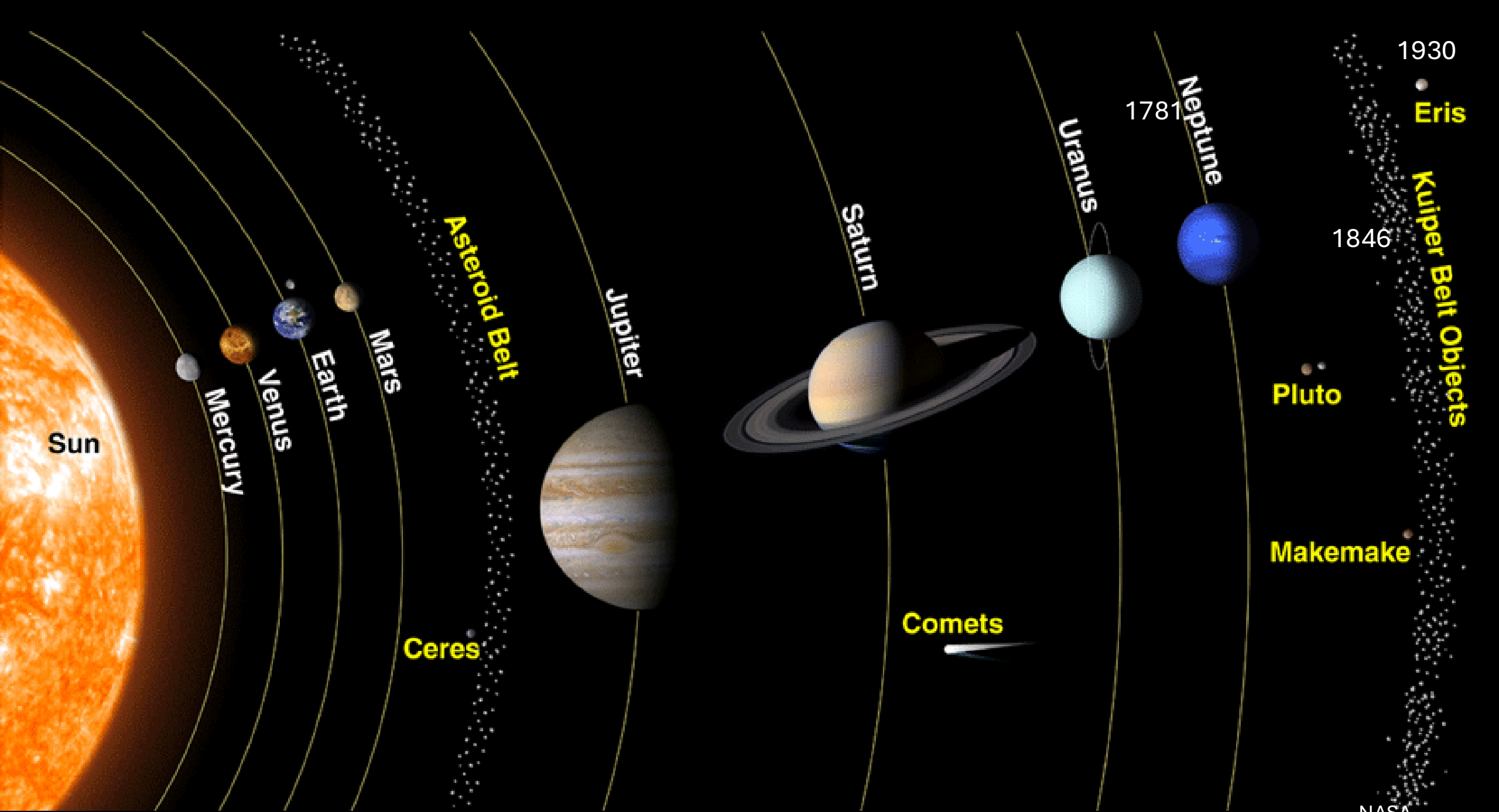


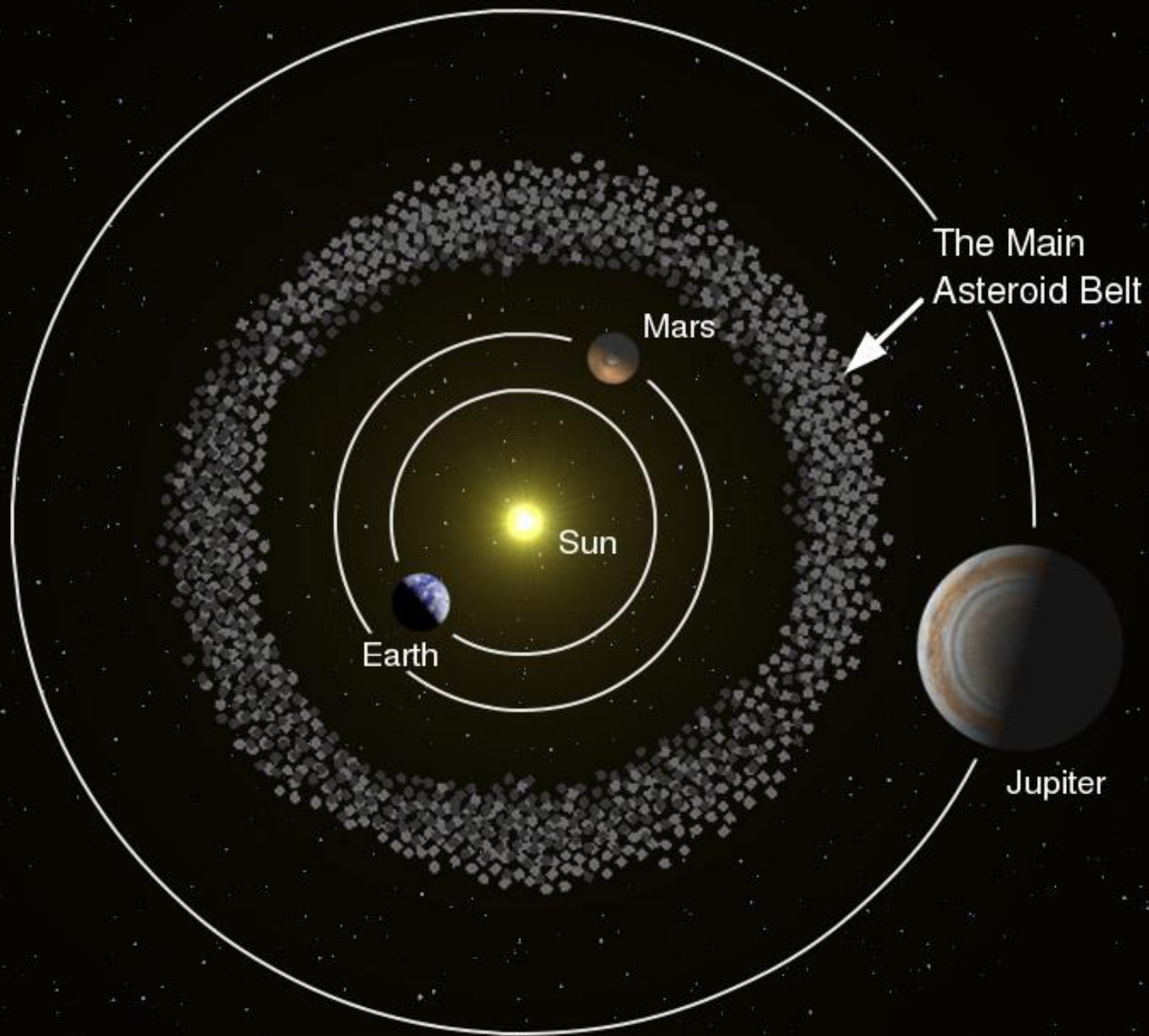
The Voyager Missions

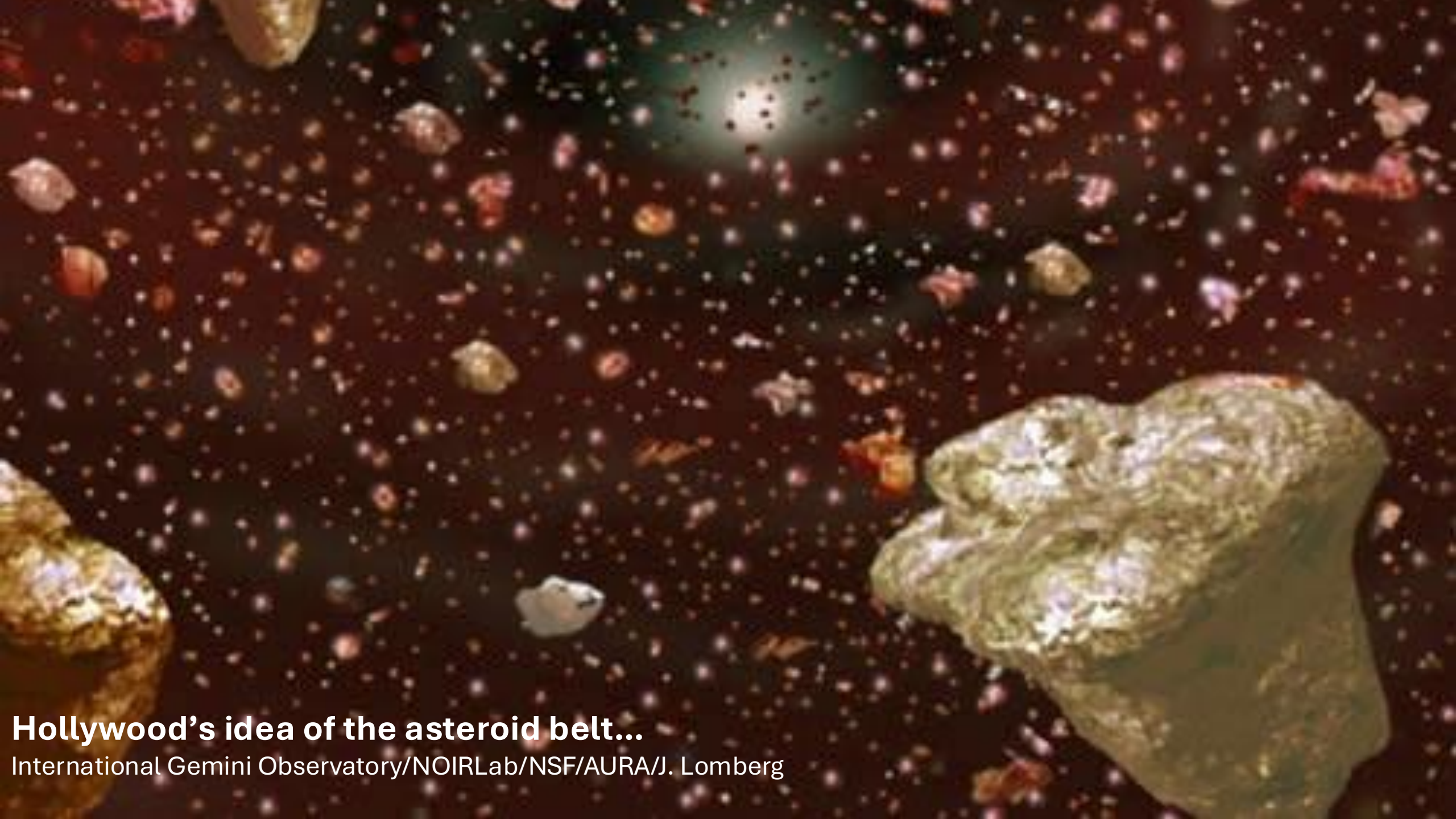
The Grand Tour of the Solar System



Things we did not know...

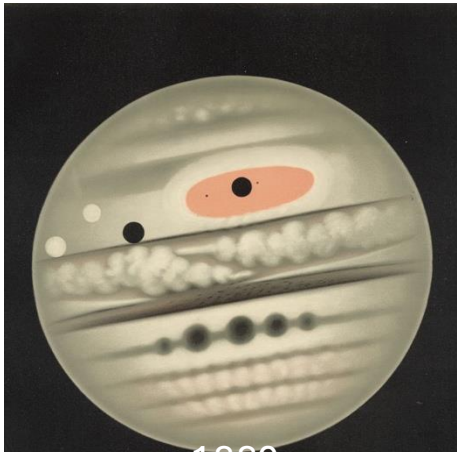






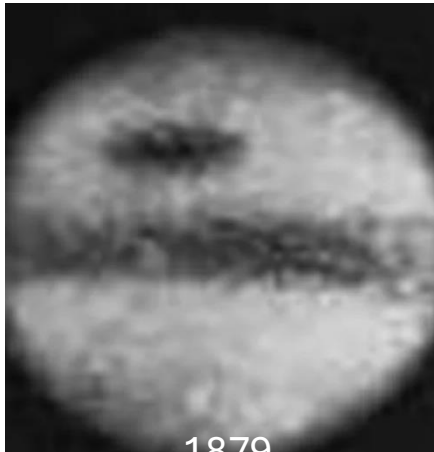
Hollywood's idea of the asteroid belt...

