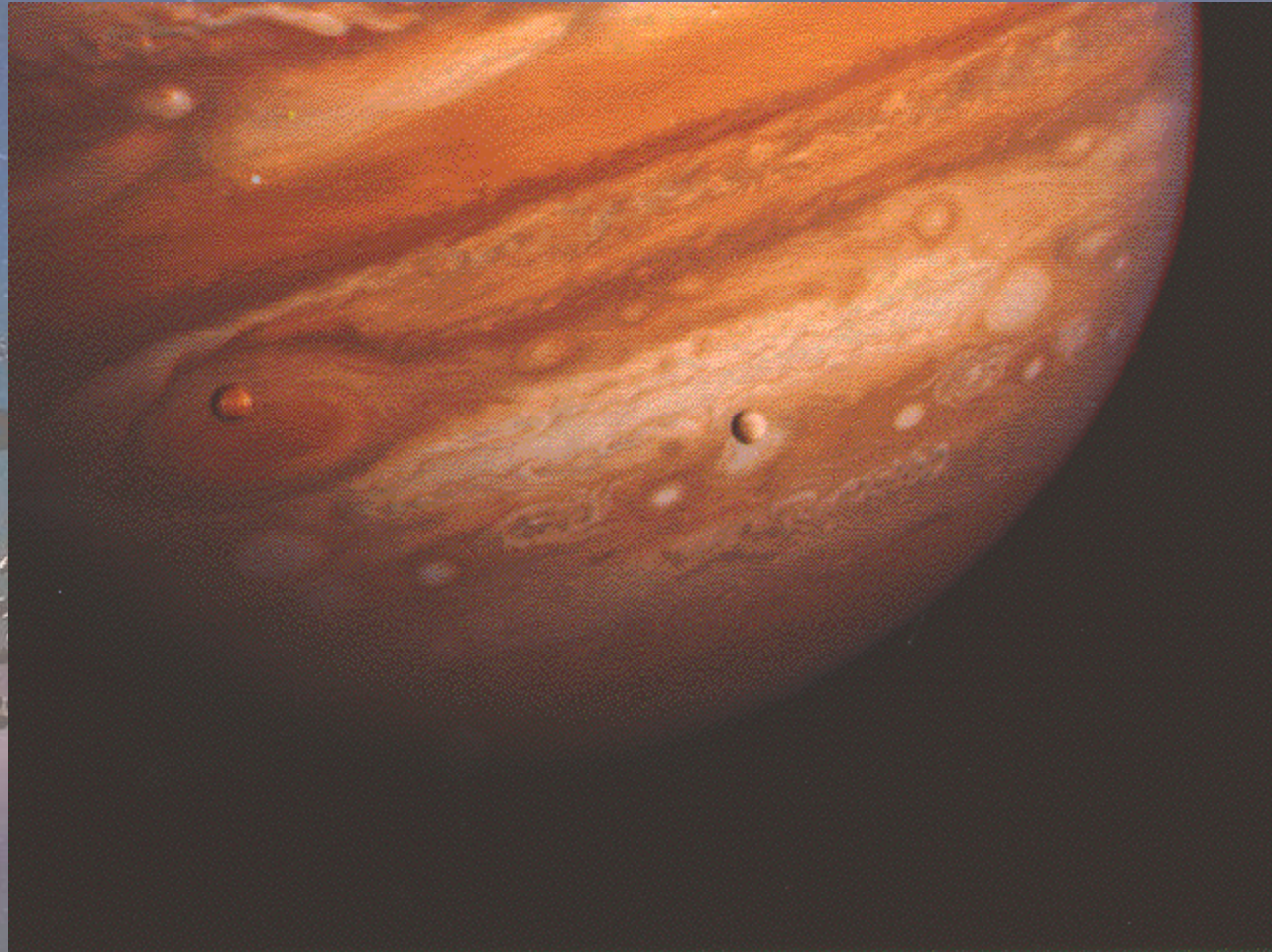
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Jupiter's Red Spot, Io and Callisto

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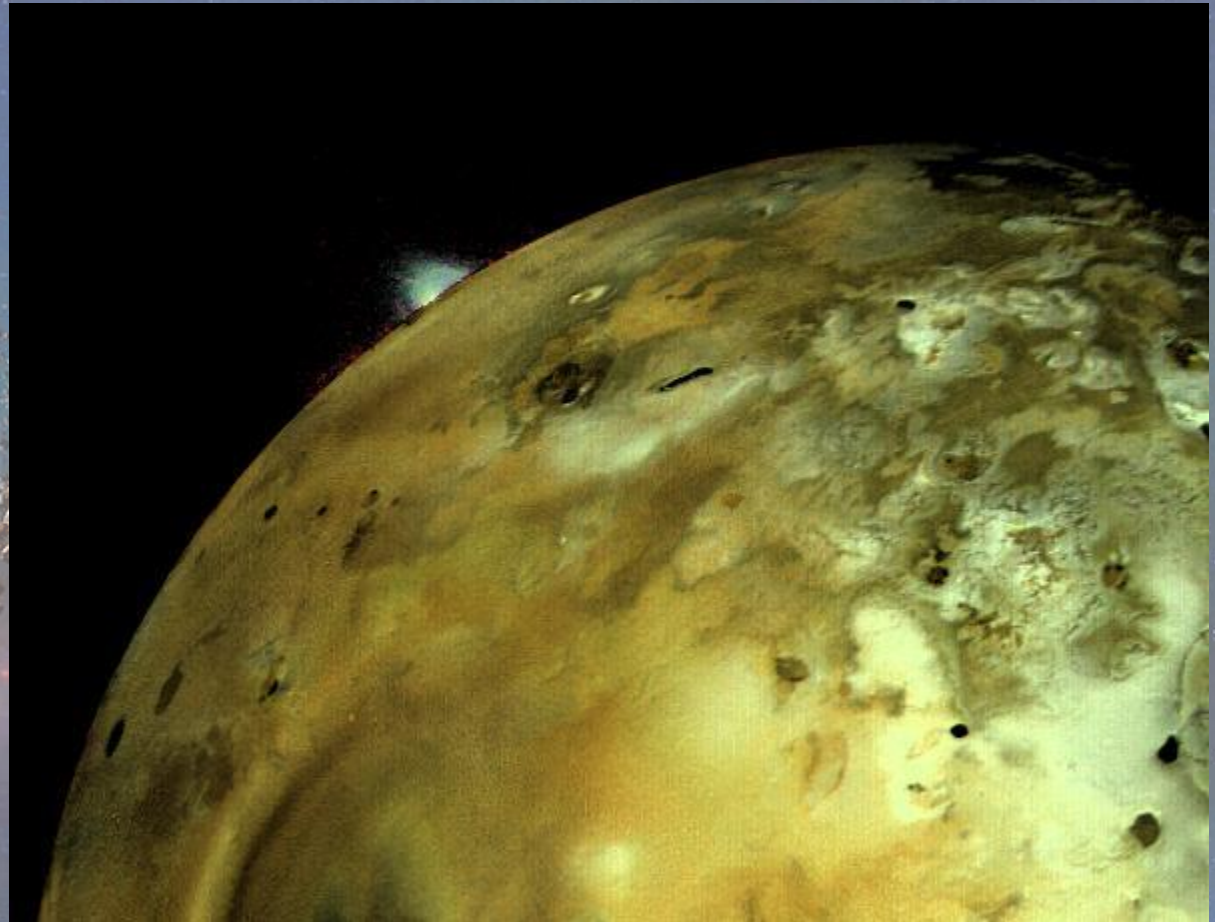
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Volcanic Eruption on Io