International Gemini Observatory/NOIRLab/NSF/AURA/J. Lomberg



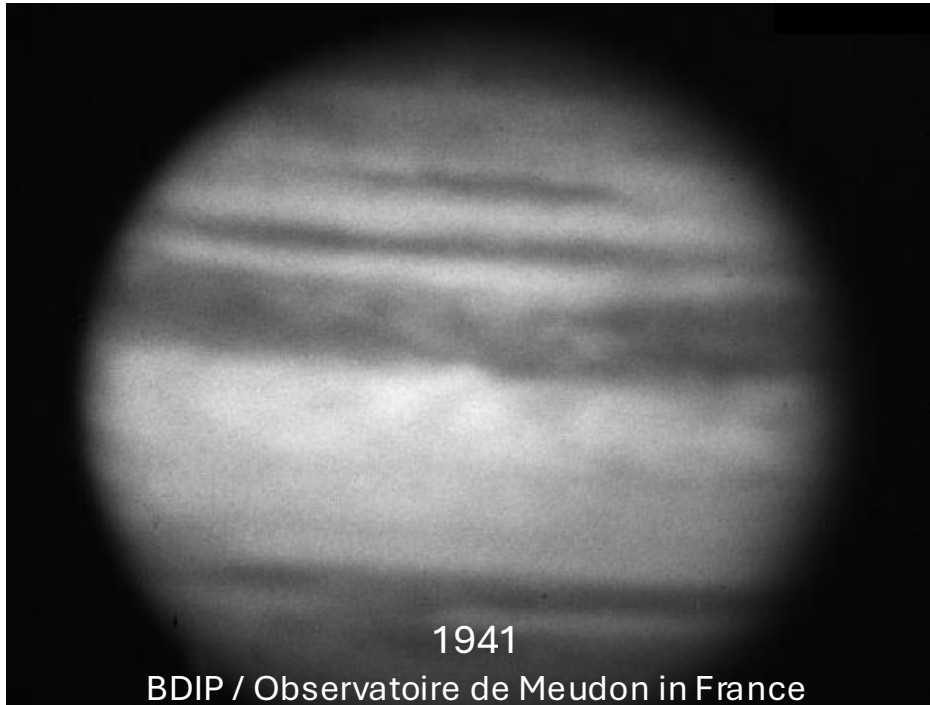
1880

Étienne Léopold Trouvelot



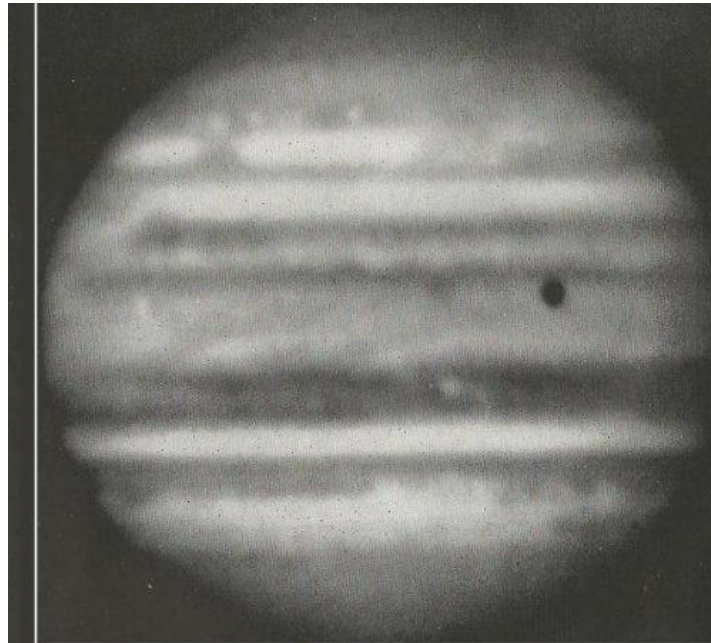
1879

Andrew Ainslie Common

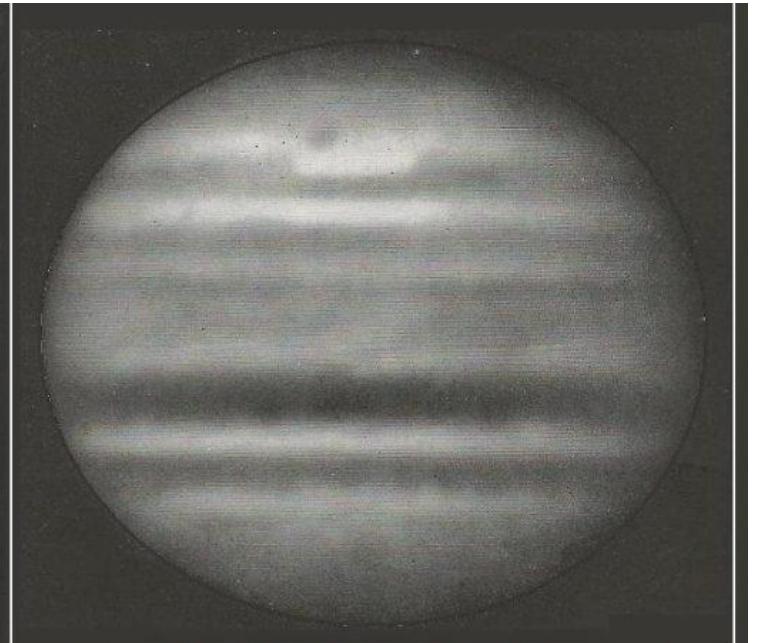


1941

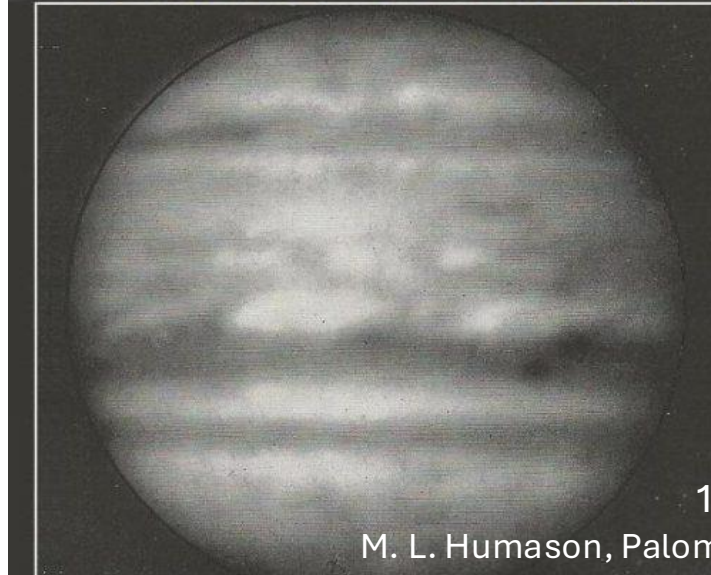
BDIP / Observatoire de Meudon in France



Oct 3d 05:03UT CM1 253 CM2 313 blue light

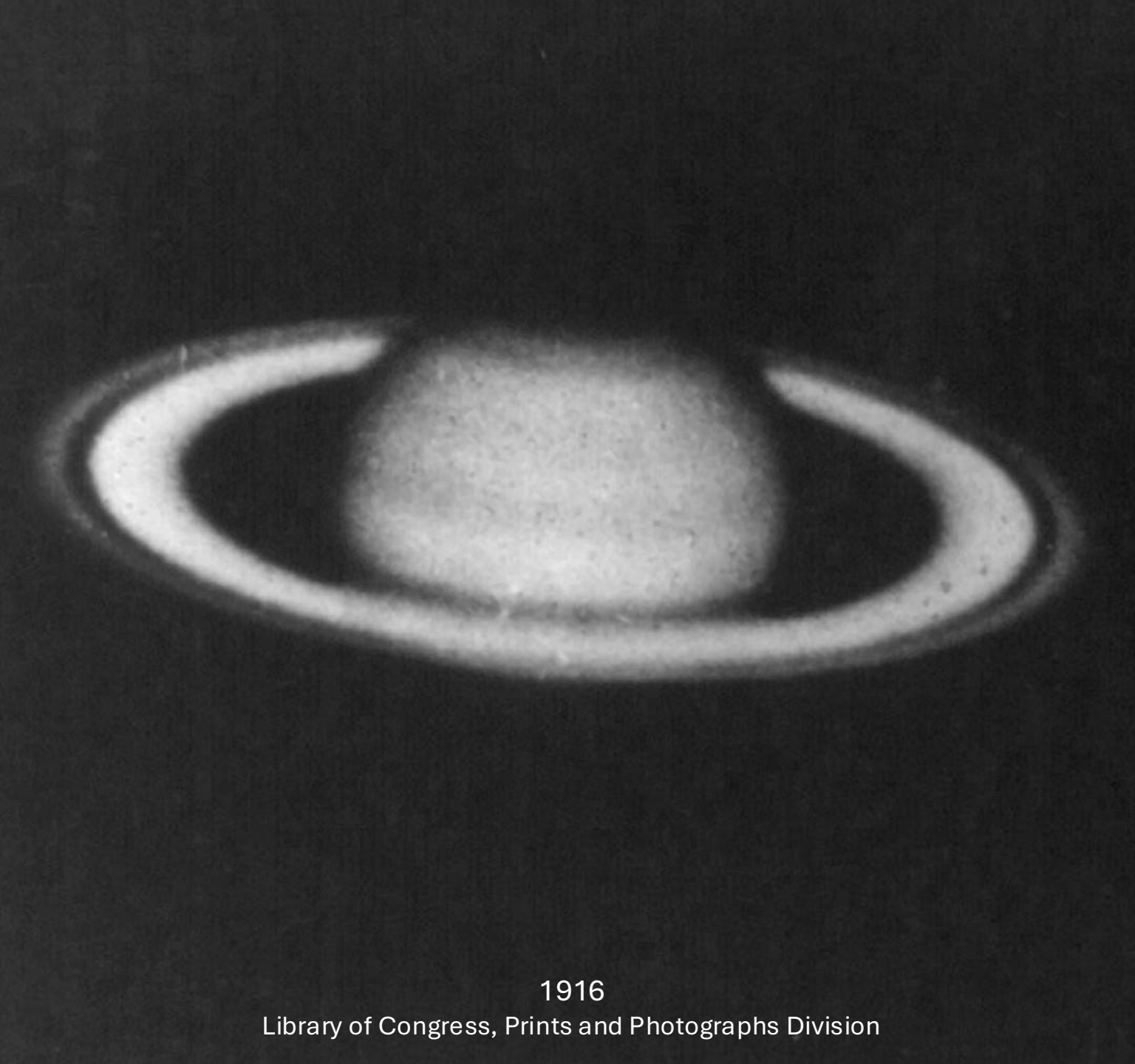


Oct 4d 04:39UT CM1 036 CM2 088 blue light



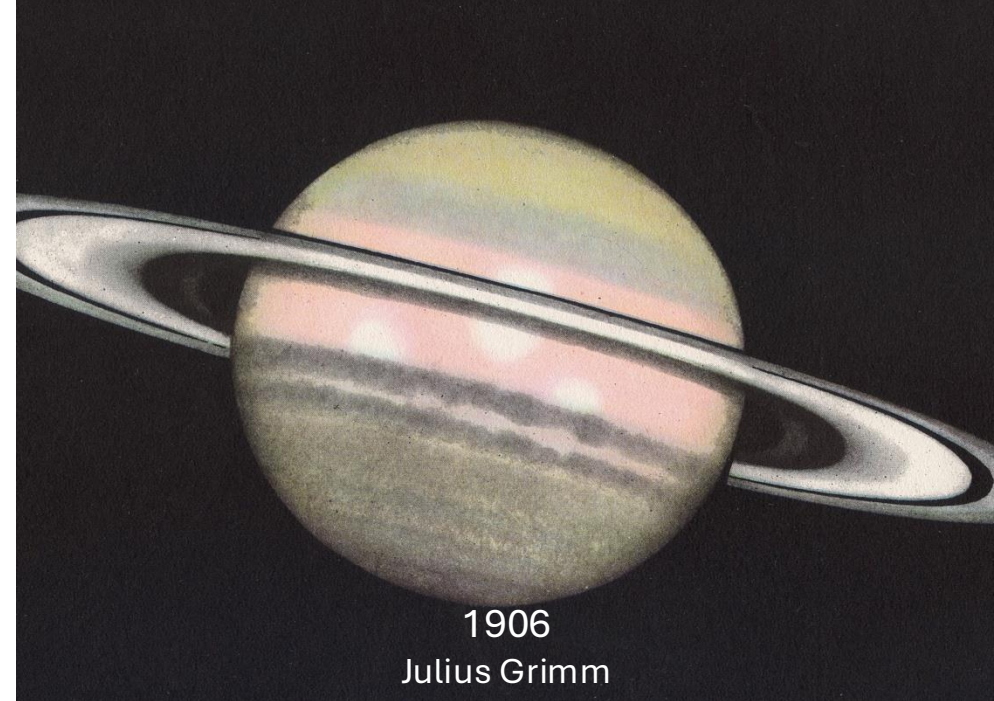
1950

M. L. Humason, Palomar Observatory / Caltech



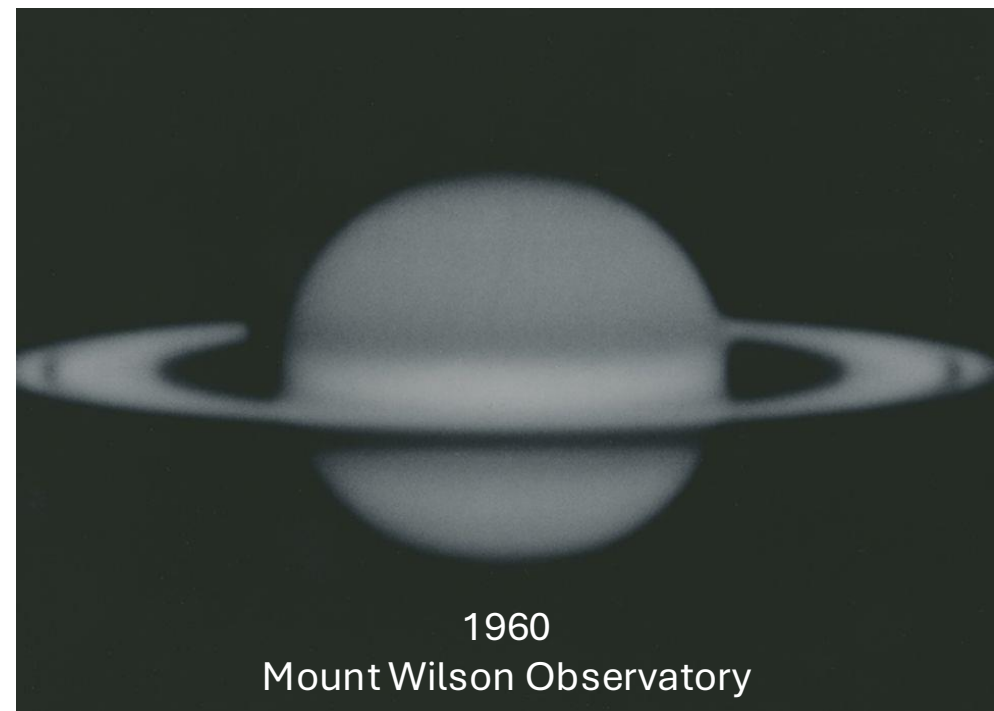
1916

Library of Congress, Prints and Photographs Division



1906

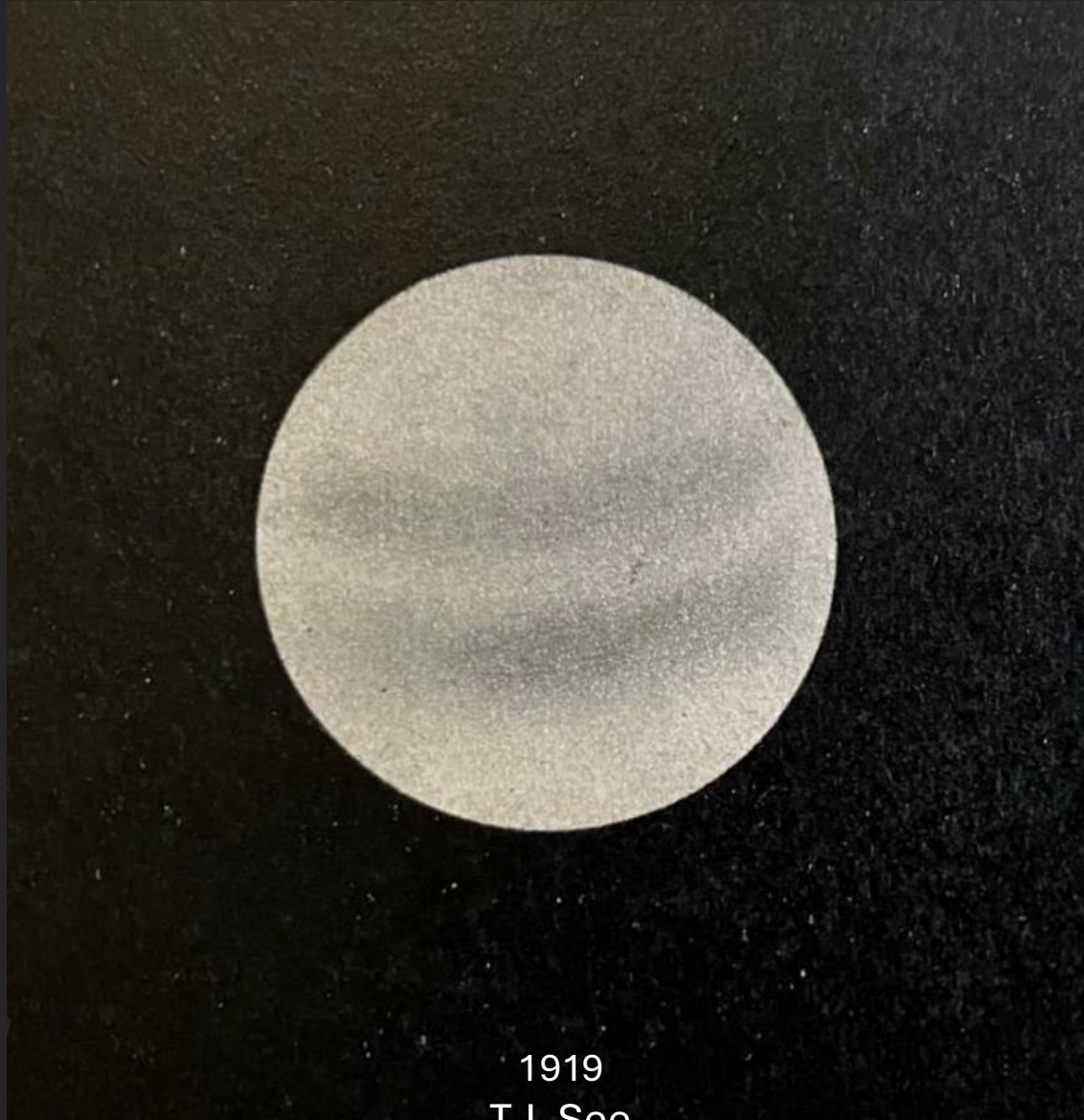
Julius Grimm



1960

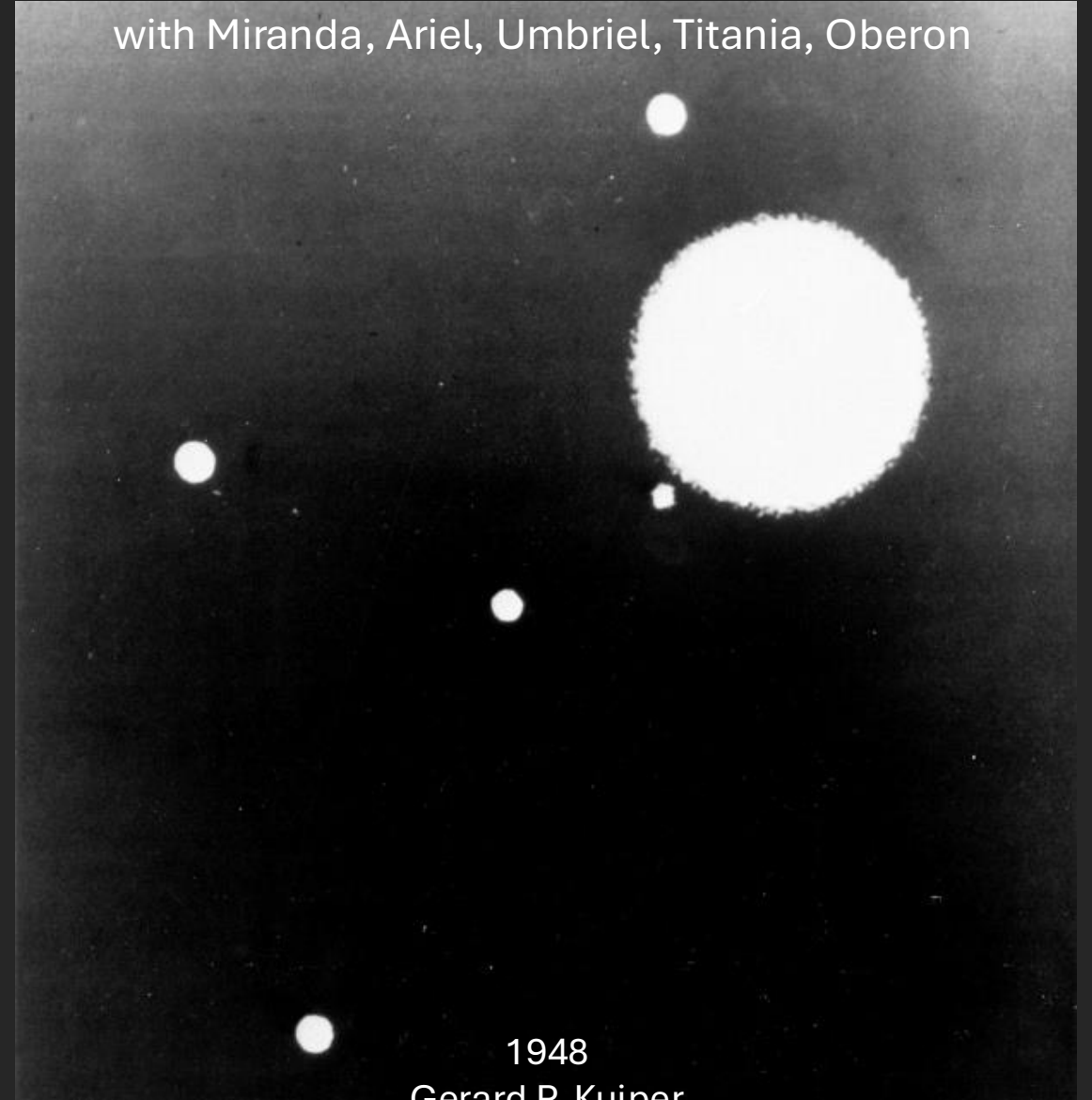
Mount Wilson Observatory

NEPTUNE



1919
T.J. See

URANUS



with Miranda, Ariel, Umbriel, Titania, Oberon

1948
Gerard P. Kuiper

Pioneer 10 and 11

Pioneer 10 – 2nd March 1972



Pioneer 11 – 5th April 1973



1972-03-03

Pioneer 10



1973-12-02 00:00

Pioneer 10

Callisto

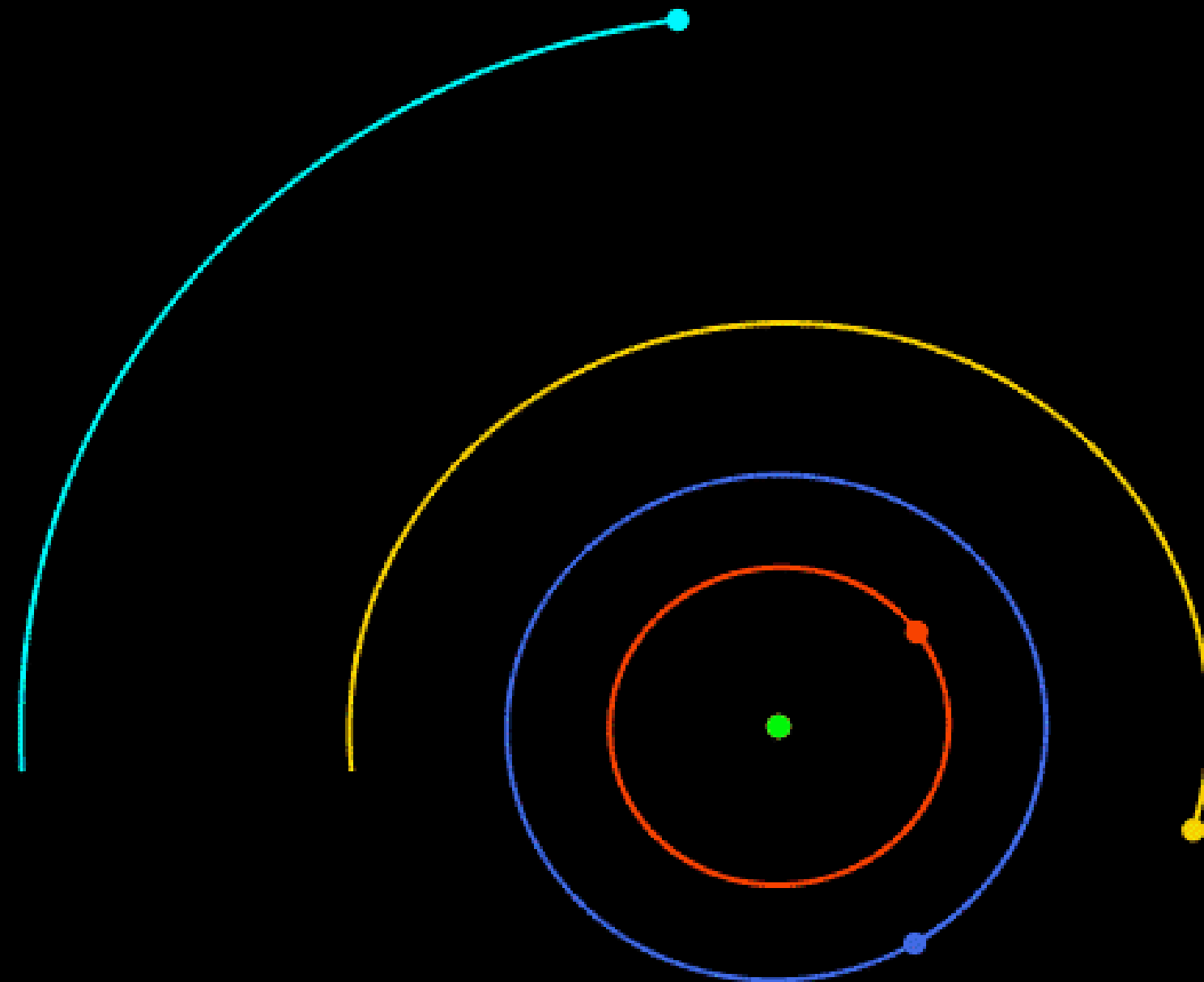
Ganymede

Europa

Io

Jupiter

Pioneer 10



0.000km/s

2,861,486km

1972-03-03

Pioneer 10

Pioneer 10 achieves...