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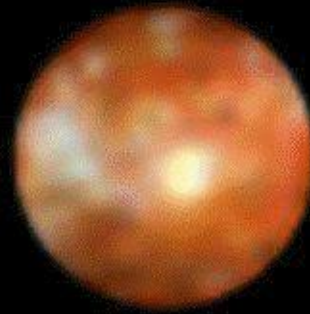
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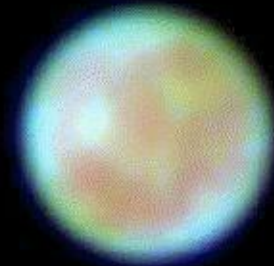
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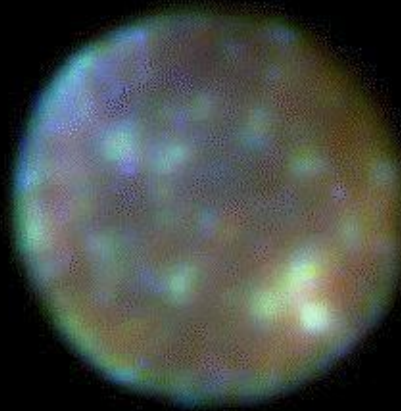
Best available images from HST



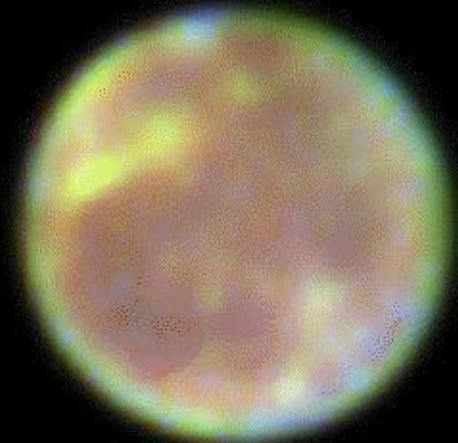
Io



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Callisto



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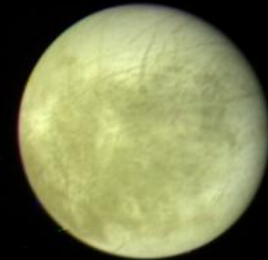
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Best available images from Voyagers



Io



Europa



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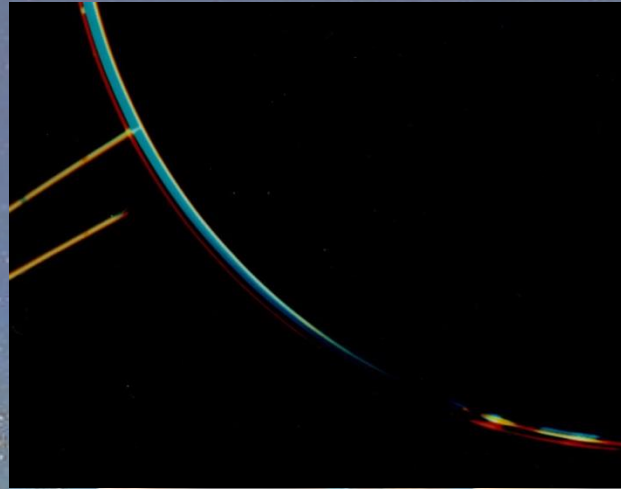
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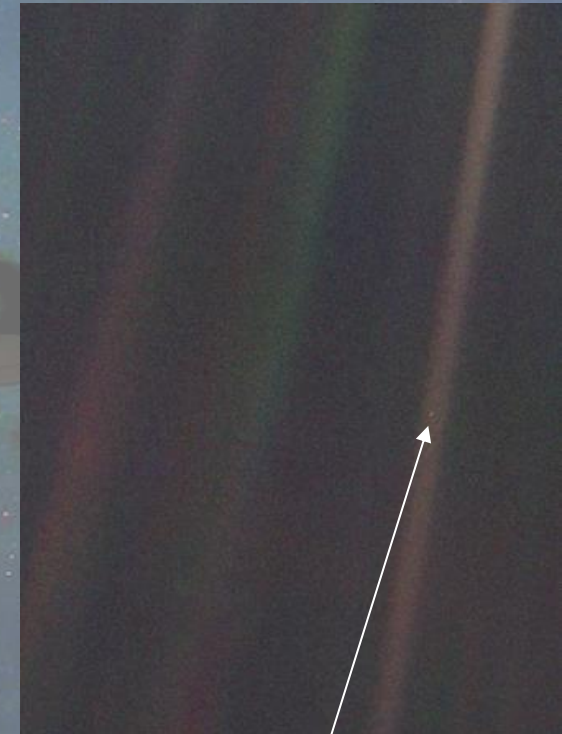
2011 Juno



Jupiter Ring



Voyager Golden Record



Pale Blue Dot - Earth

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Voyager 1 and 2 @ Saturn

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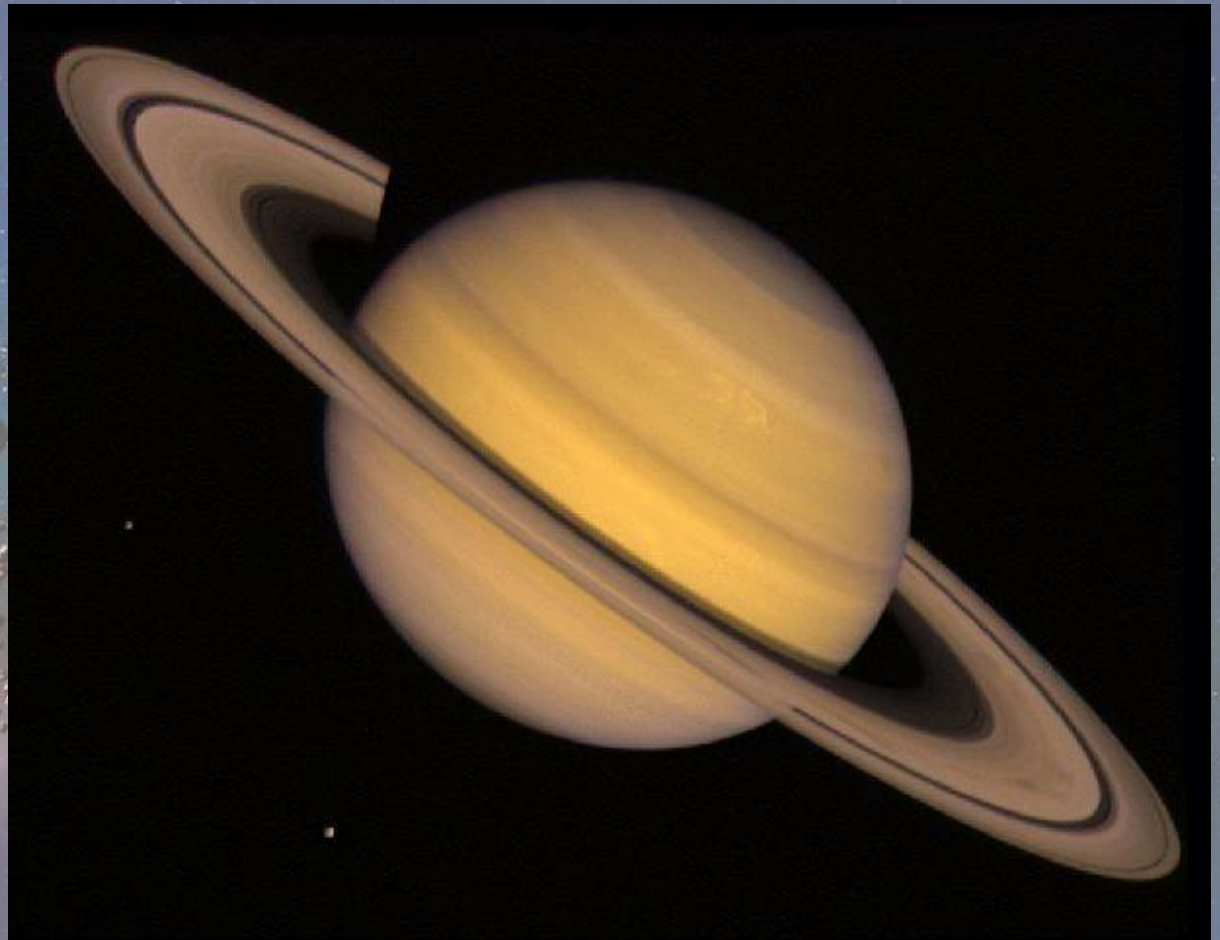
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Saturn from 21 million miles, 1 month before closest approach

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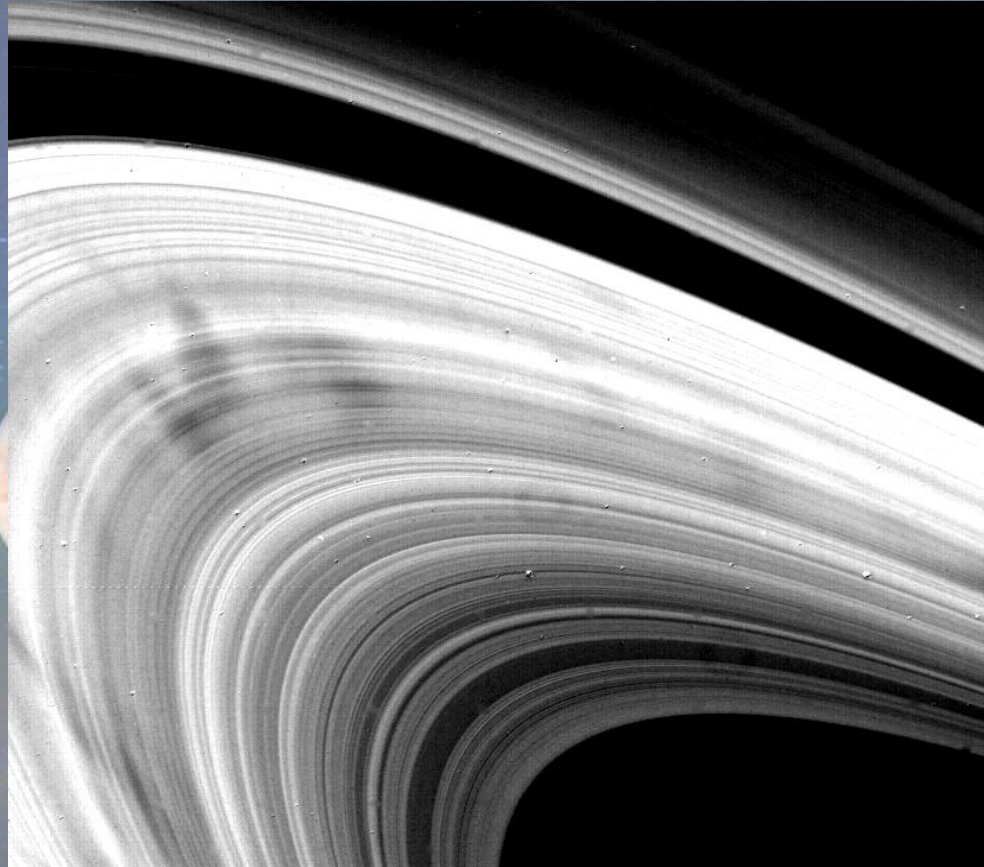
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- spokes caused by charged dust particles suspended above and below the rings due to interaction with Saturn's magnetic field
- thought to be seasonal over Saturn's near-30 year solar orbit