First trajectory to escape the solar system

First flight through the main asteroid belt

Measurement of the solar wind beyond the asteroid belt

First fly past Jupiter

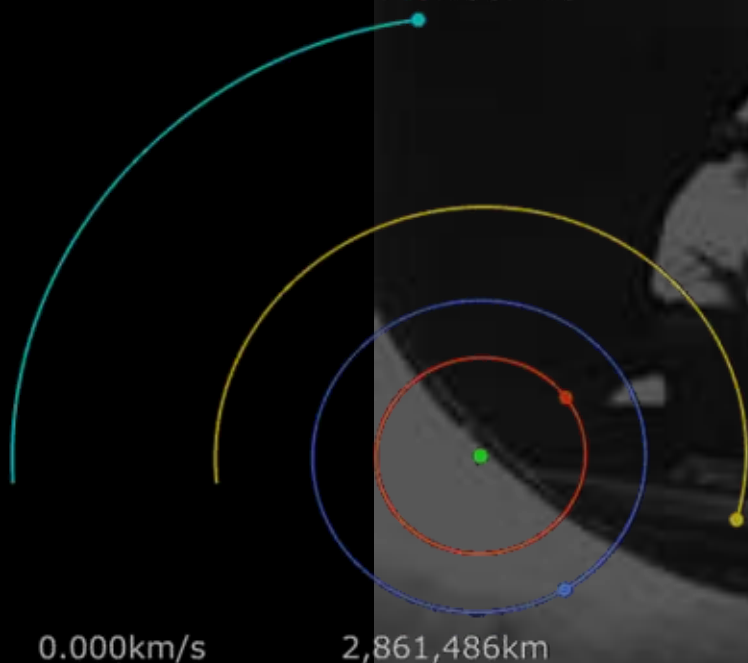
Measurement of Jupiter's magnetosphere and radiation belts

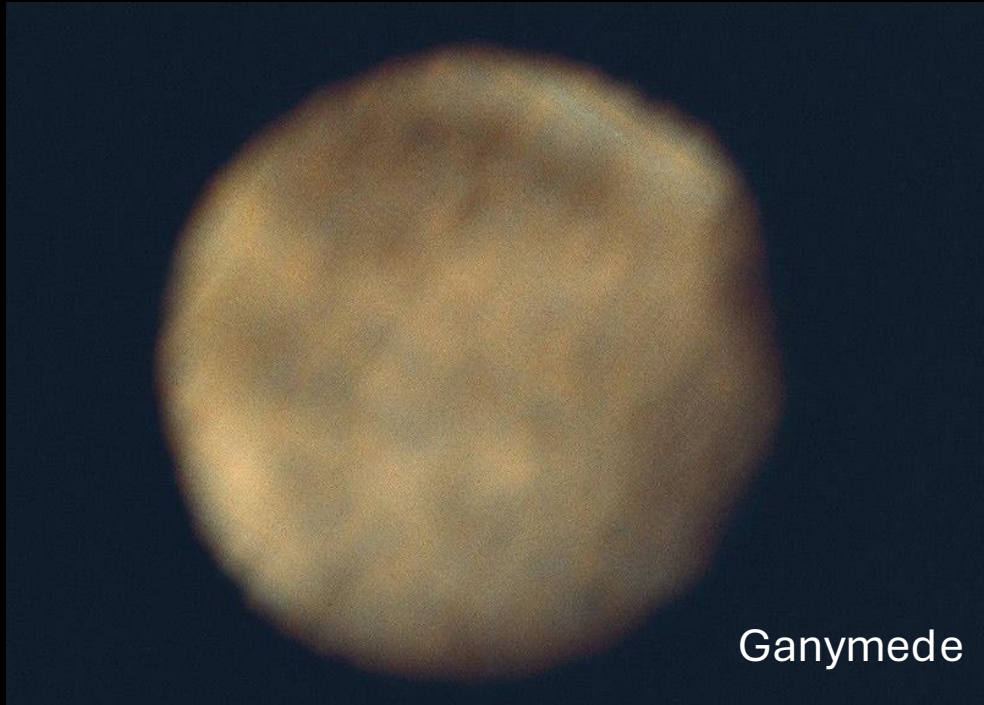
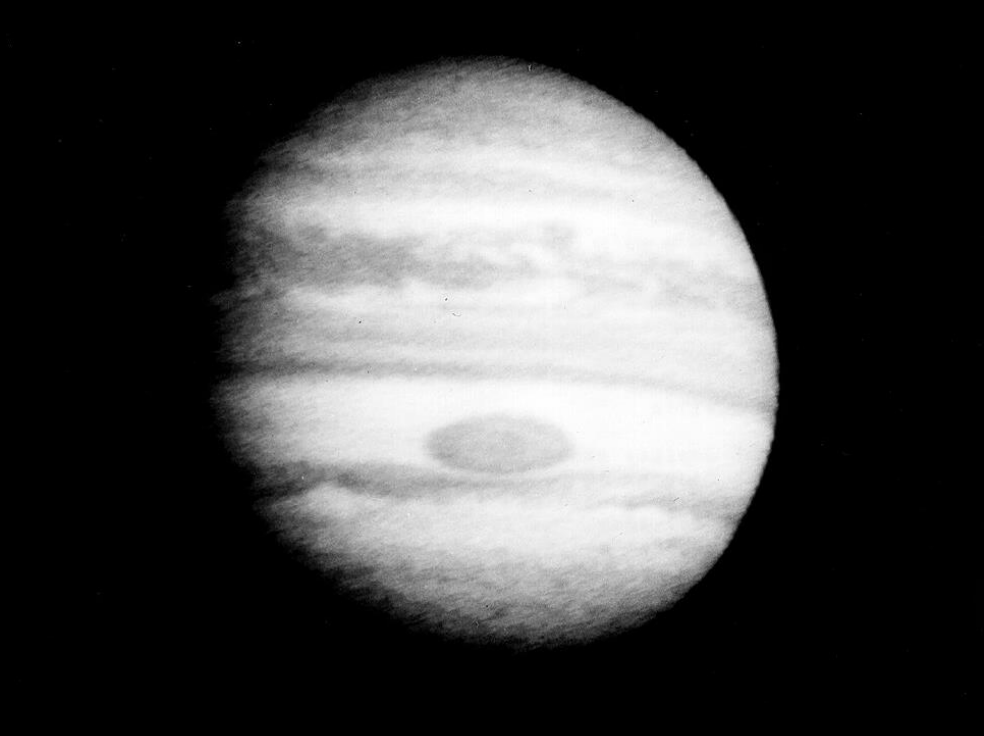
First human-made object to go beyond Neptune

First all-nuclear electrical power

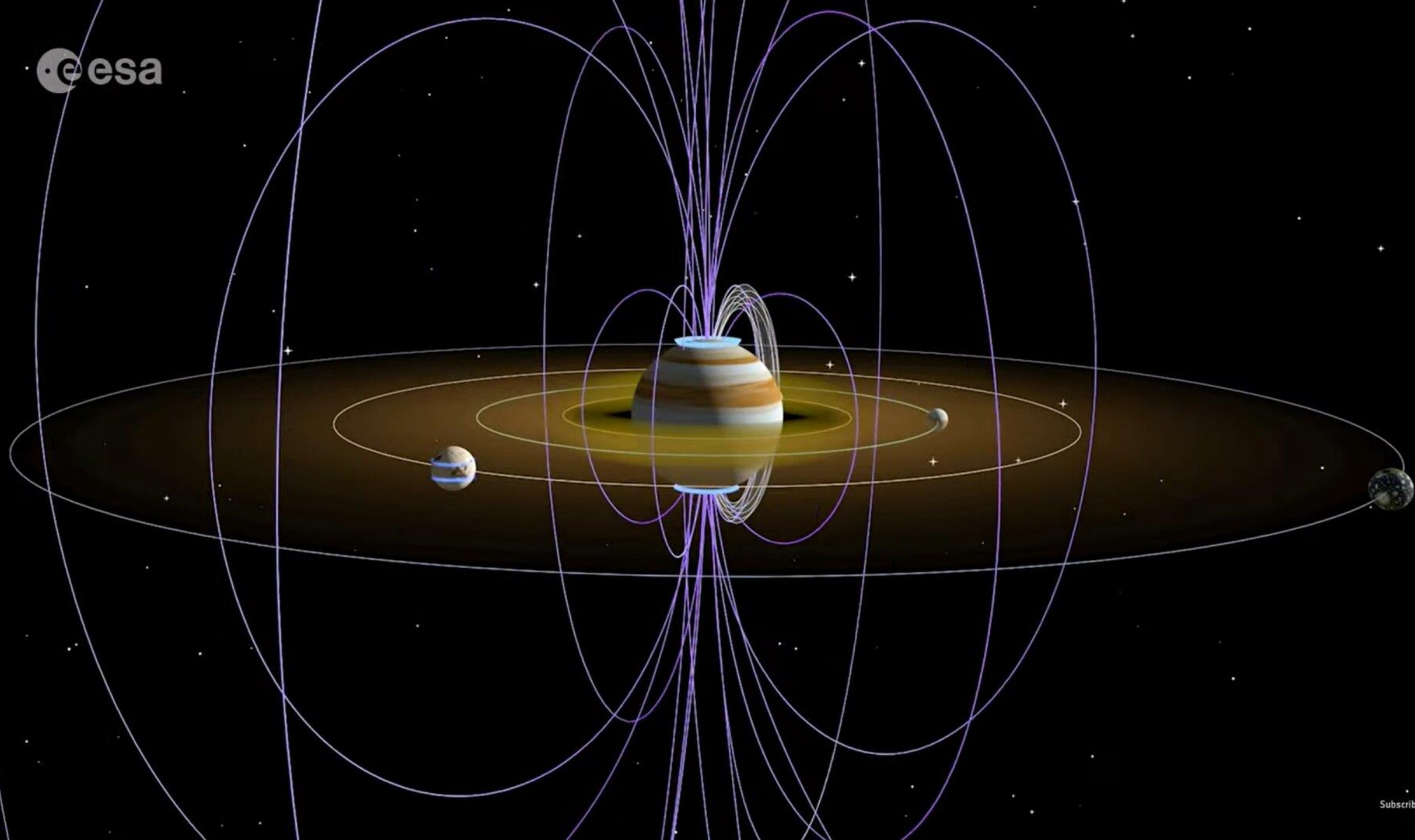


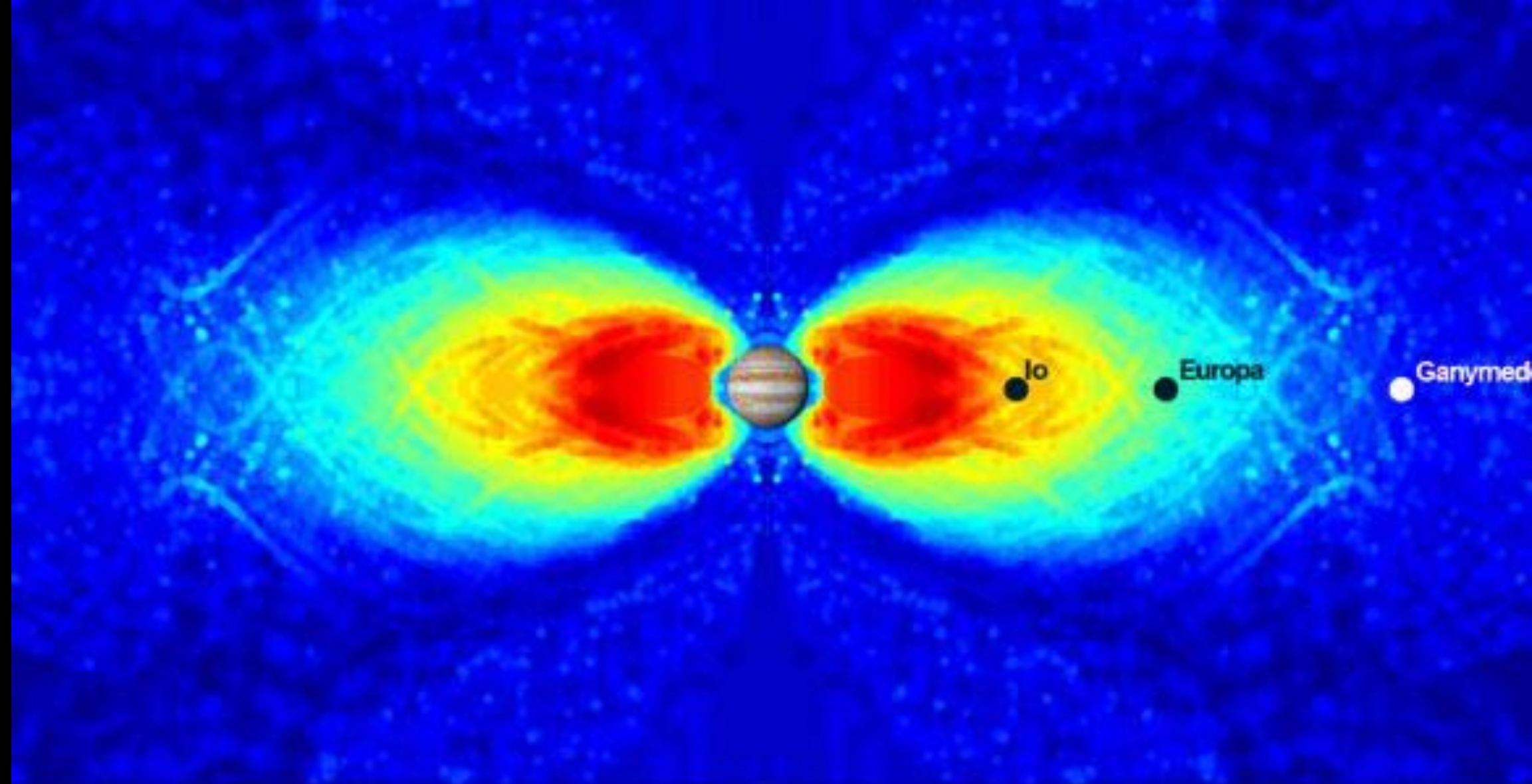
1973-12-02 00:00 Pioneer 10





Ganymede





1973-04-06

Pioneer 11

Sun

Earth

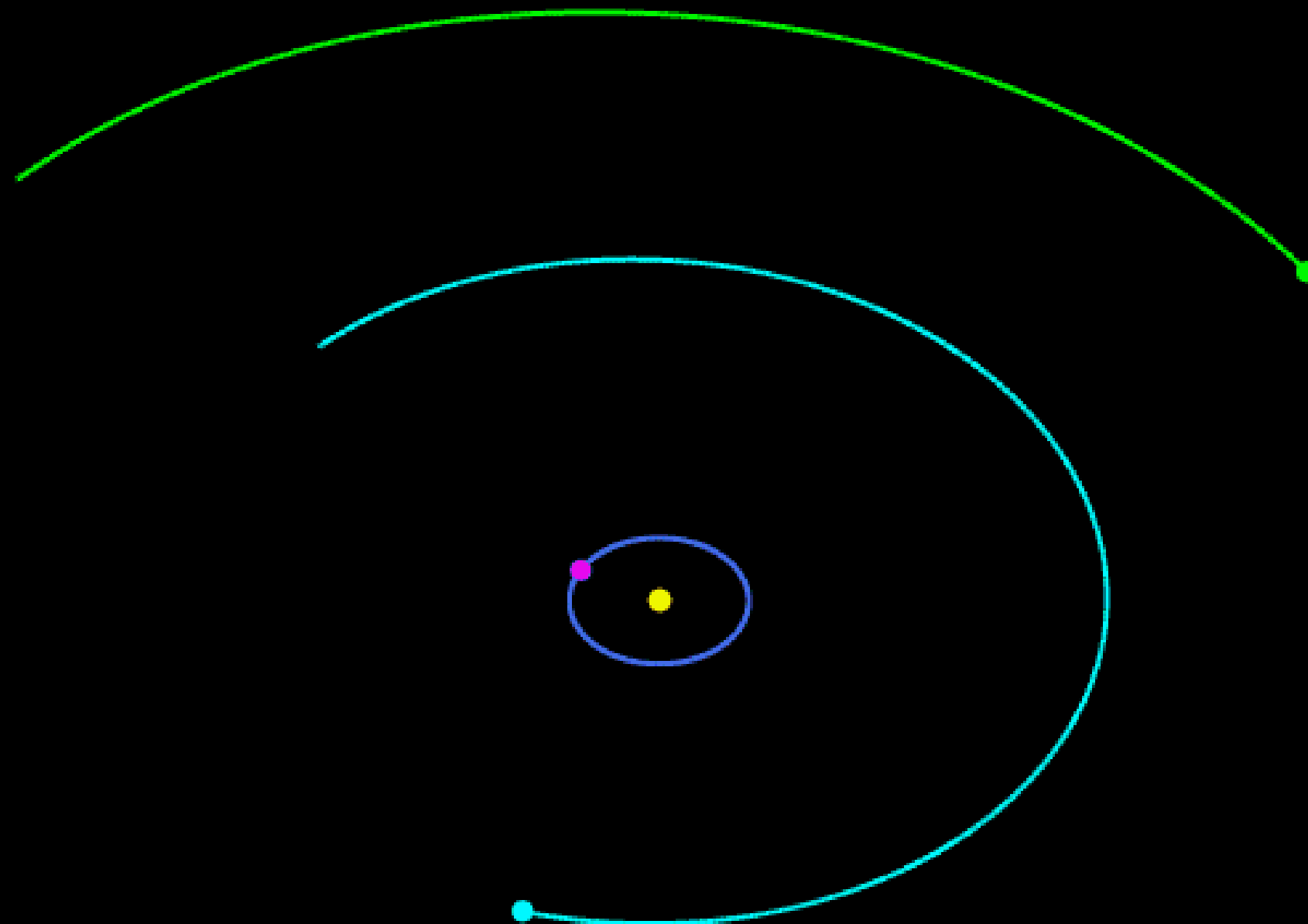
Jupiter

Saturn

Pioneer 11

0.000km/s

1,418,830,477km



1974-11-30 00:00

Pioneer 11

Callisto

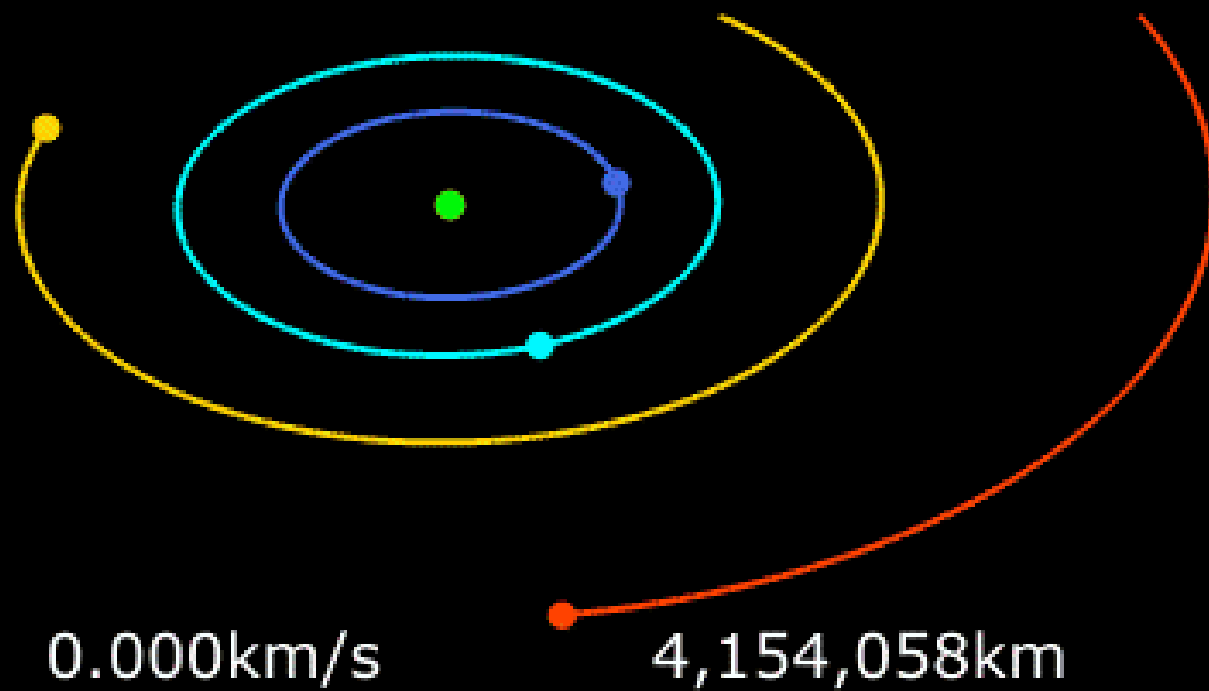
Ganymede

Europa

Io

Jupiter

Pioneer 11



1979-09-01 12:00

Pioneer 11

Enceladus

Mimas

Epimetheus

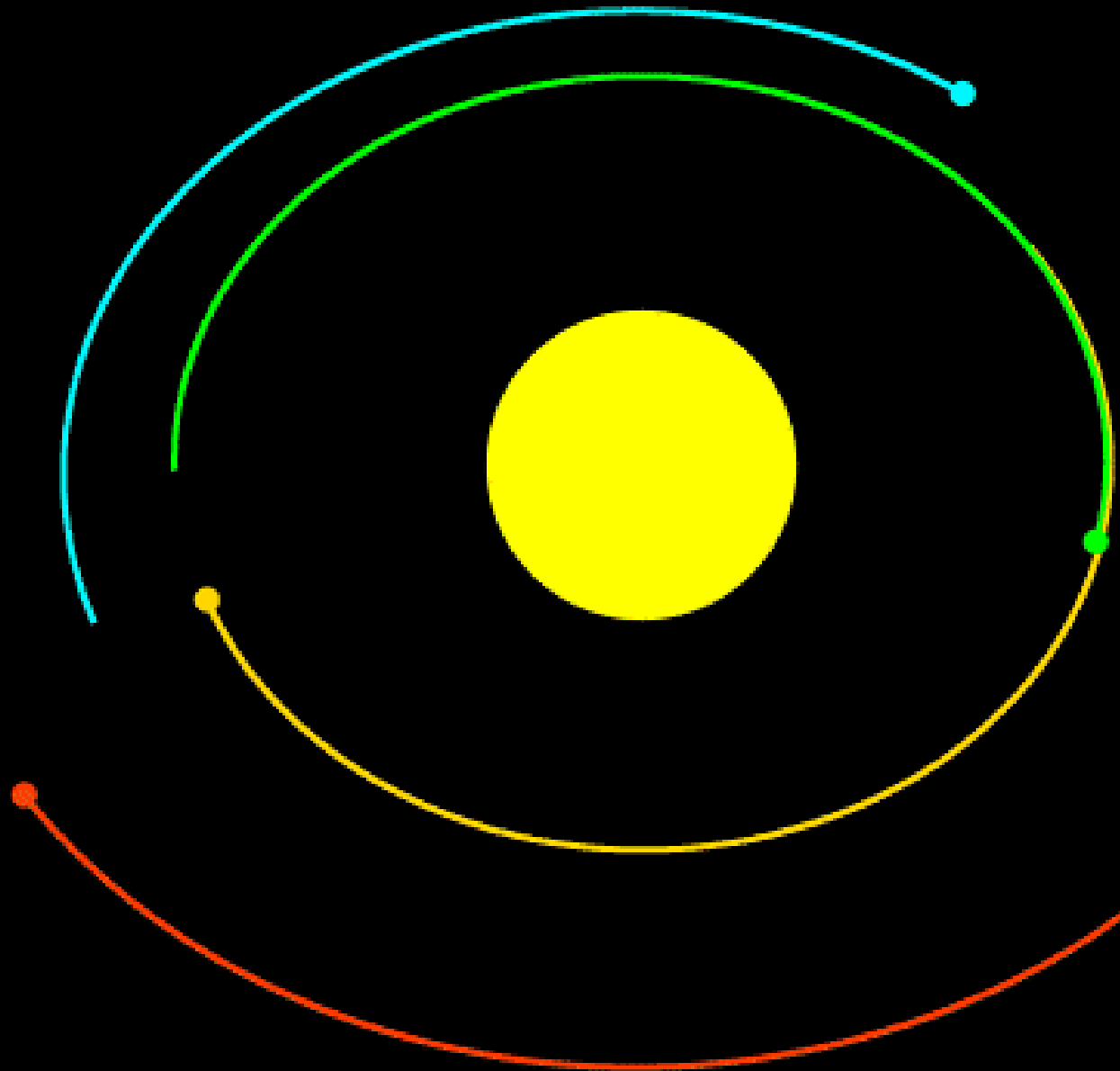
Janus

Saturn

Pioneer 11

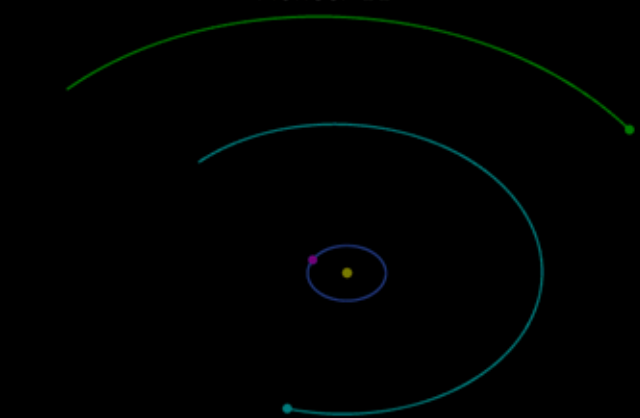
0.000km/s

321,152km



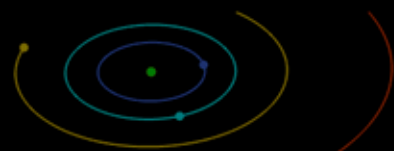
1973-04-06

Pioneer 11



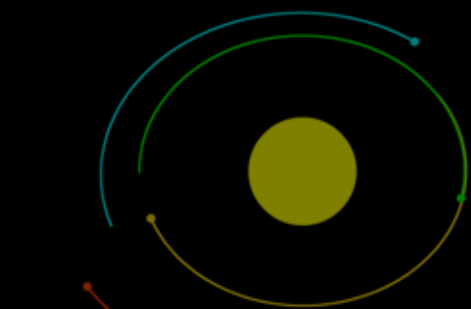
0.000km/s 1,418,830,477km

1974-11-30 00:00 Pioneer 11



0.000km/s 4,154,058km

1979-09-01 12:00 Pioneer 11



0.000km/s 321,152km

Pioneer 11 achieves...