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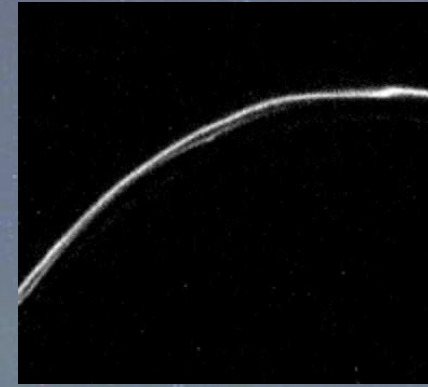
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Dione – wispy features thought to be due to cryovolcanism



Discovered F-Ring



Mimas

- smallest body known to be rounded in shape because of self gravitation (256 mi)
- responsible for clearing Cassini division

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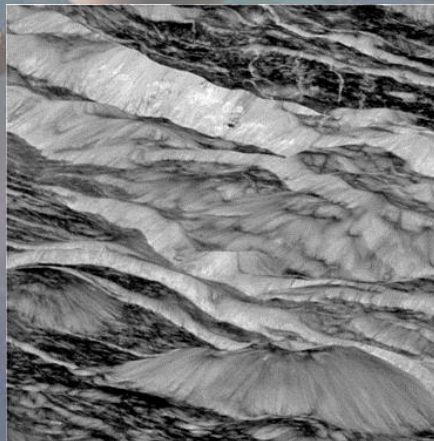
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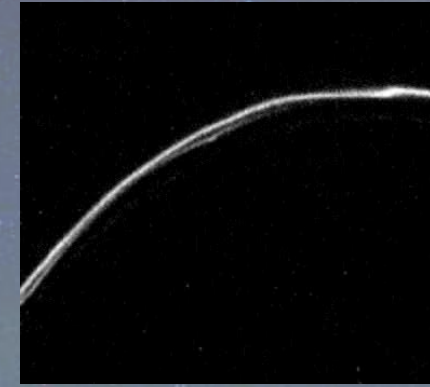
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Ice cliffs caused by tectonic fractures due to subsurface liquid water ocean



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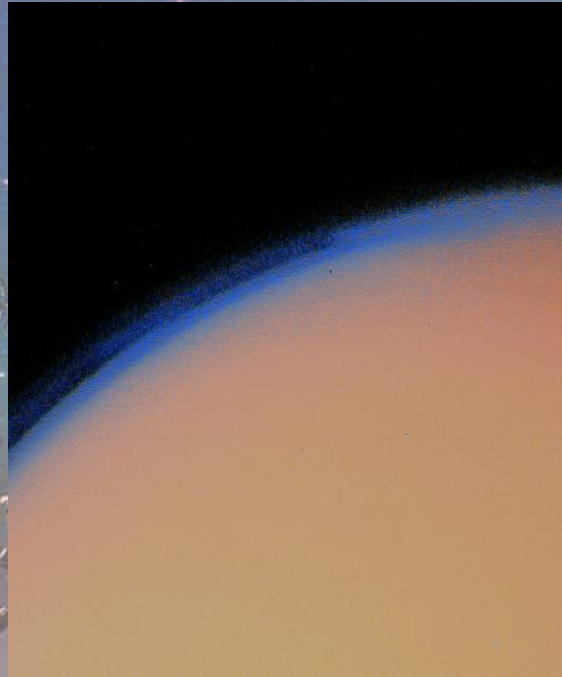
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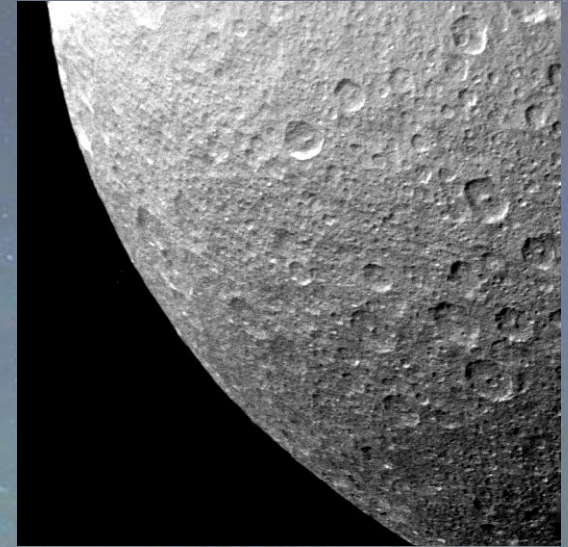
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Titan Haze



Rhea – pockmarked with craters

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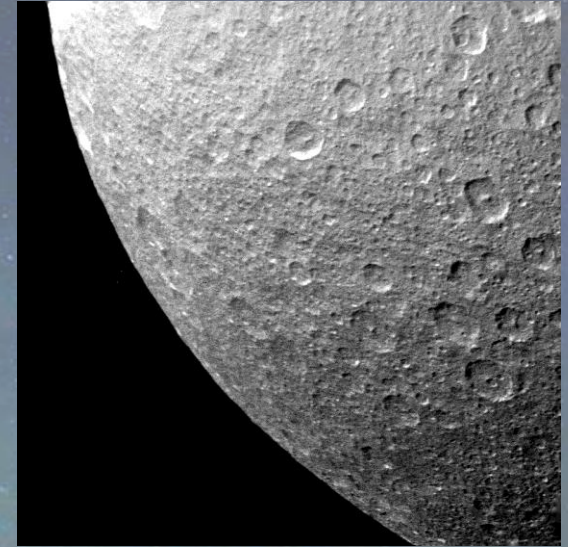
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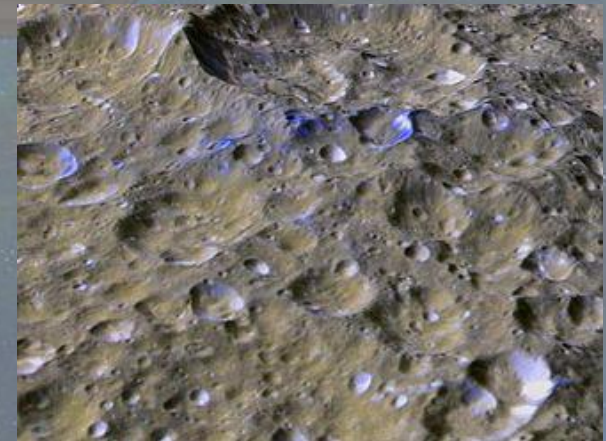
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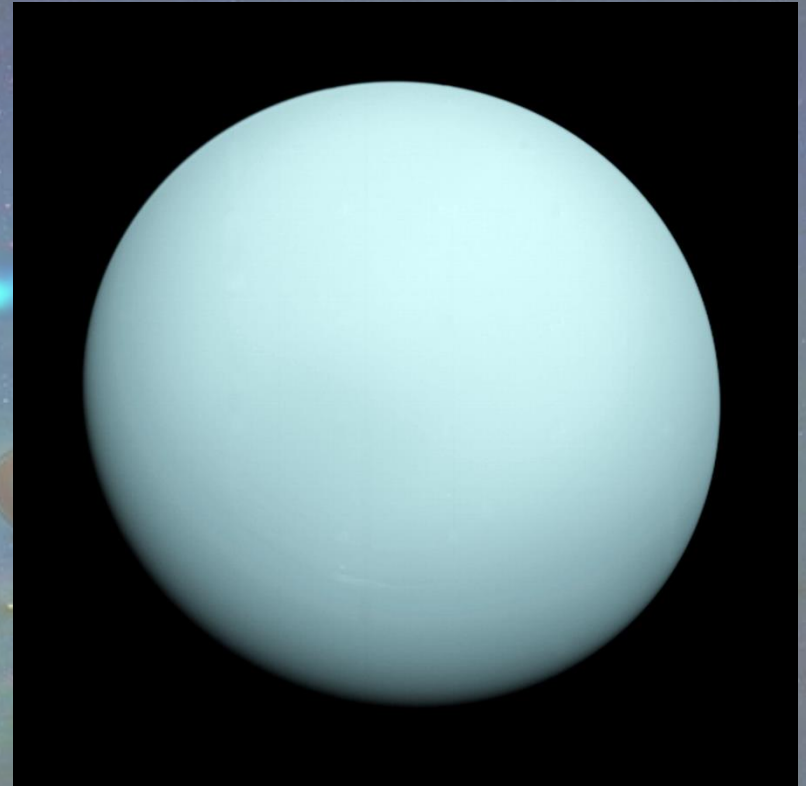
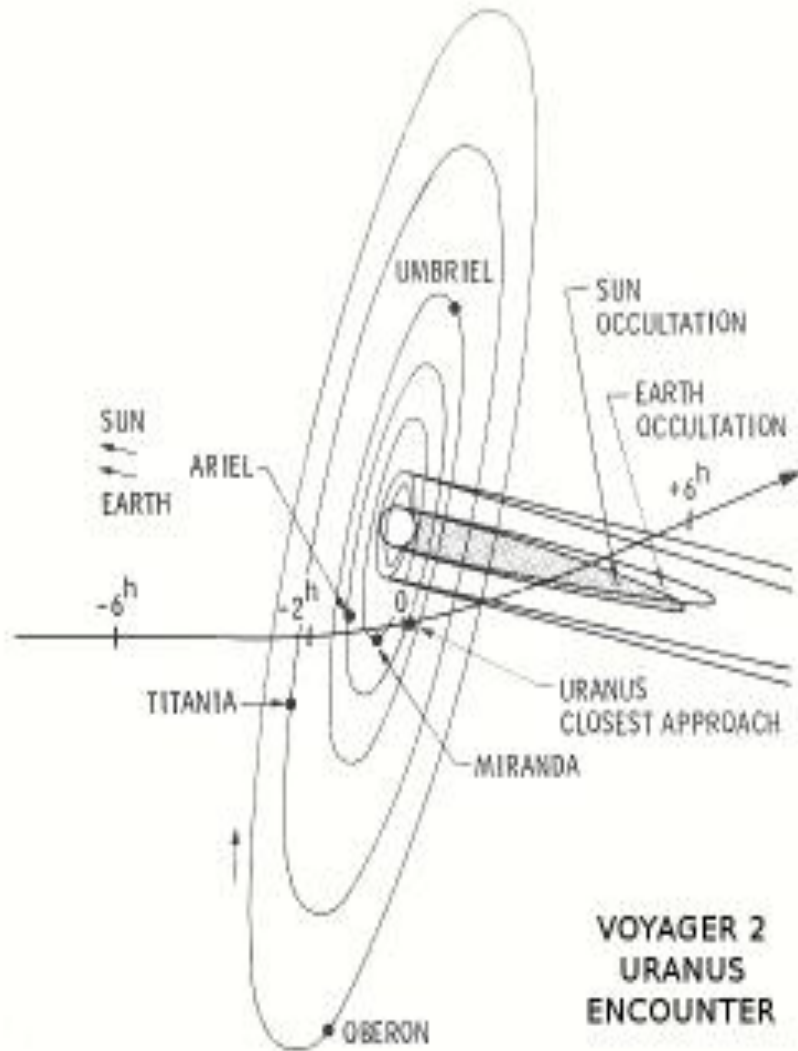
Rhea – pockmarked with craters



Fresh blue ice suggests regular impacts from deorbited material

Probes to the Outer Solar System

Voyager 2 @ Uranus



- Closest approach of 50,000 mi in Jan. 1986
- Discovered 10 new moons
- Corrected planet's rotation rate (17h 14m)
- Found equatorial region to be warmer than polar region facing the Sun