First gravity assist to Jupiter onwards to Saturn

Closer path past Jupiter

First to photograph the polar regions of Saturn

flight past Saturn

Navigate safe path through Saturn

Determined magnetic field and radiation belts around Saturn

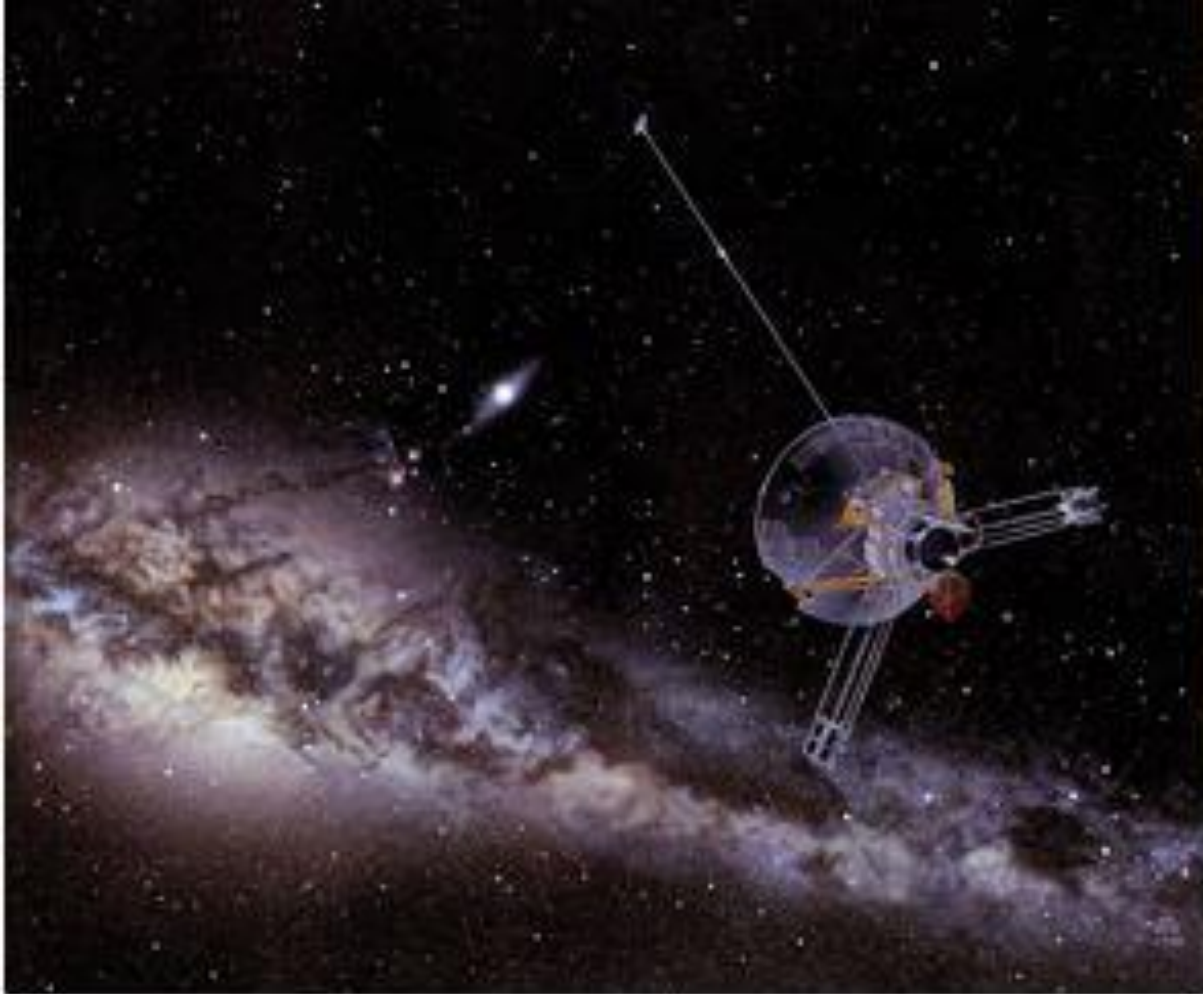
Discovery of Saturn's F-ring



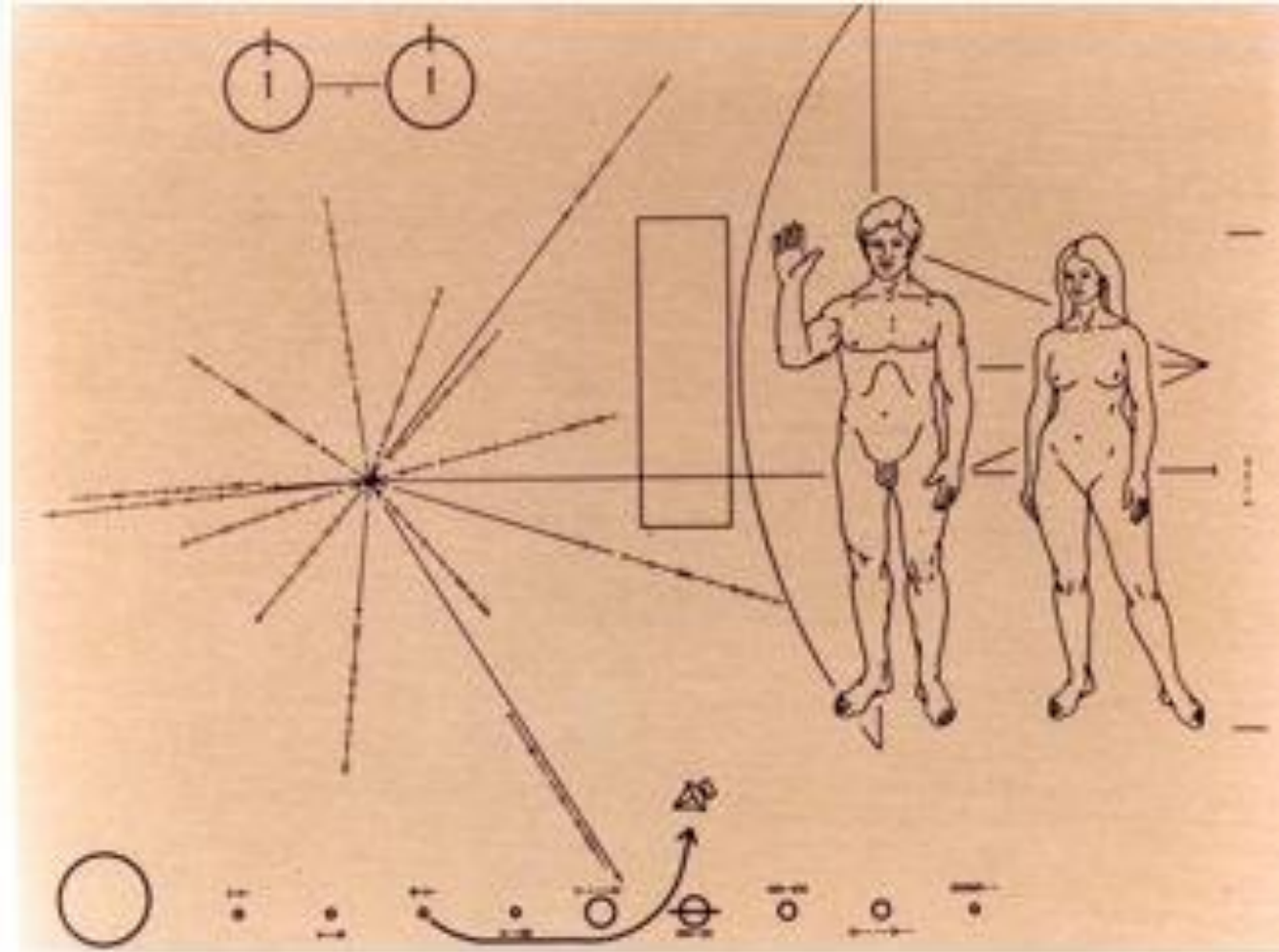
Io







Both Pioneer craft carry a gold-anodised aluminium plaque within the structure, to protect it from interstellar dust

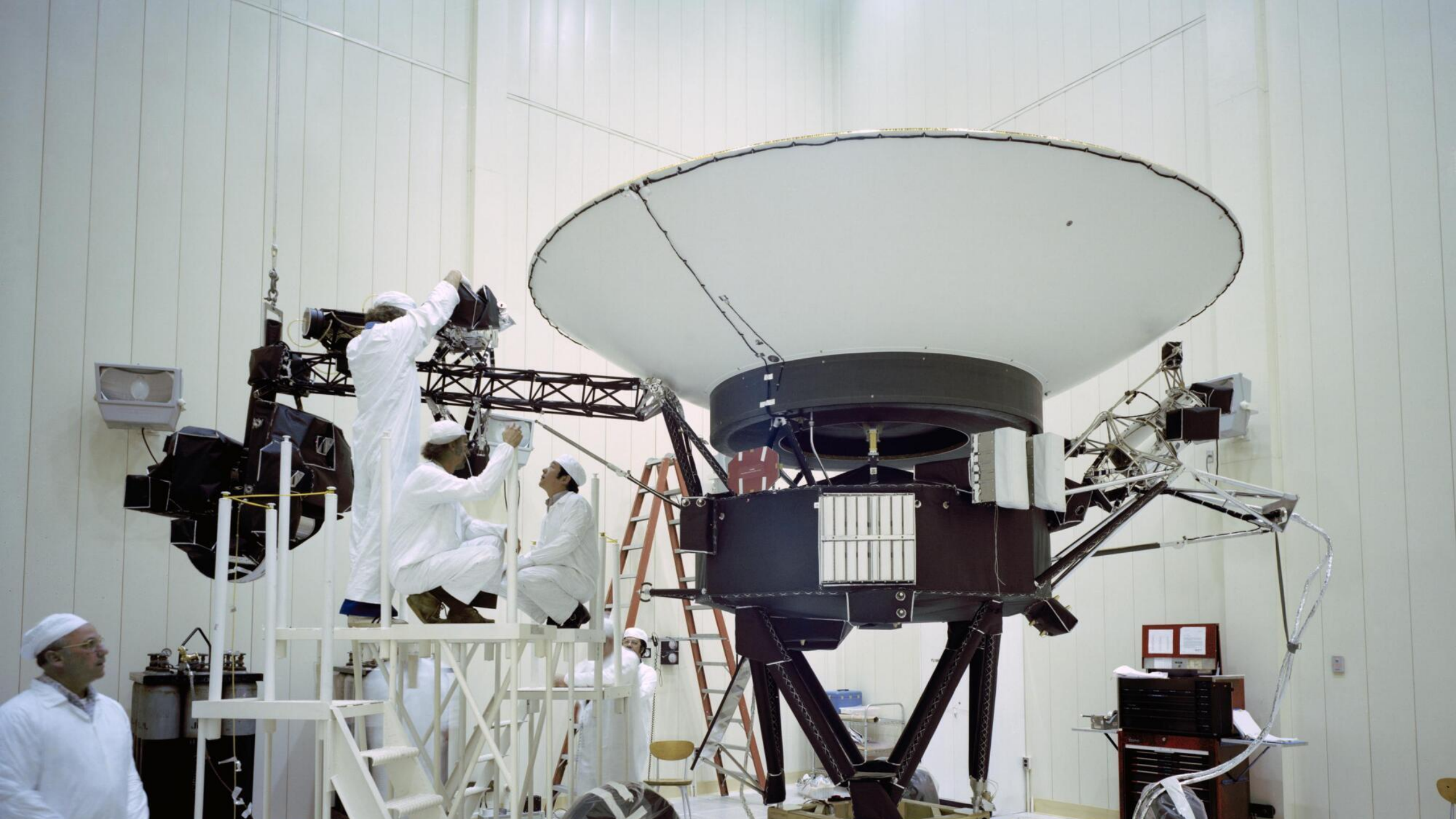


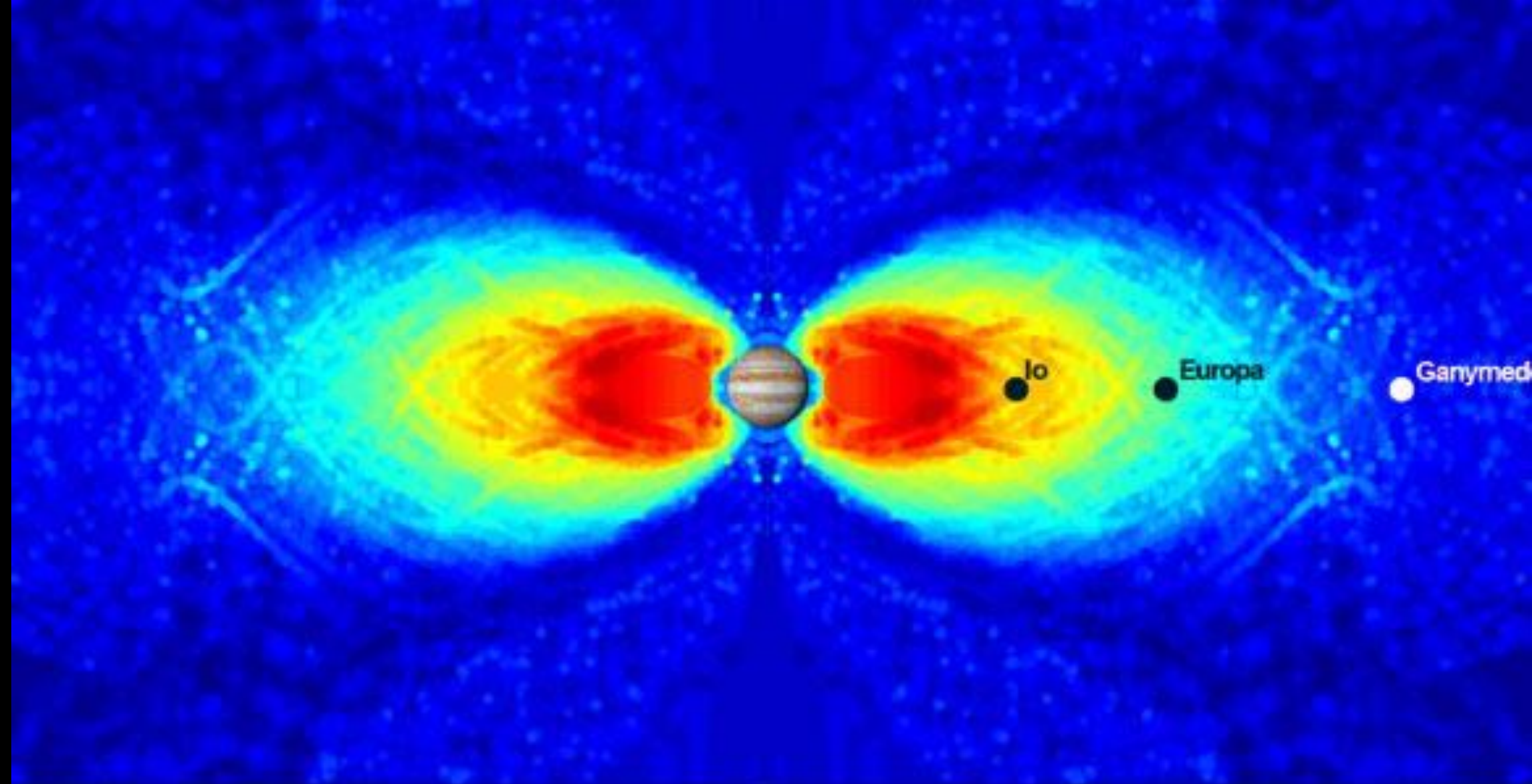
Hydrogen
silhouette of the craft itself
representation of binary 8
position in relation to 14 pulsars and galactic centre
Earth's position is within our solar system

Pioneers 10 and 11 taught us...

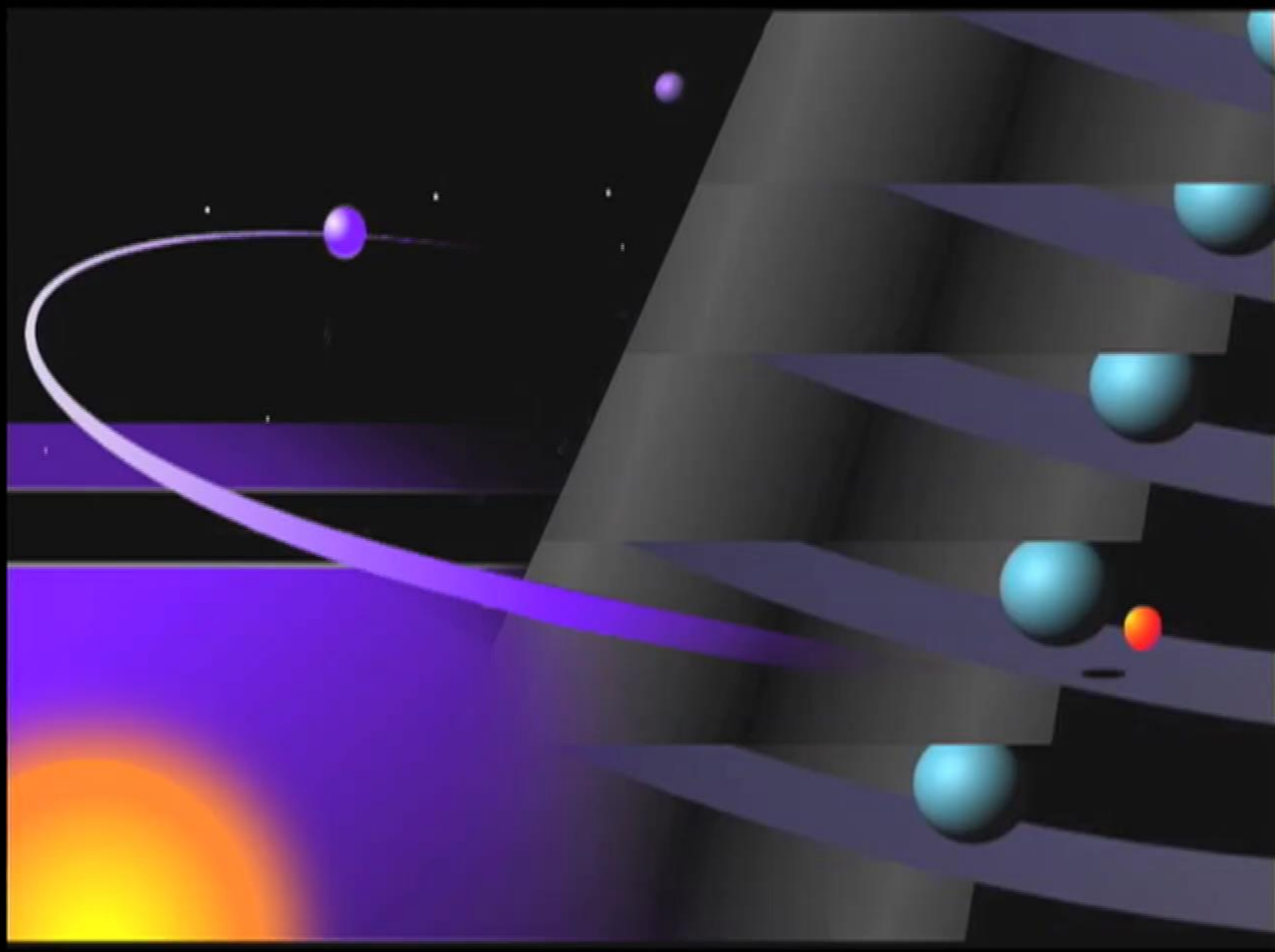
- ✓ Asteroid belt navigable
- ✓ Gravitational assist proven
- ✓ Jupiter's magnetosphere/radiation far more extensive and intense
- ✓ Saturn ring plane crossing survivable
- ✓ Navigation possible across billions of kilometres
- ✓ Signals successfully sent and received across the entire solar system