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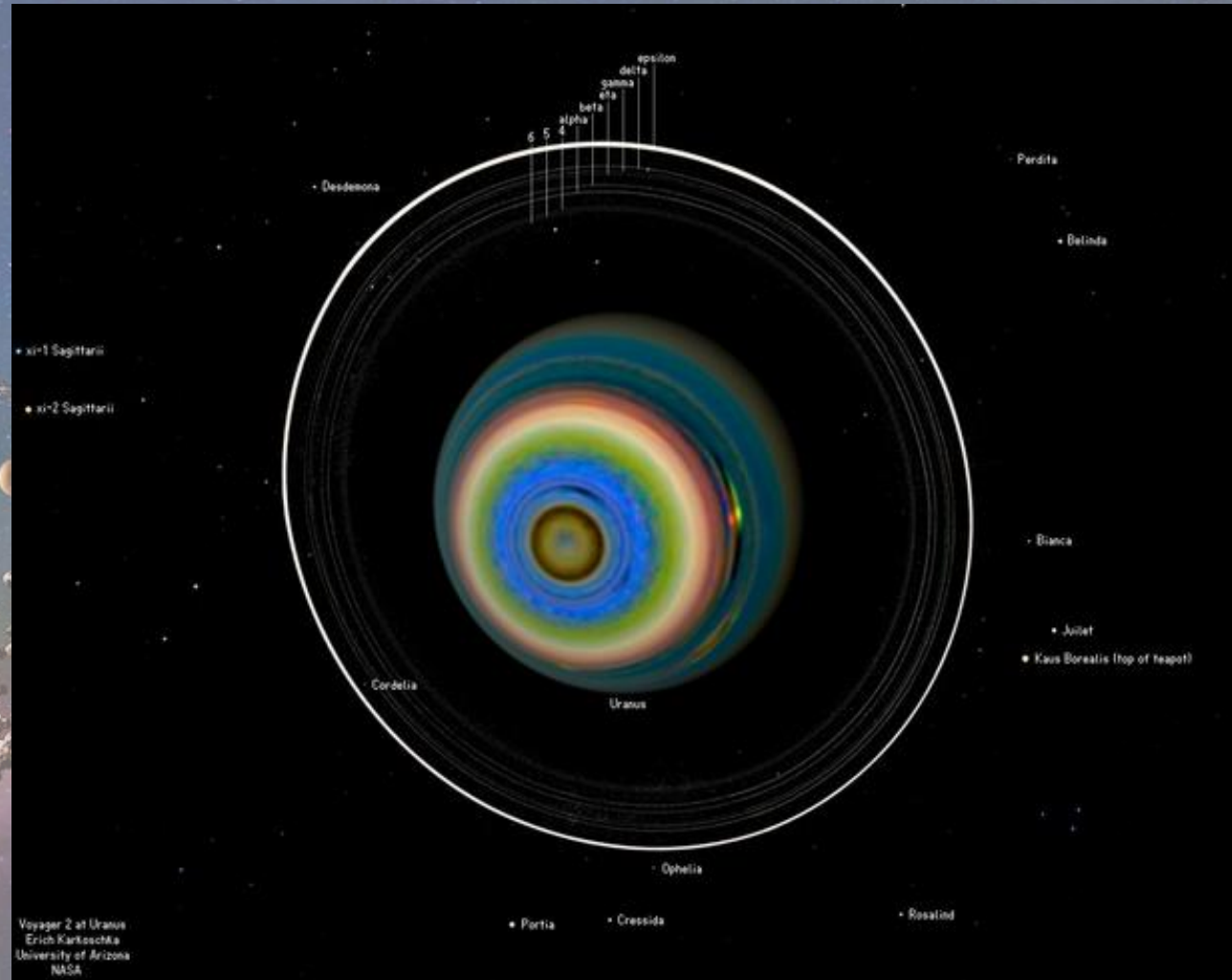
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Reprocessed Uranus images showing more southern hemisphere detail, rings and moons

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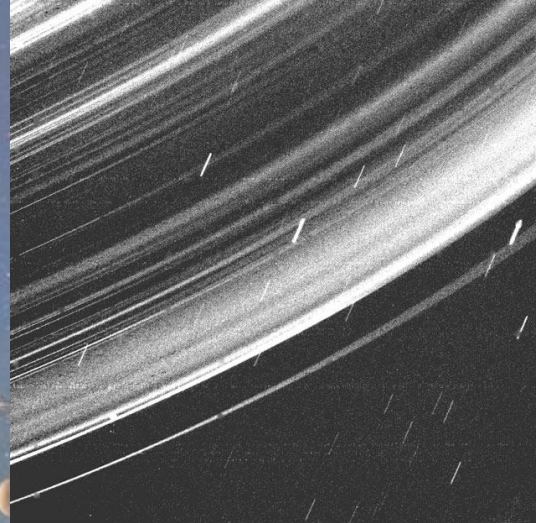
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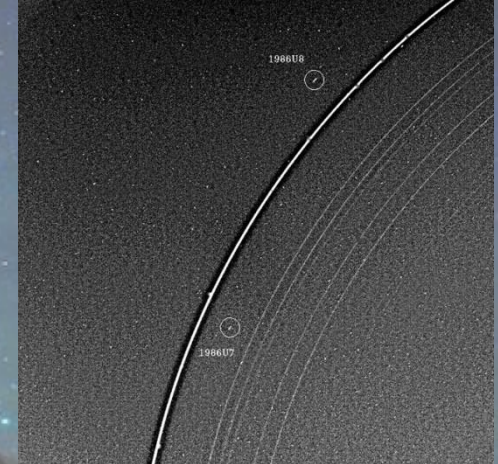
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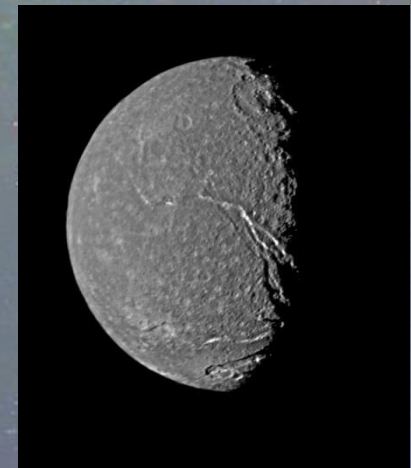
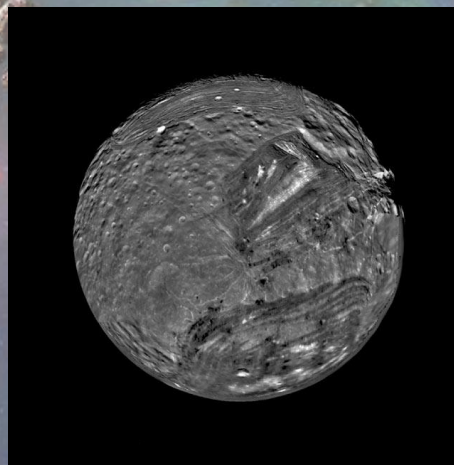
2011 — Juno



Backlit View of Rings



Two "shepherd" moons, 1986U7 and 1986U8, with epsilon ring



Miranda (left) and Titania (right) showing evidence of geological activity

Probes to the Outer Solar System

Voyager 2 @ Neptune



Neptune and the Dark Spot

- Closest approach to Neptune in 1989 (3000 mi) and 25,000 mi from Triton
- Strongest winds in the solar system (3 times stronger than Jupiter)
- Updated mass disproved Planet X
- Discovered six new moons



Triton

Discovered active geysers and polar caps on Triton, thin atmosphere with nitrogen ice particles

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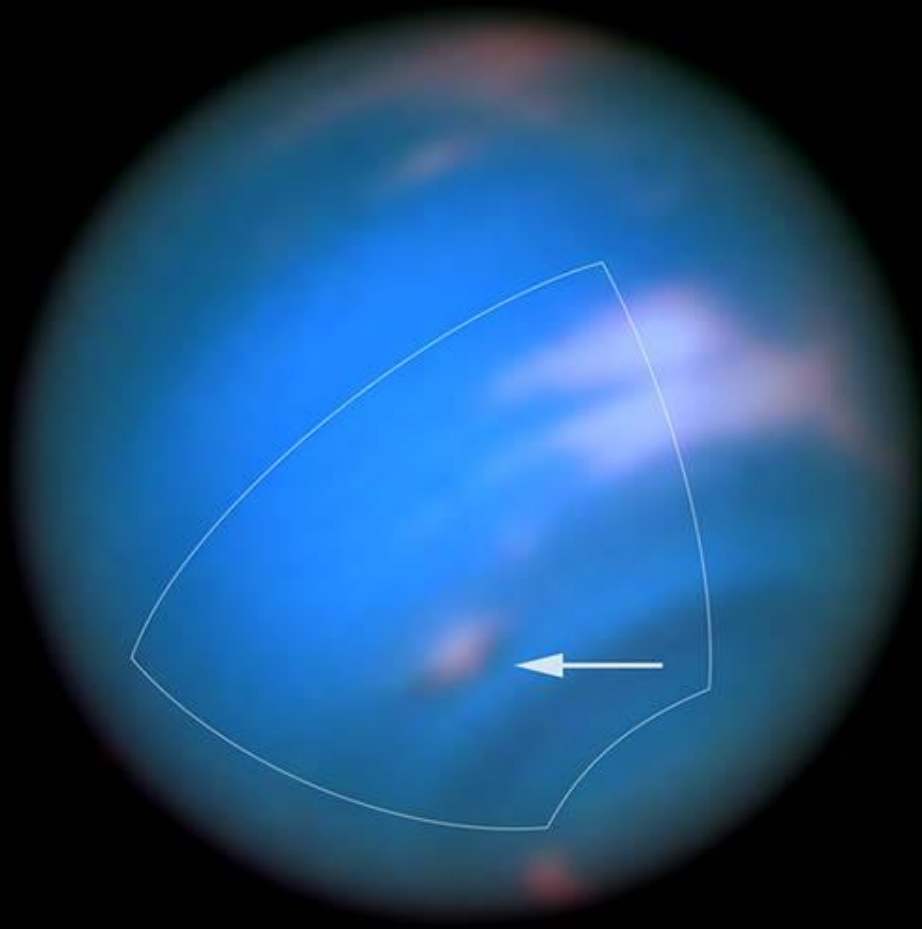
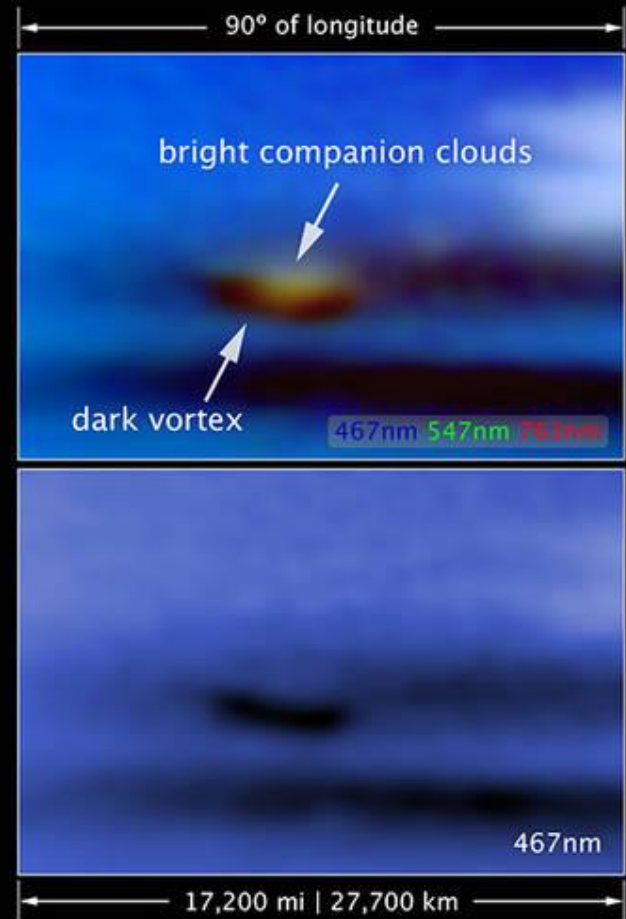
Triton moon mosaic