The Grand Tour









1977-08-20

Voyager 2

Sun

Earth

Jupiter

Saturn

Uranus

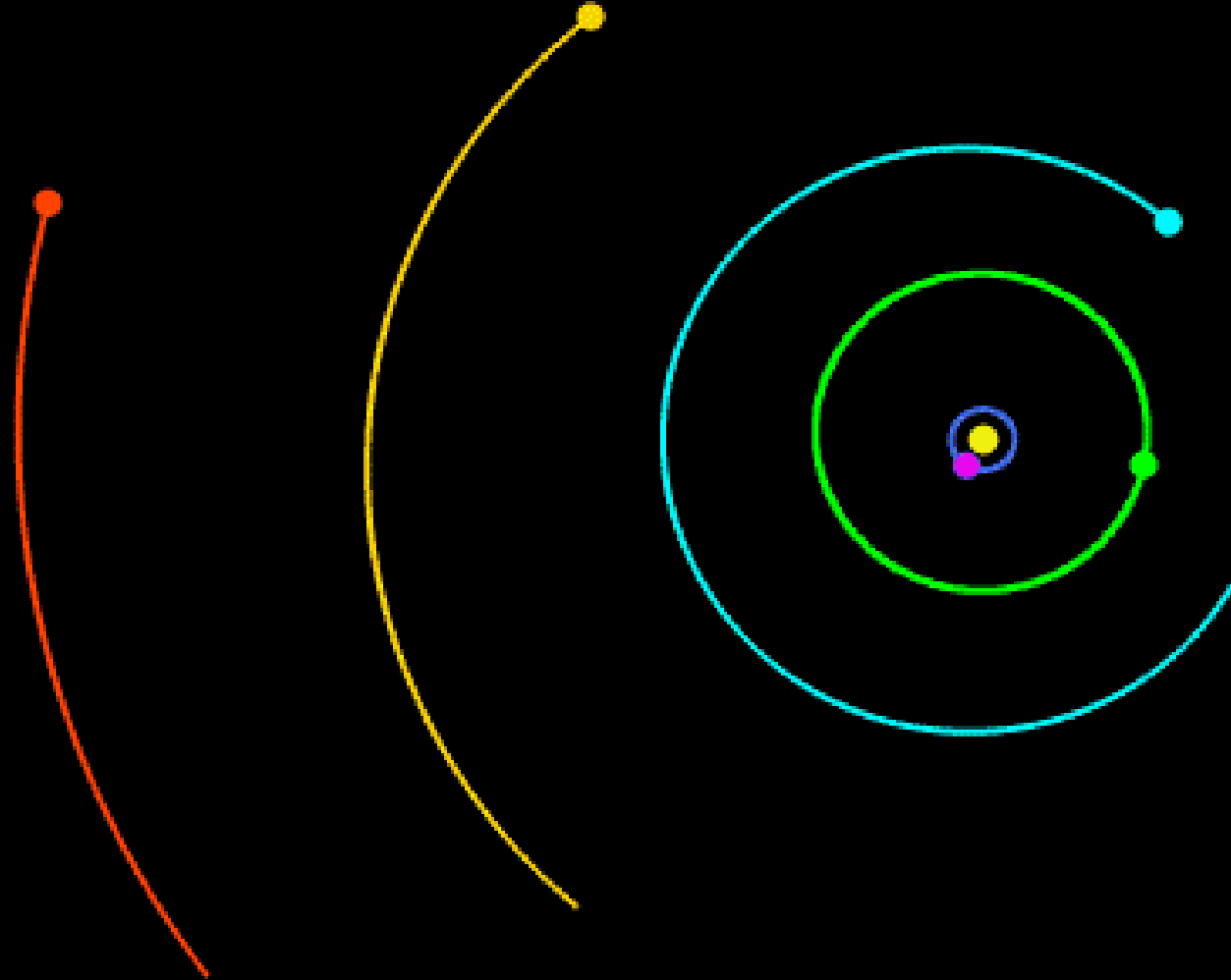
Neptune

Voyager 2

0.0km/s

4,487,373,409km

August 20, 1977



1977-09-05

Voyager 1

Sun

Earth

Jupiter

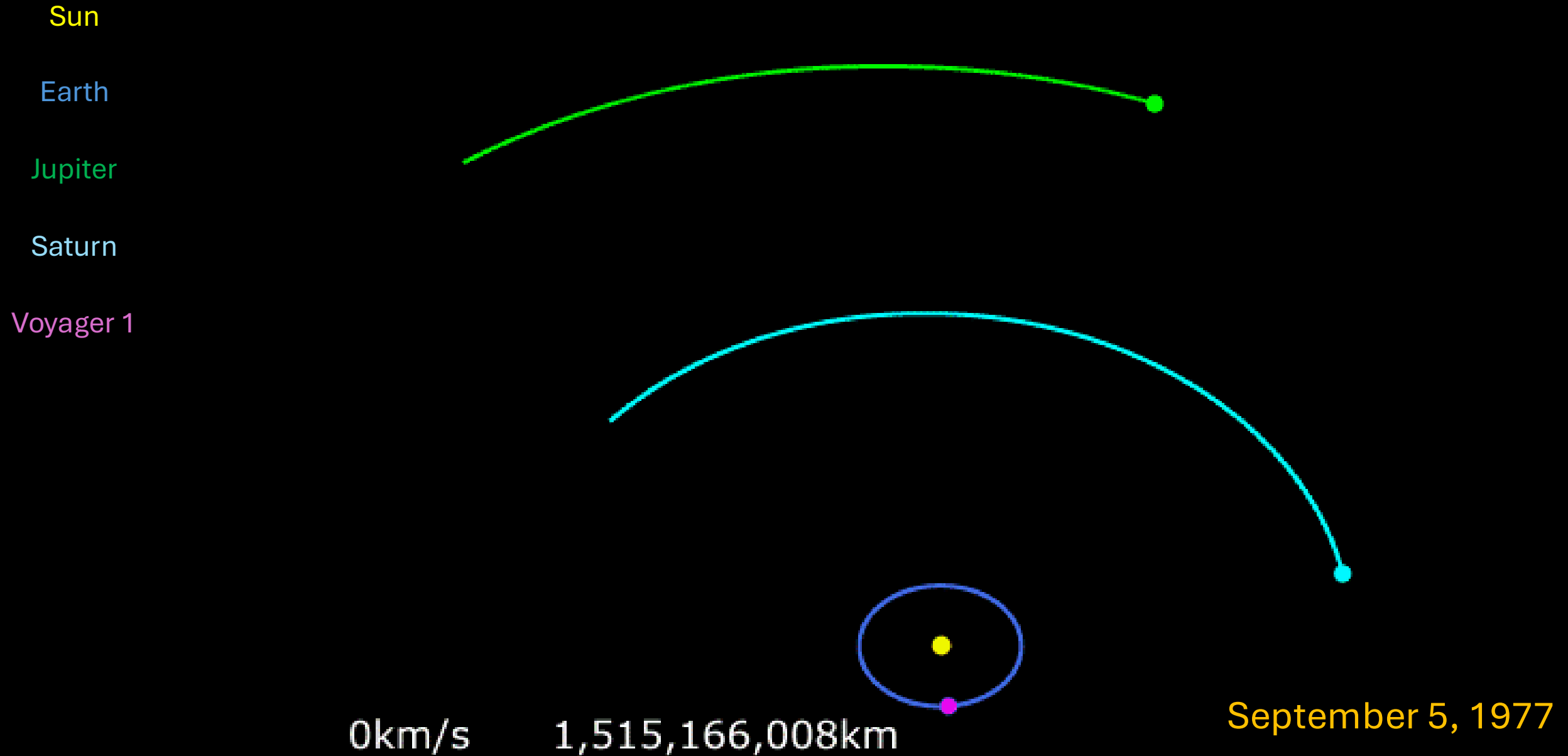
Saturn

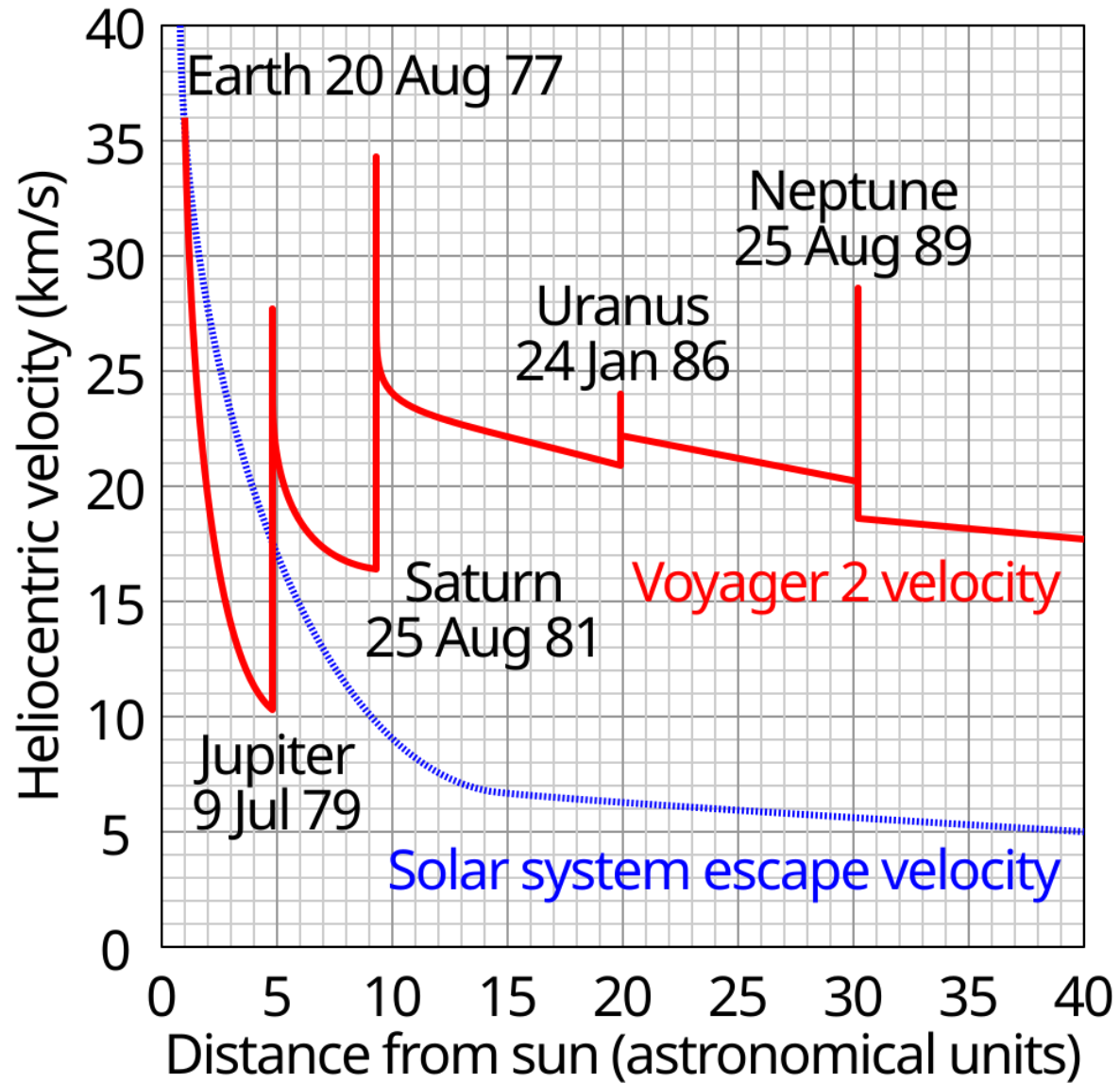
Voyager 1

0km/s

1,515,166,008km

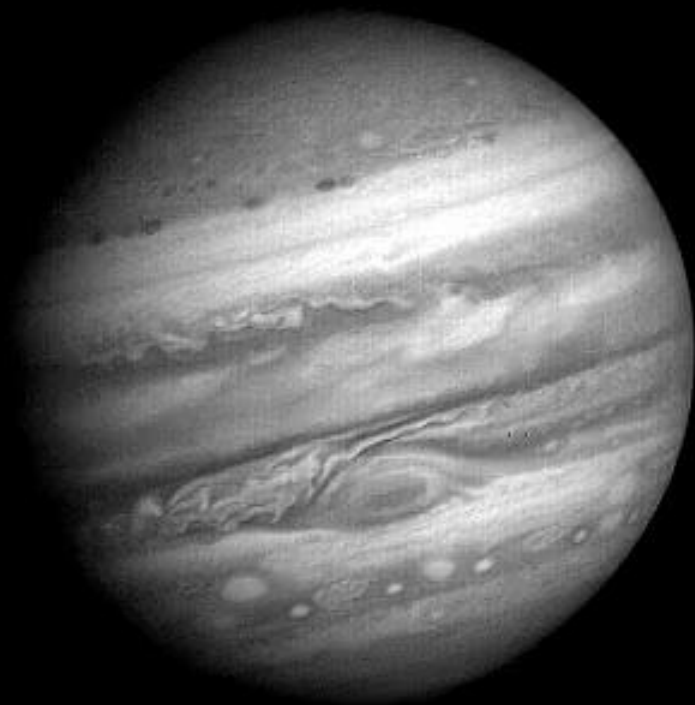
September 5, 1977

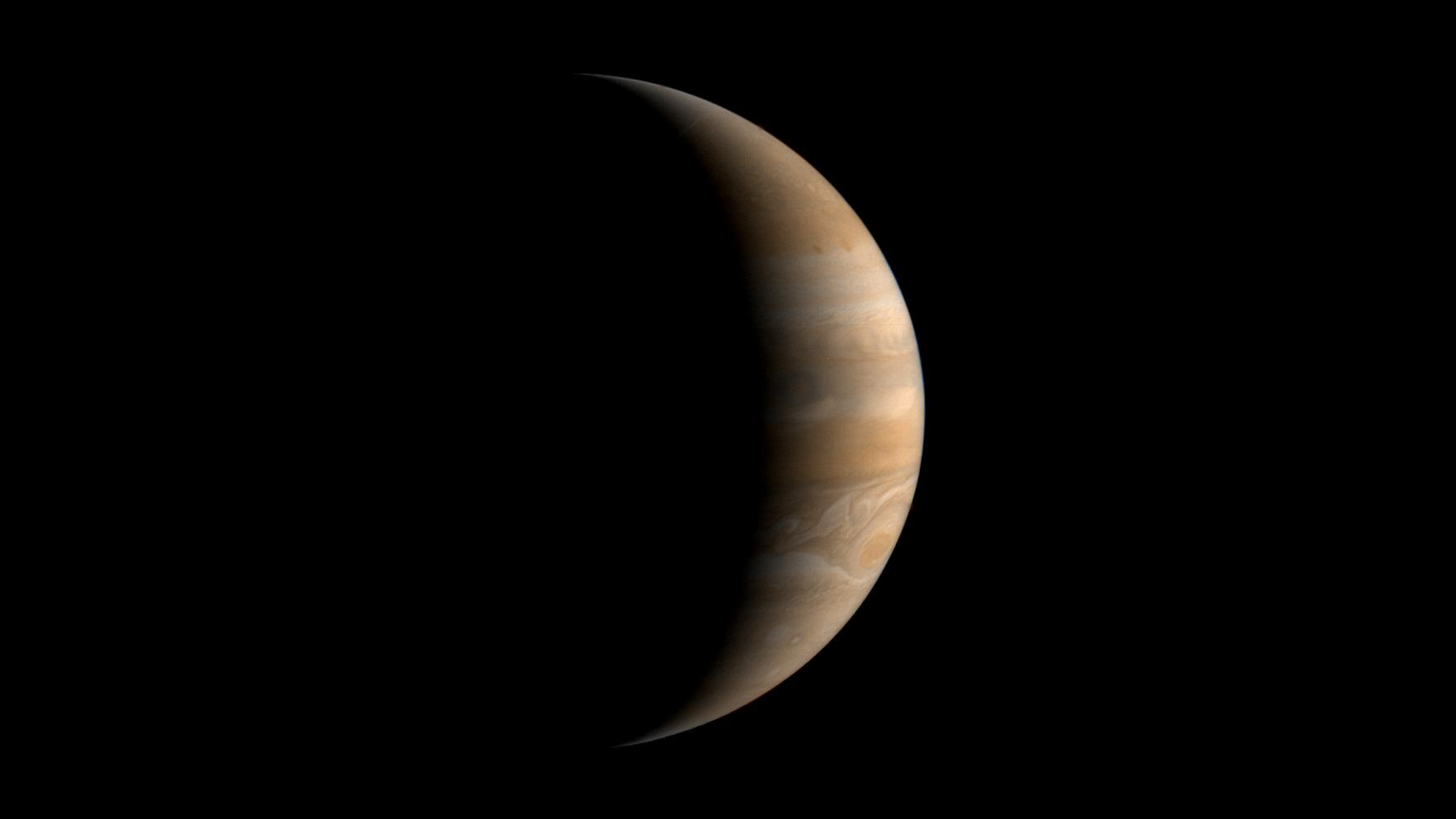




Why is gravitational assist beneficial?