Probes to the Outer Solar System

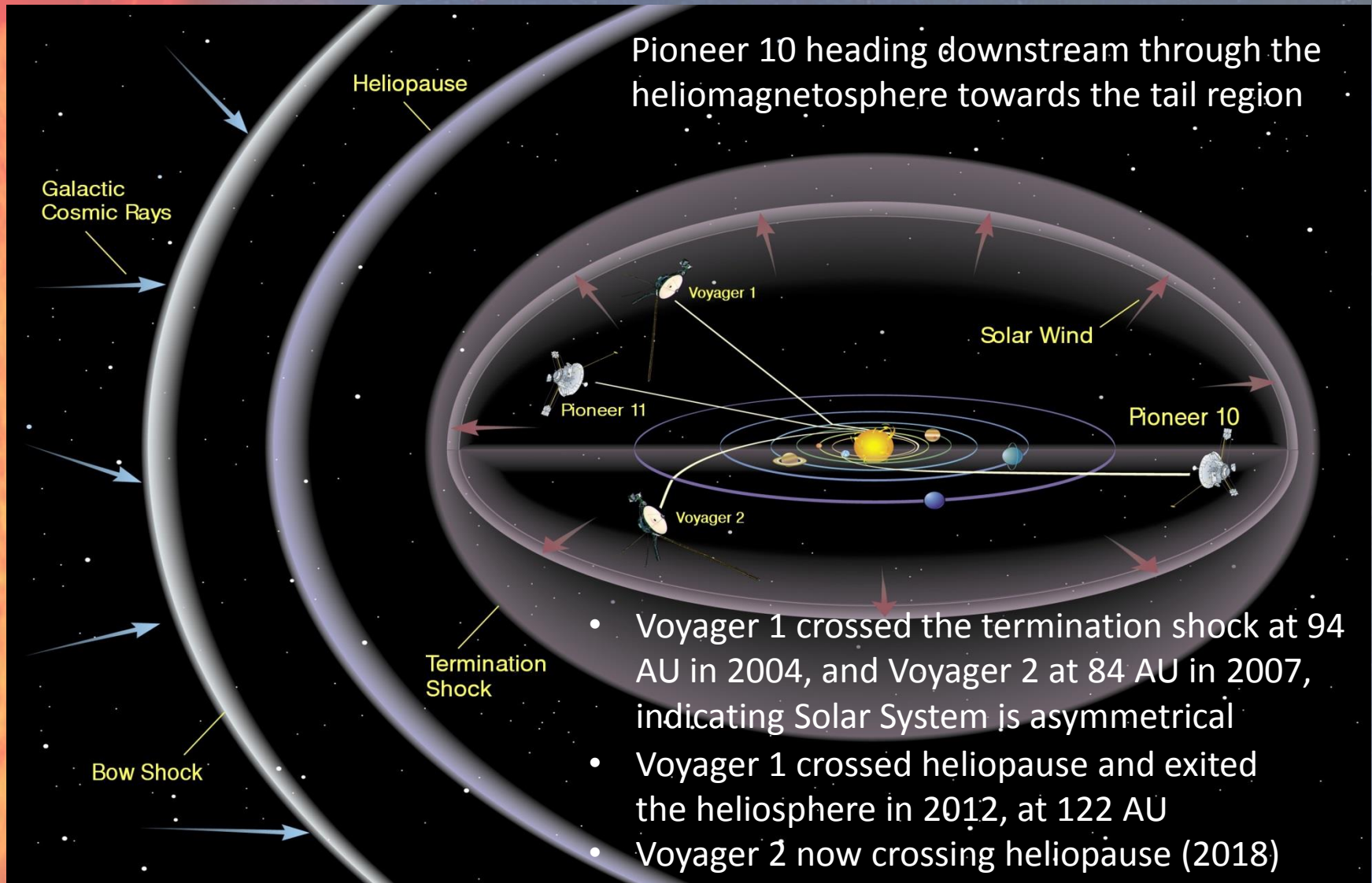
Voyager 2 @ Neptune

Dark Spot on Neptune ■ May 16, 2016
Hubble Space Telescope ■ WFC3/UVIS



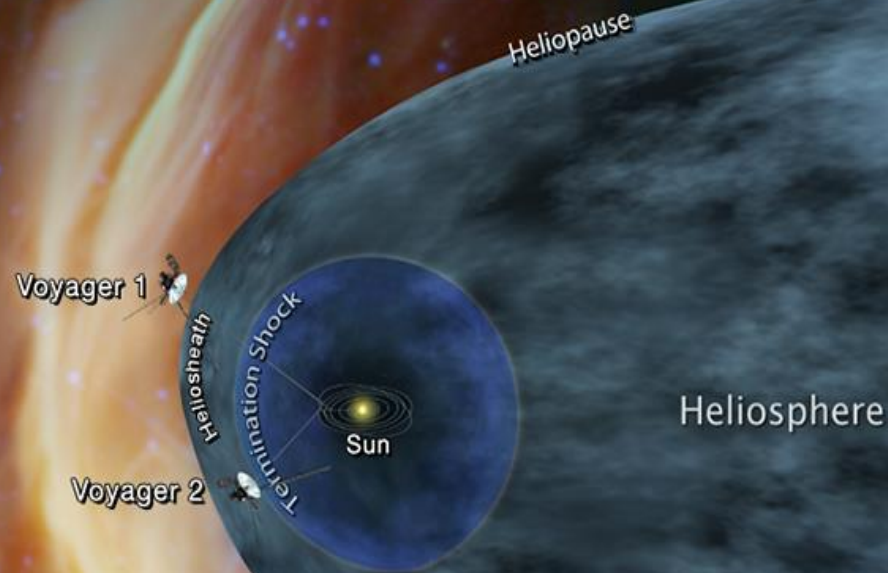
Probes to the Outer Solar System

Voyager 1 and 2



Probes to the Outer Solar System

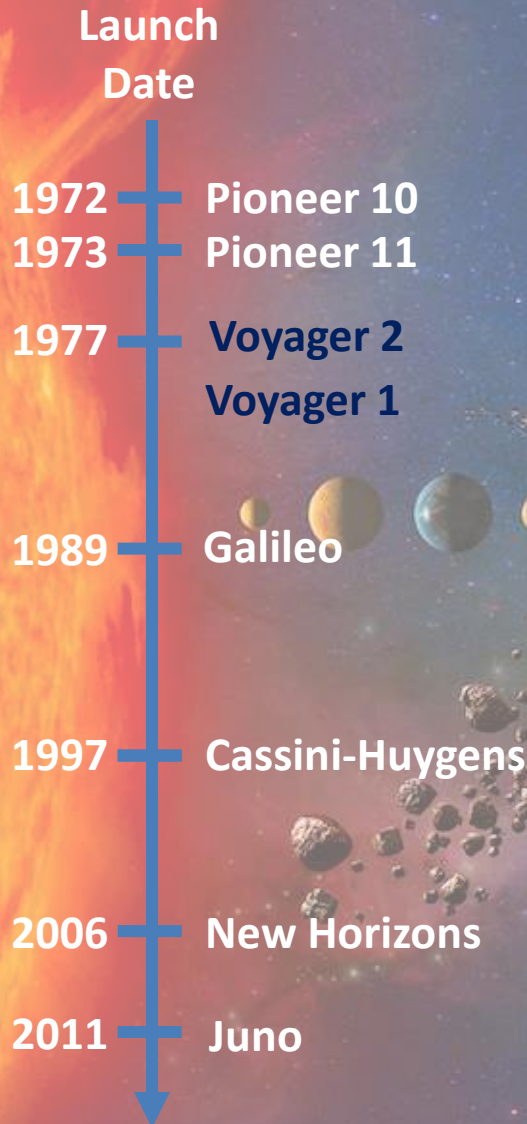
Voyager 1 and 2



Most accurate graphical depiction of the Heliosphere to date (2018)

Probes to the Outer Solar System

Voyager 1 and 2



Voyager 1 is escaping the solar system at the speed of 3.6 AU per year

In about 40,000 years, *Voyager 1* will be within 1.6 light years of AC+79 3888, which is a star in the constellation of Camelopardalis.

In 40,000 years *Voyager 2* will be within 1.7 light years from star Ross 248 and in 296,000 years it will pass within 4.6 light years of Sirius

Probes to the Outer Solar System

End

Thank you!