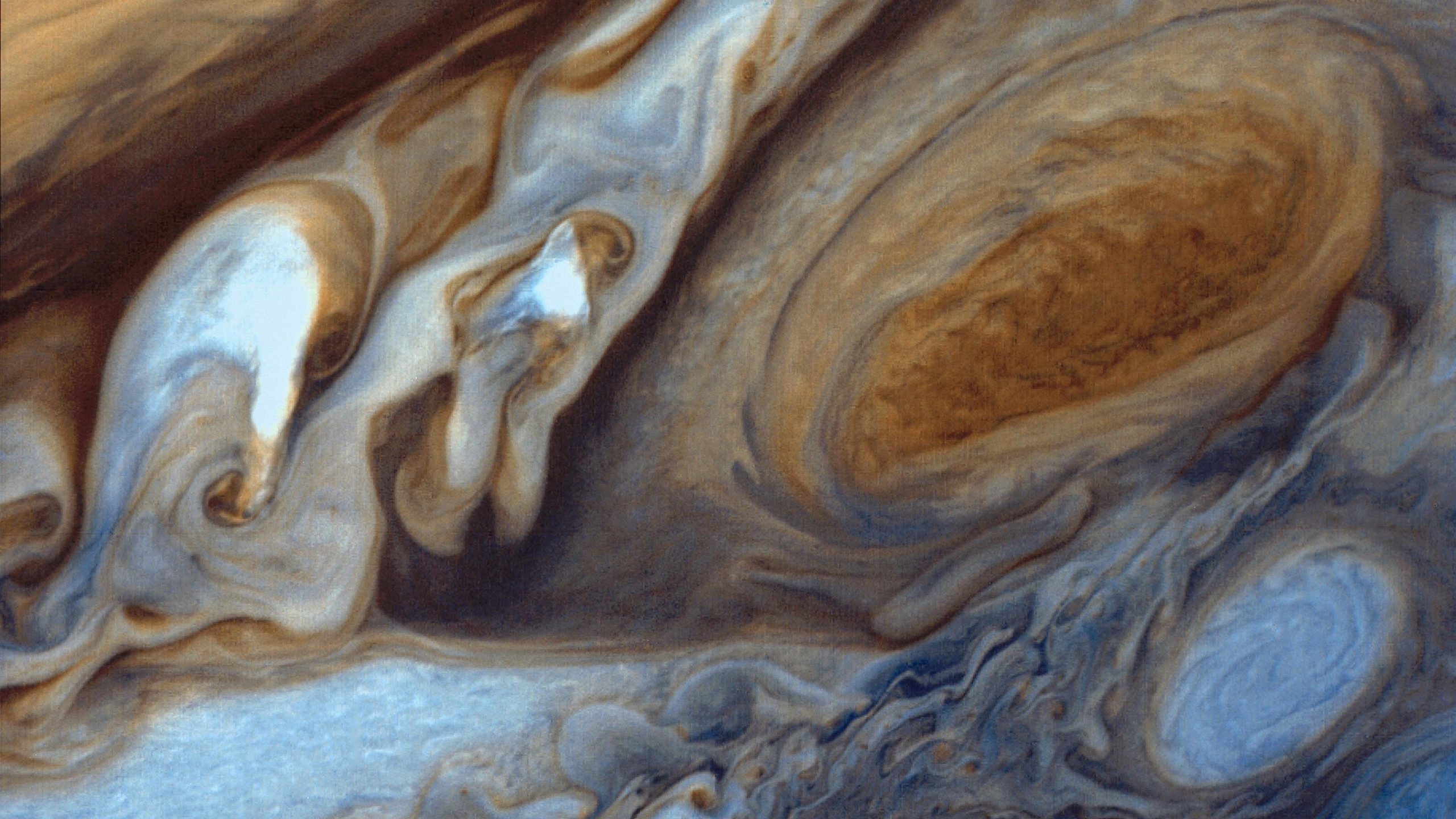
Voyager 1 and Jupiter







February 13th 1979 – Jupiter with Io and Europa



Ganymede

Most massive moon in the solar system - $\frac{1}{40}$ th Earth's Mass

Rocky, ice moon with an internal ocean of water

Up to 25 times the water on Earth

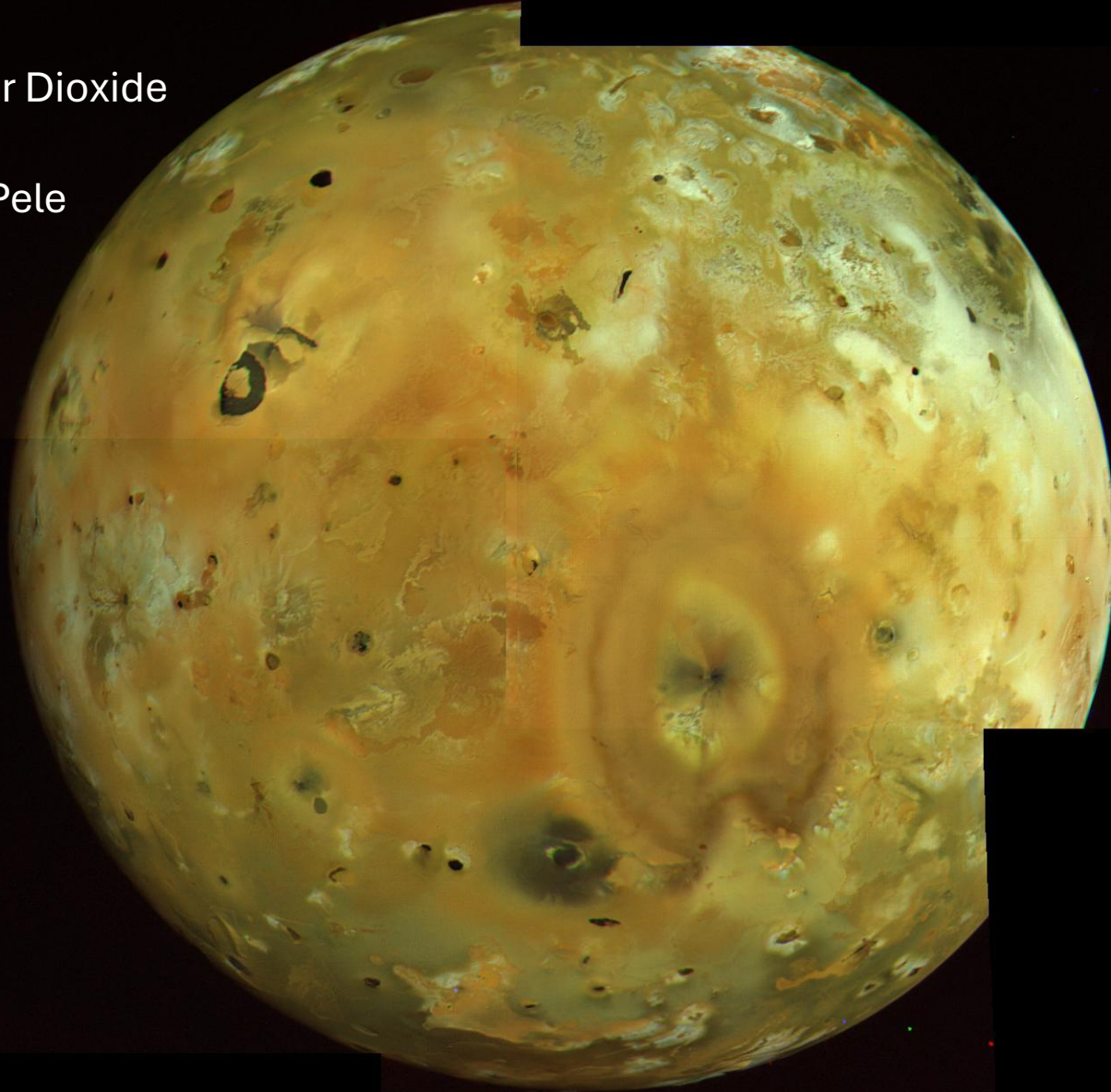
Impact craters with radial lines



Io

Surface of Sulphur and Sulphur Dioxide

Volcanoes including Loki and Pele

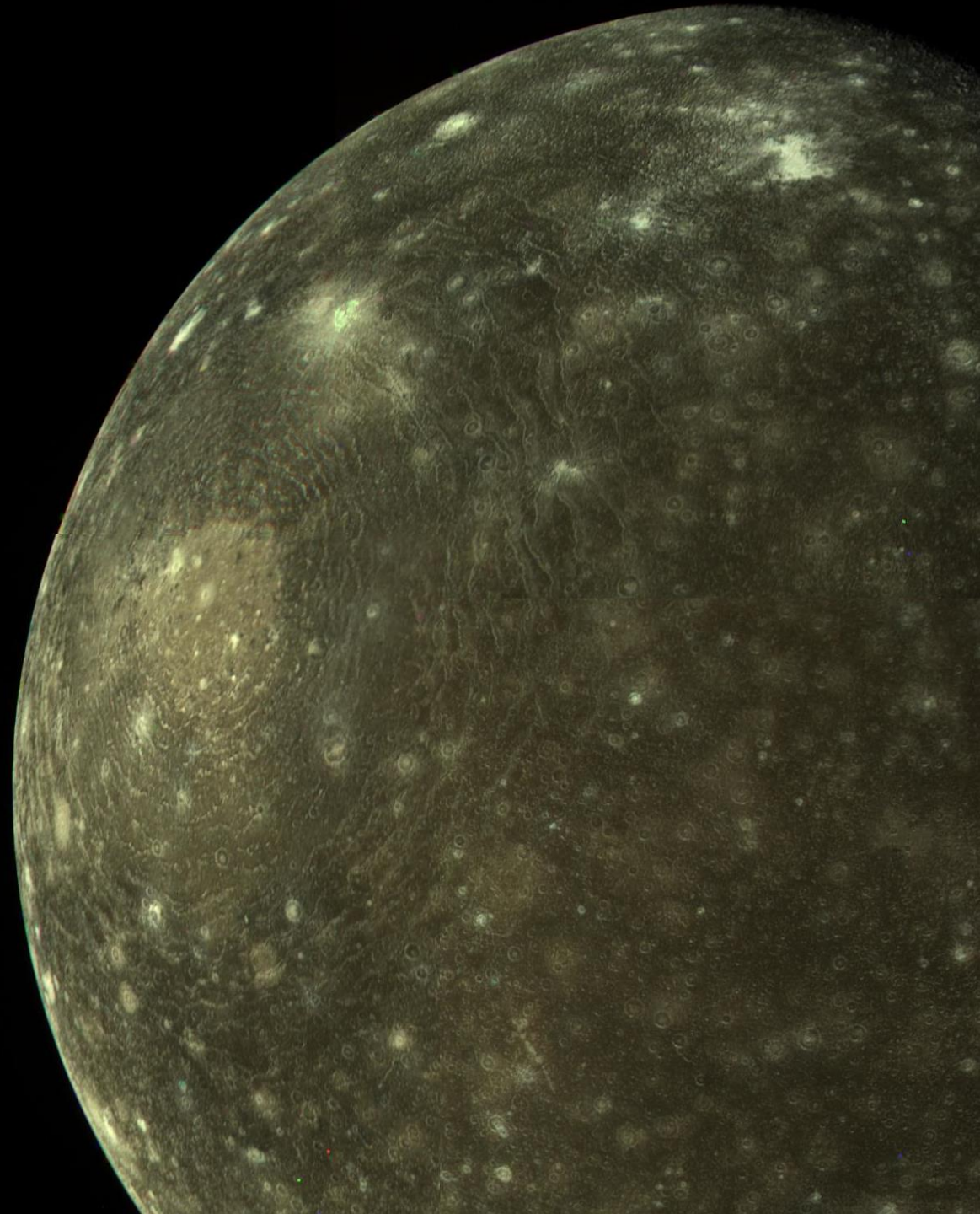


Callisto

The crater of Valhalla is apparent on the surface

Geologically inactive

Water not tidally churned; unlikely to sustain life

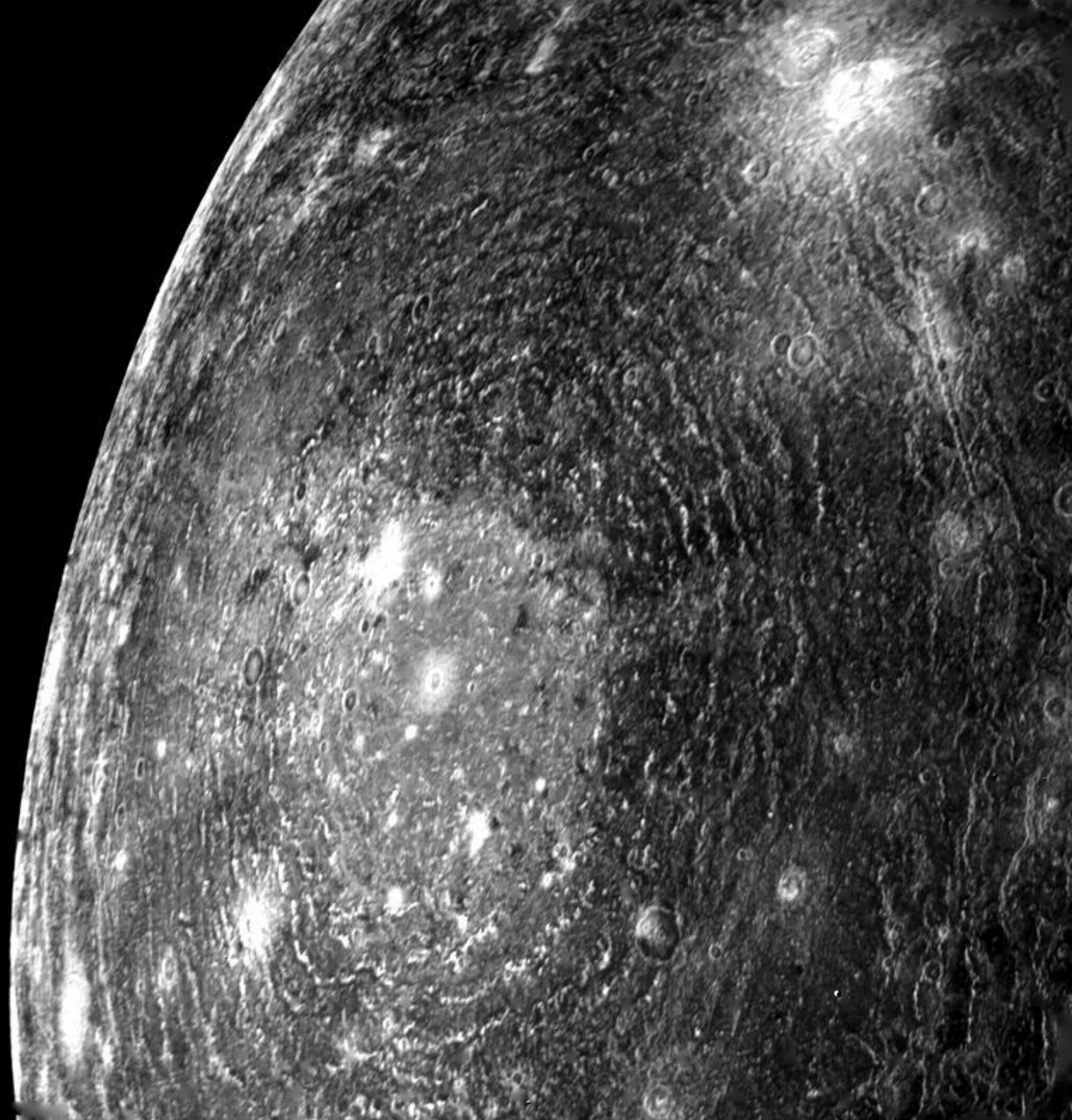


Callisto

200,000 km distance

Valhalla's concentric impact rings are apparent

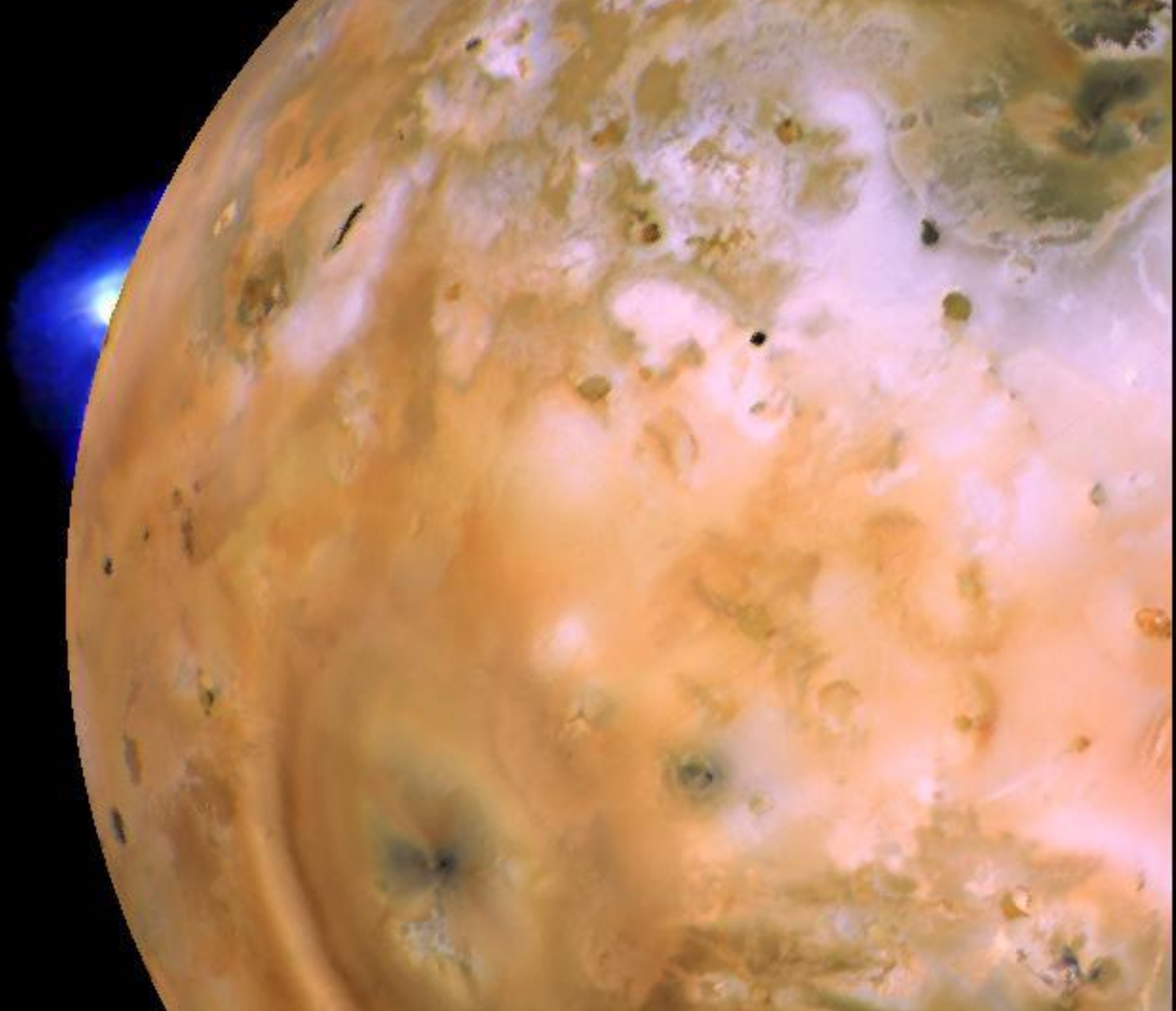
Like those on our own Moon and Mercury



Io

Volcanic eruption

Most active moon in our solar system

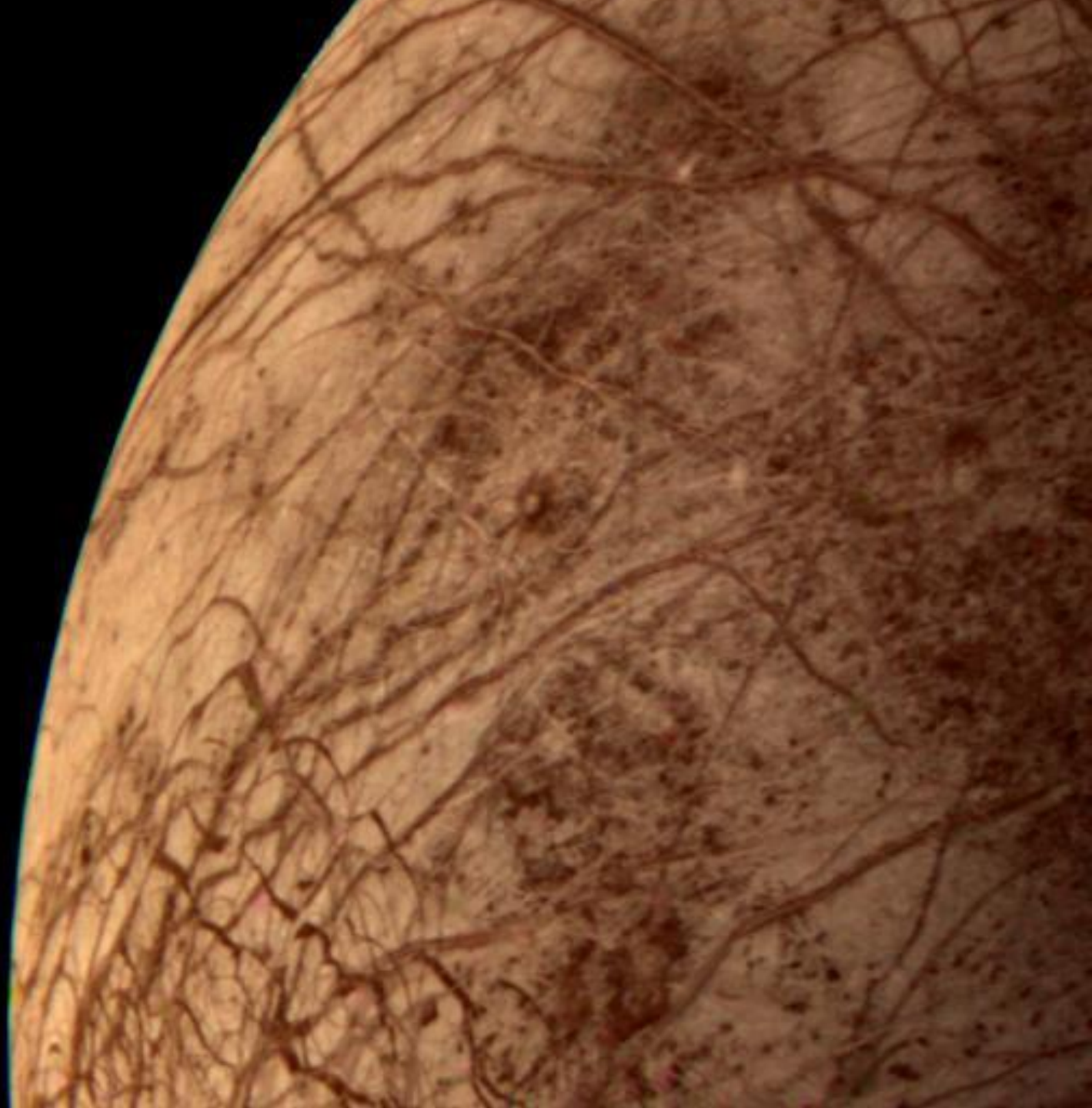


Voyager 2 and Jupiter

Europa

Slightly smaller than our Moon

Liquid water lays just below the surface



Europa Clipper

Launched October 14th, 2024

Arrives April 2030

Orbit Jupiter and make 49 close Europa flybys

Examining its ice shell, subsurface ocean,
composition and potential habitability

It is not specifically a life-detection mission



JUICE

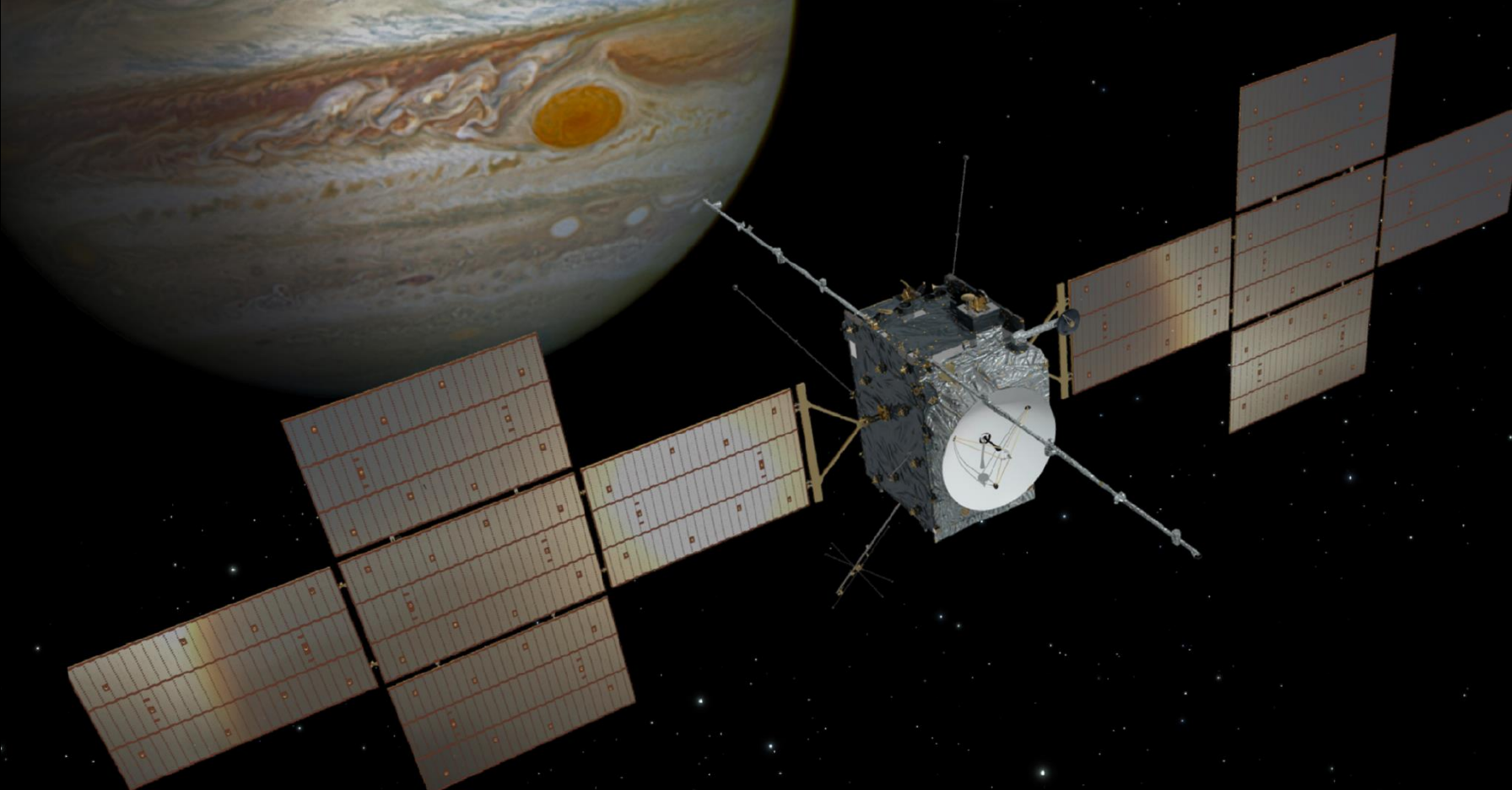
Launched April 2023

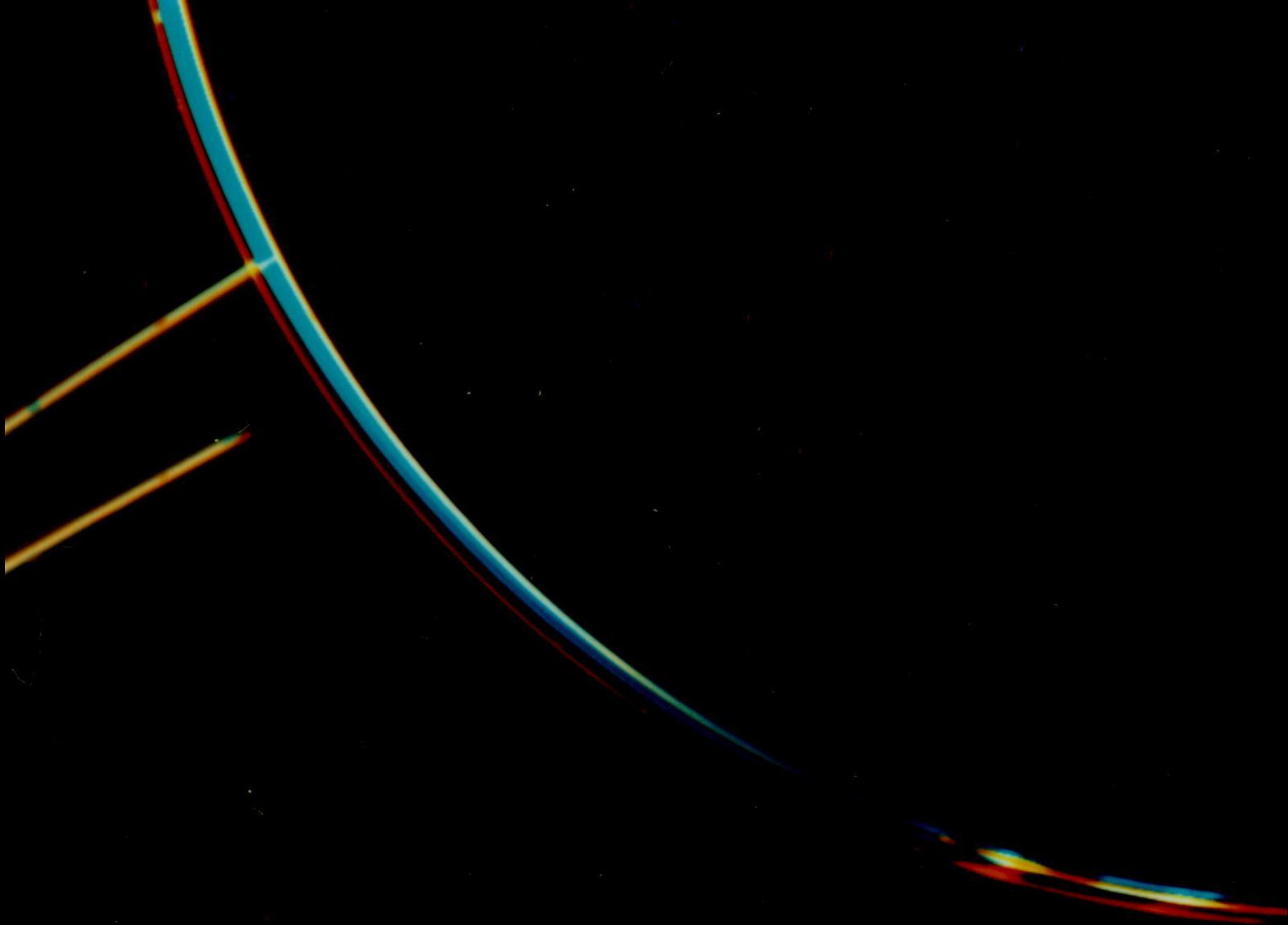
Arrives July 2031

Ganymede, Callisto and Europa

Conduct 35 Jovian-moon flybys

First spacecraft to orbit a moon other than Earth's Moon when it enters orbit around Ganymede.





Jovian Rings

Voyager 1 and Saturn

Saturn

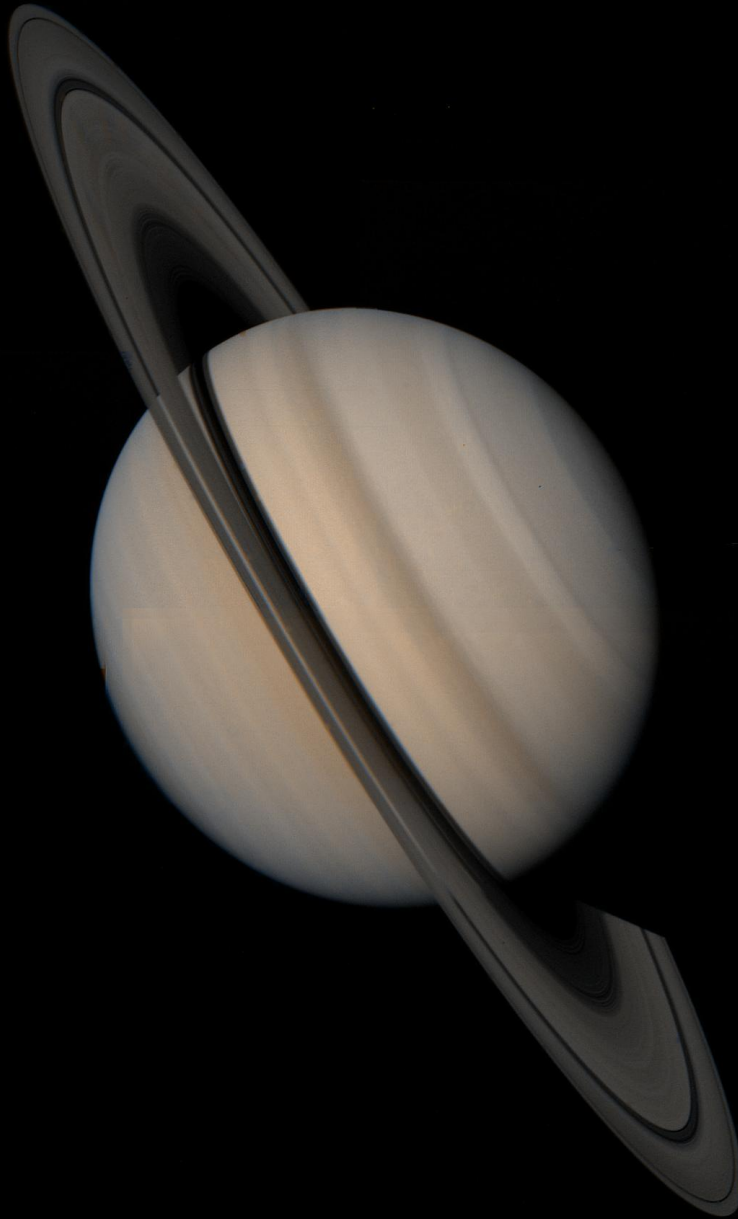
Dione and Tethys

The three rings and their divisions

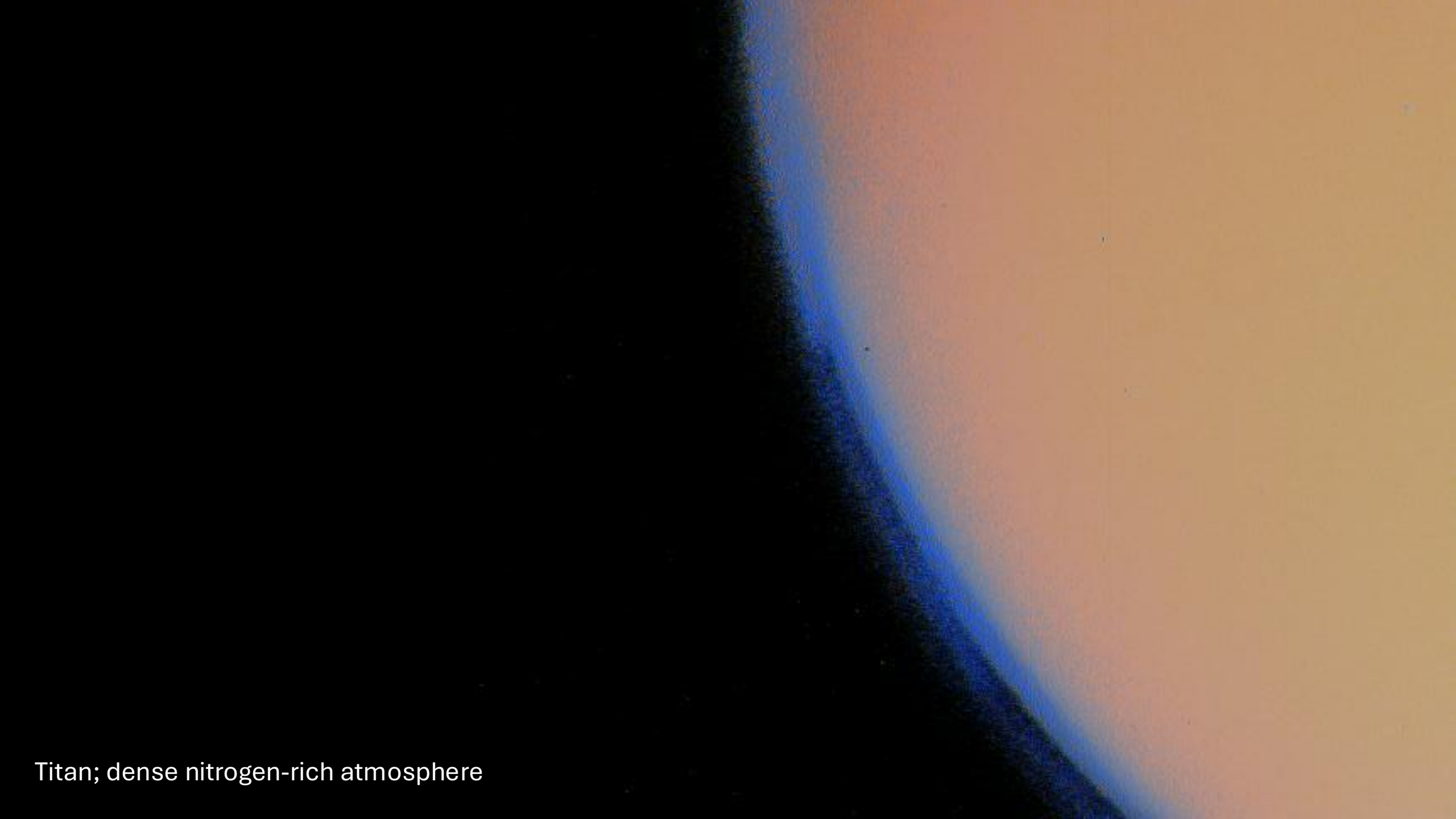
- Rings A and B
- Cassini Division
- Encke Division
- Ring C or the Crepe Ring



Tethys and Enceladus



Mimas



Titan; dense nitrogen-rich atmosphere

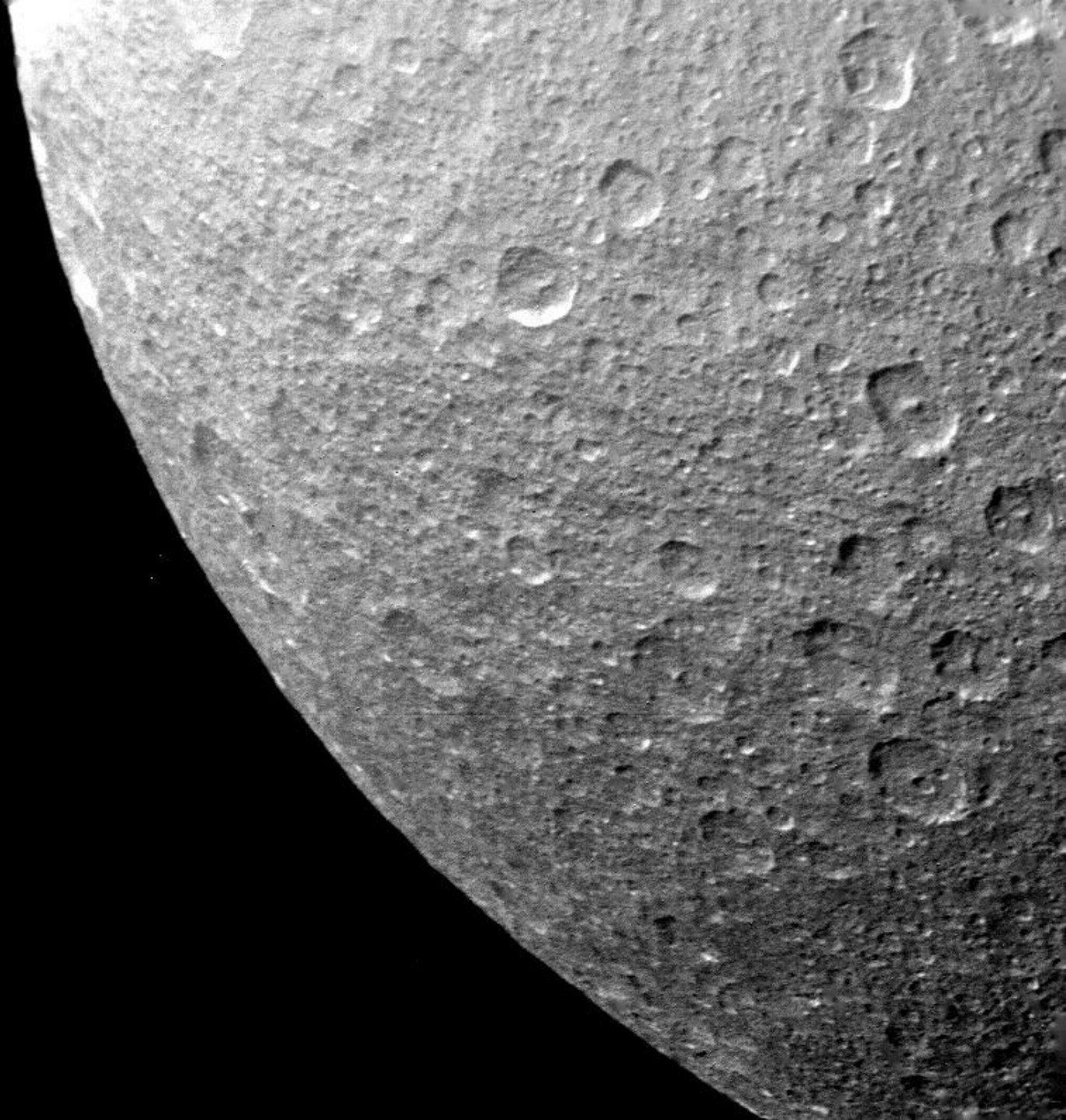
Rhea

Saturn's second largest moon

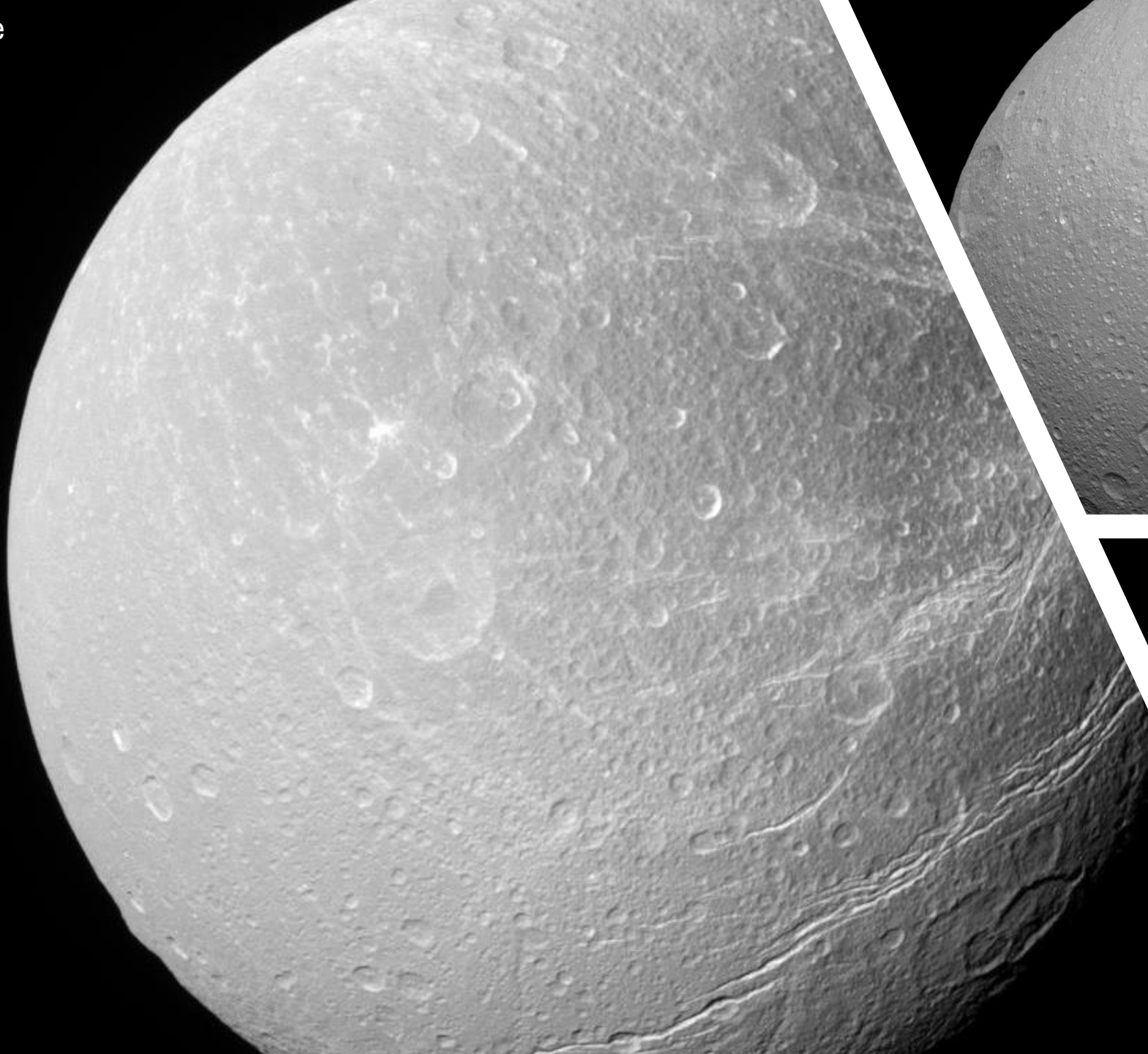
Ninth largest in the solar system

Half the size of our Moon (5th largest)

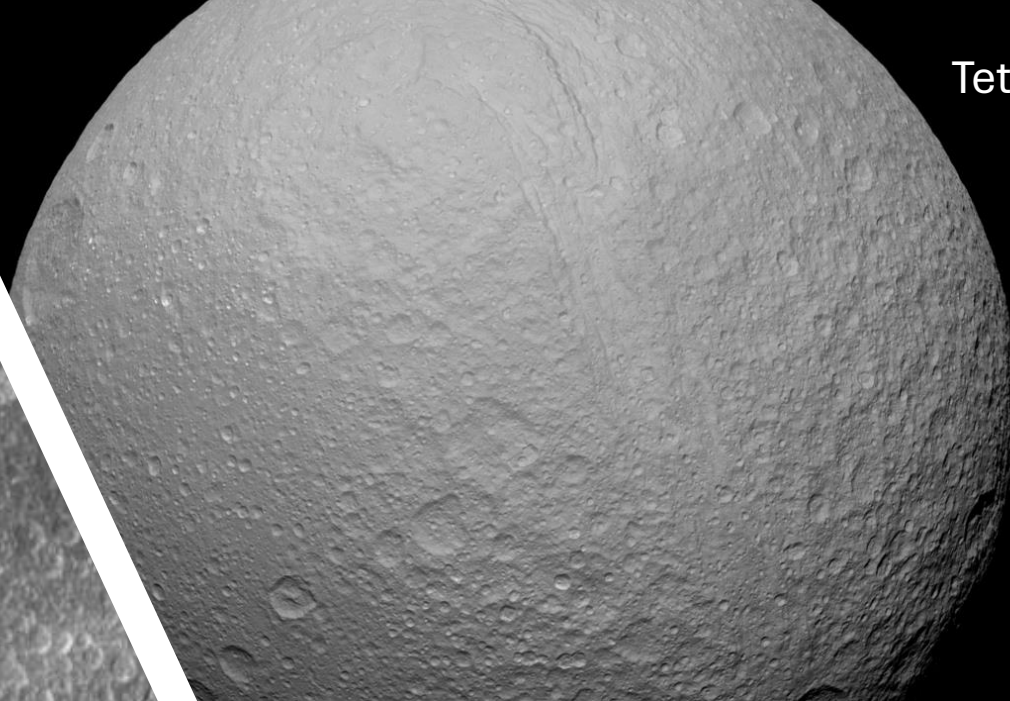
Icy moon



Dione



Tethys



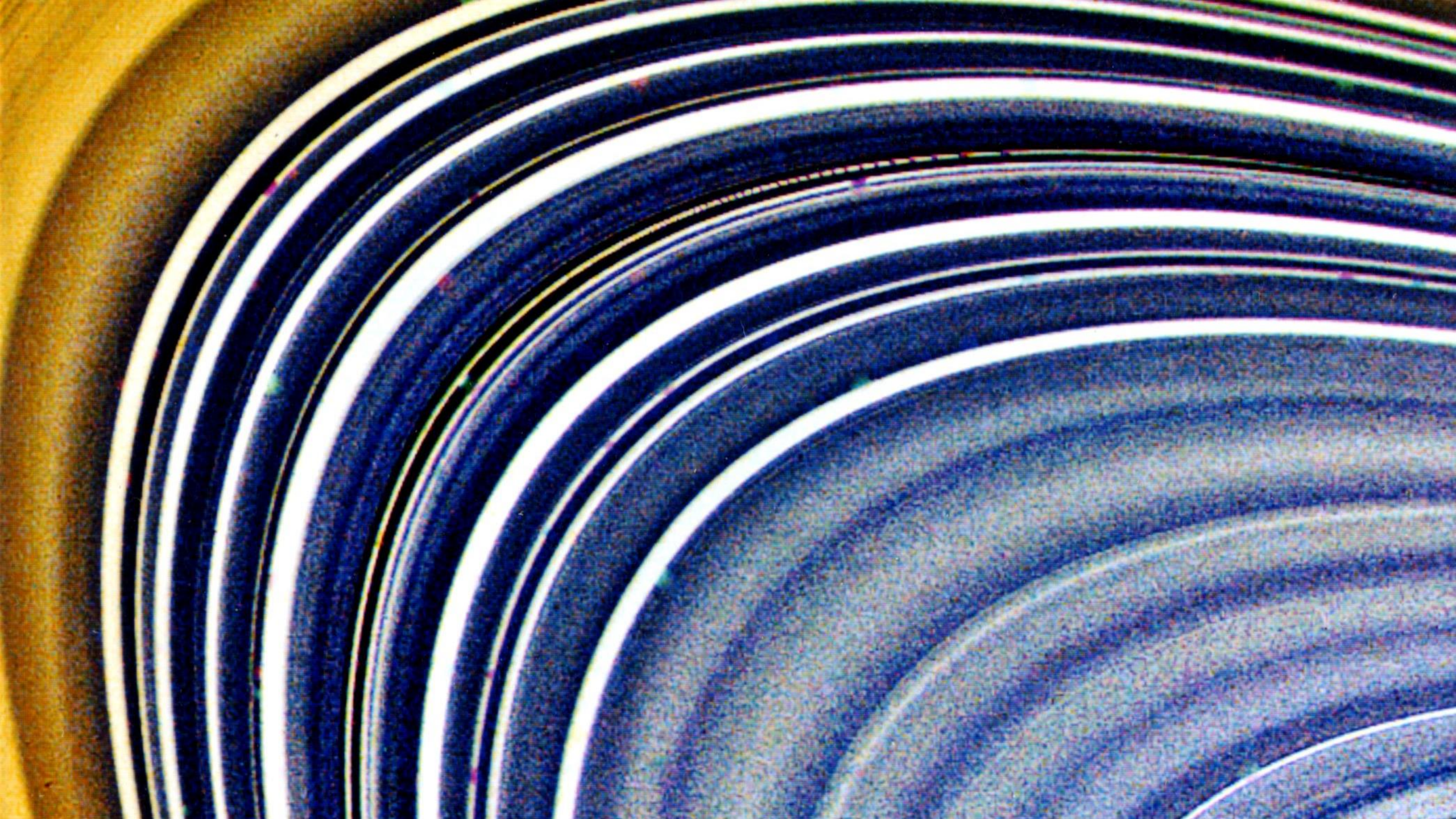
Mimas



A farewell to Saturn



Voyager 2 and Saturn



Iapetus

Outermost major moon

Predominately ice

Mountain chain along equator

The dark region is a coating



Voyager 2 and Uranus

Uranus

Voyager 2 discovered 10 moons

There are now 29 recognised moons

Rotates sideways; it wobbles!

Almost entirely featureless surface

Extremely cold

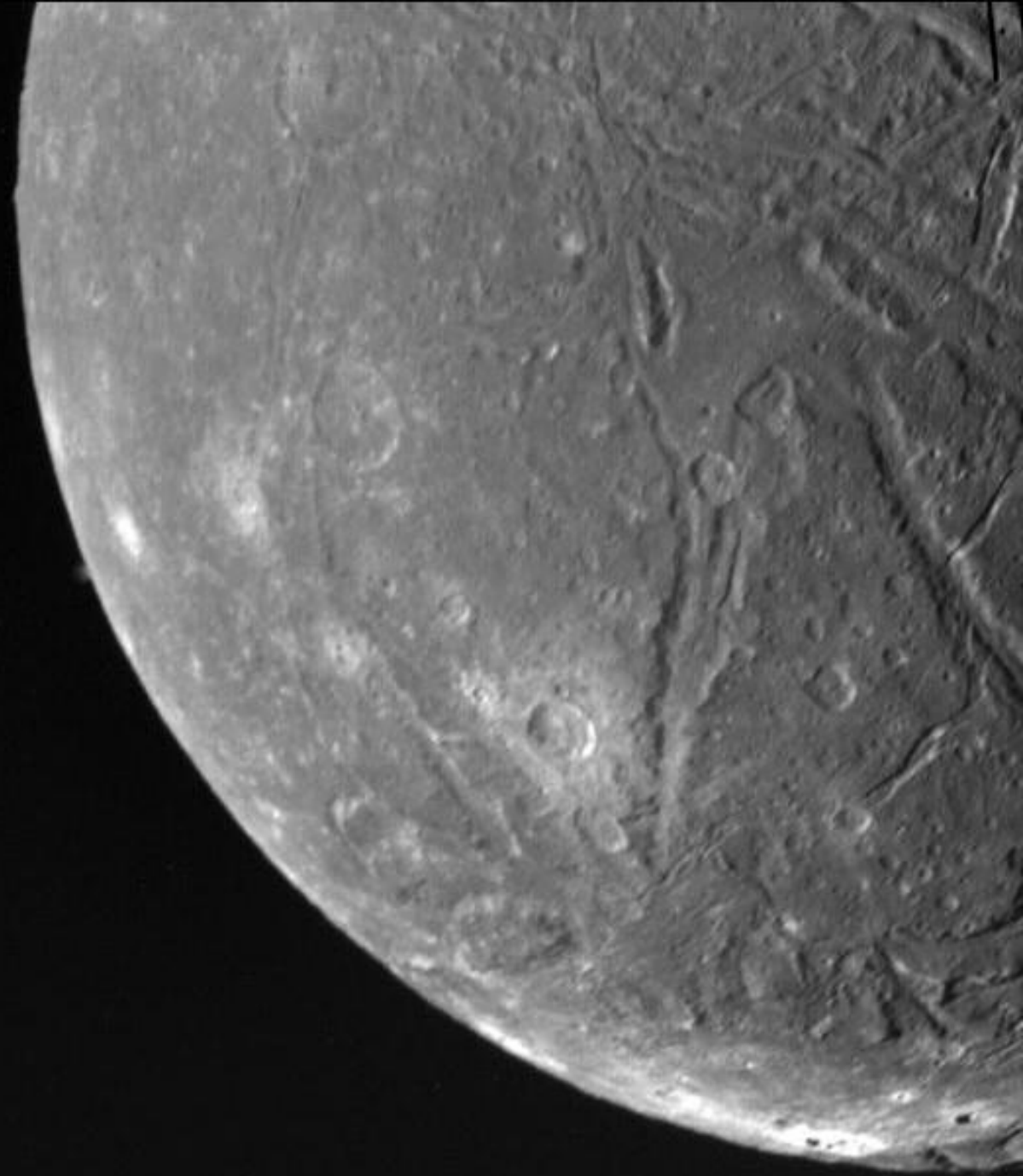




Ariel

Much smaller than our Moon

Rocky, water-ice moon



A final farewell



Voyager 2 and Neptune

Neptune

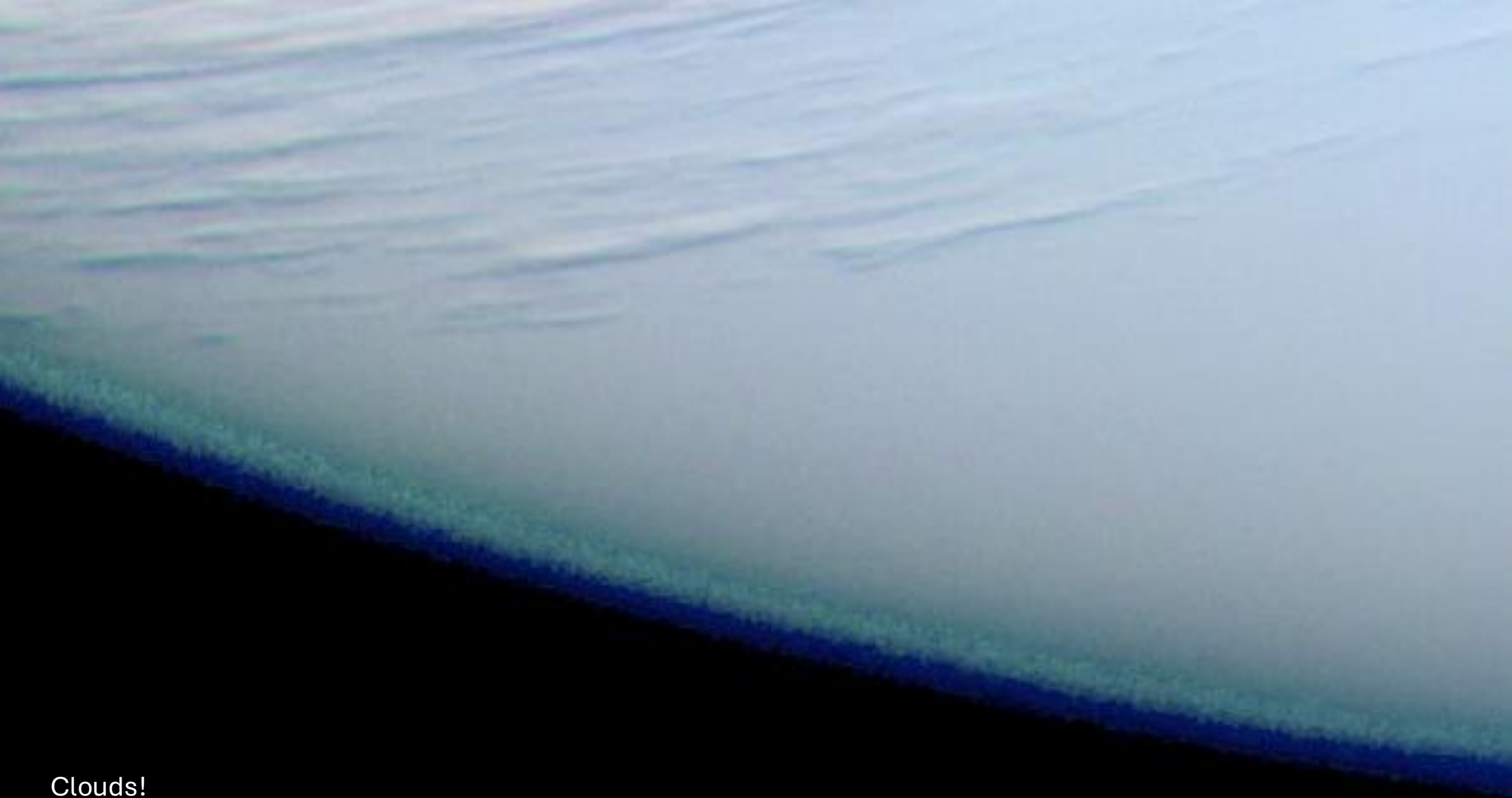
Fastest planetary winds

Large internal heat supply

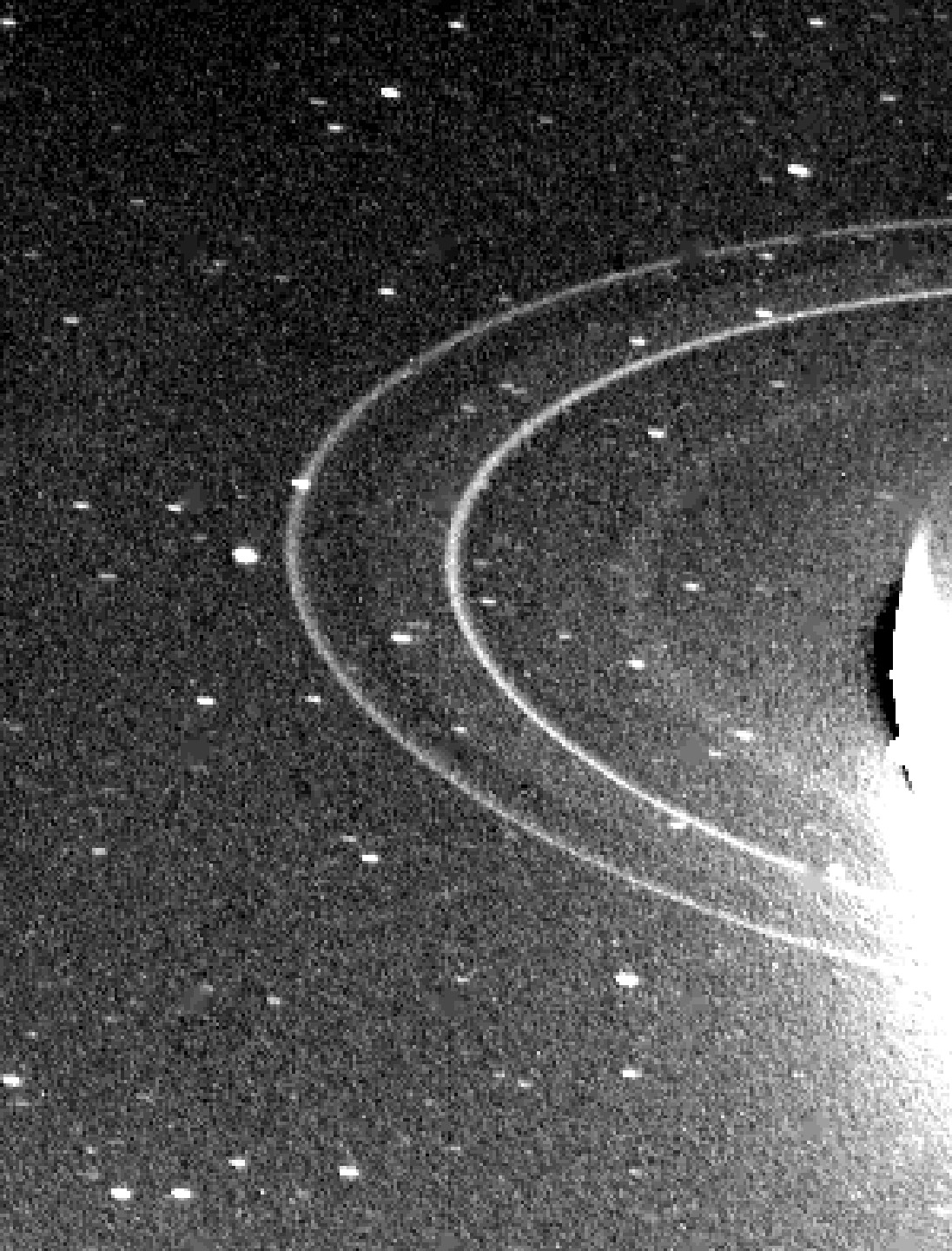
Voyager 2 discovered 8 moons

There are now 16 recognised moons





Clouds!

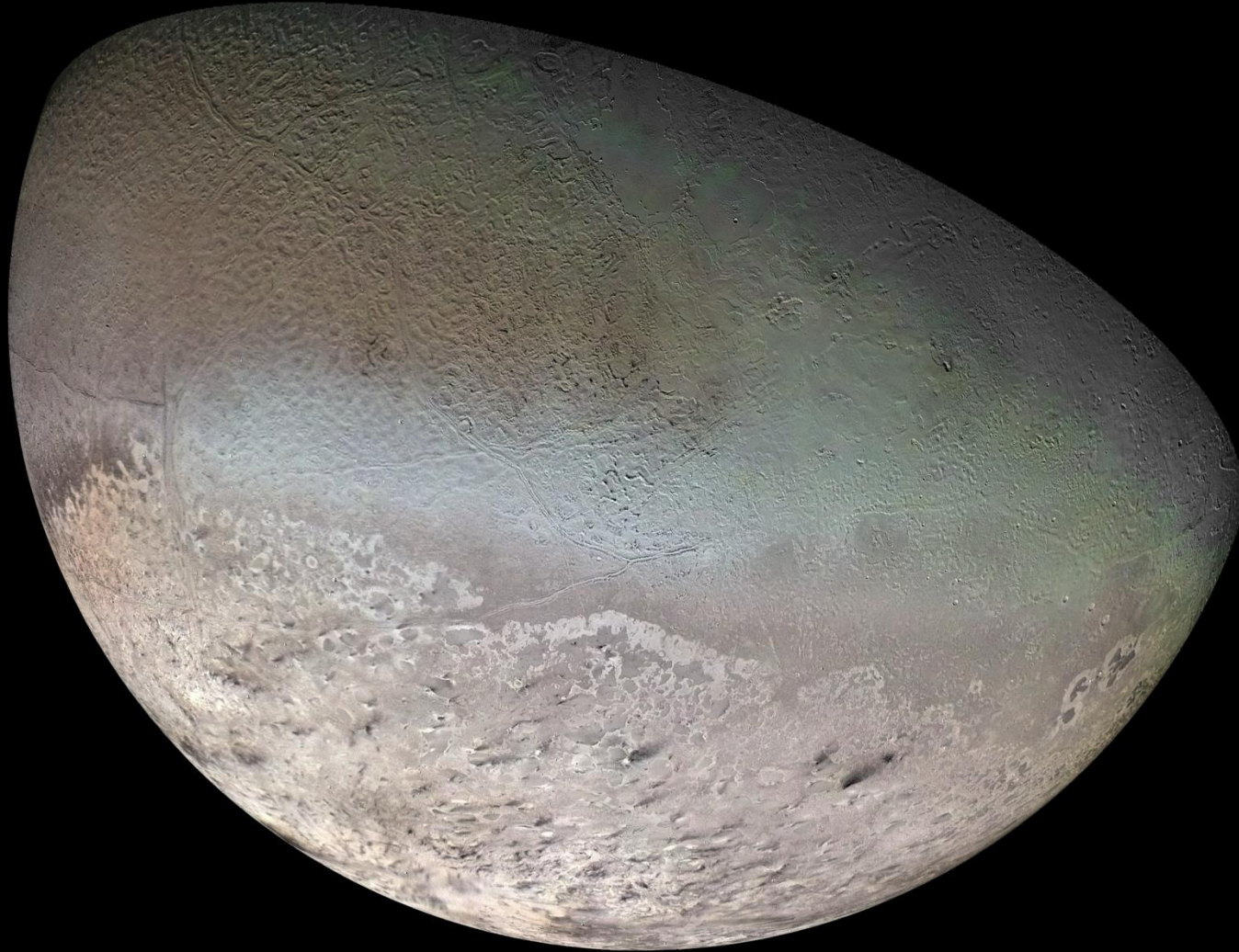


Triton

Active nitrogen geysers

Extremely cold (-235°C)

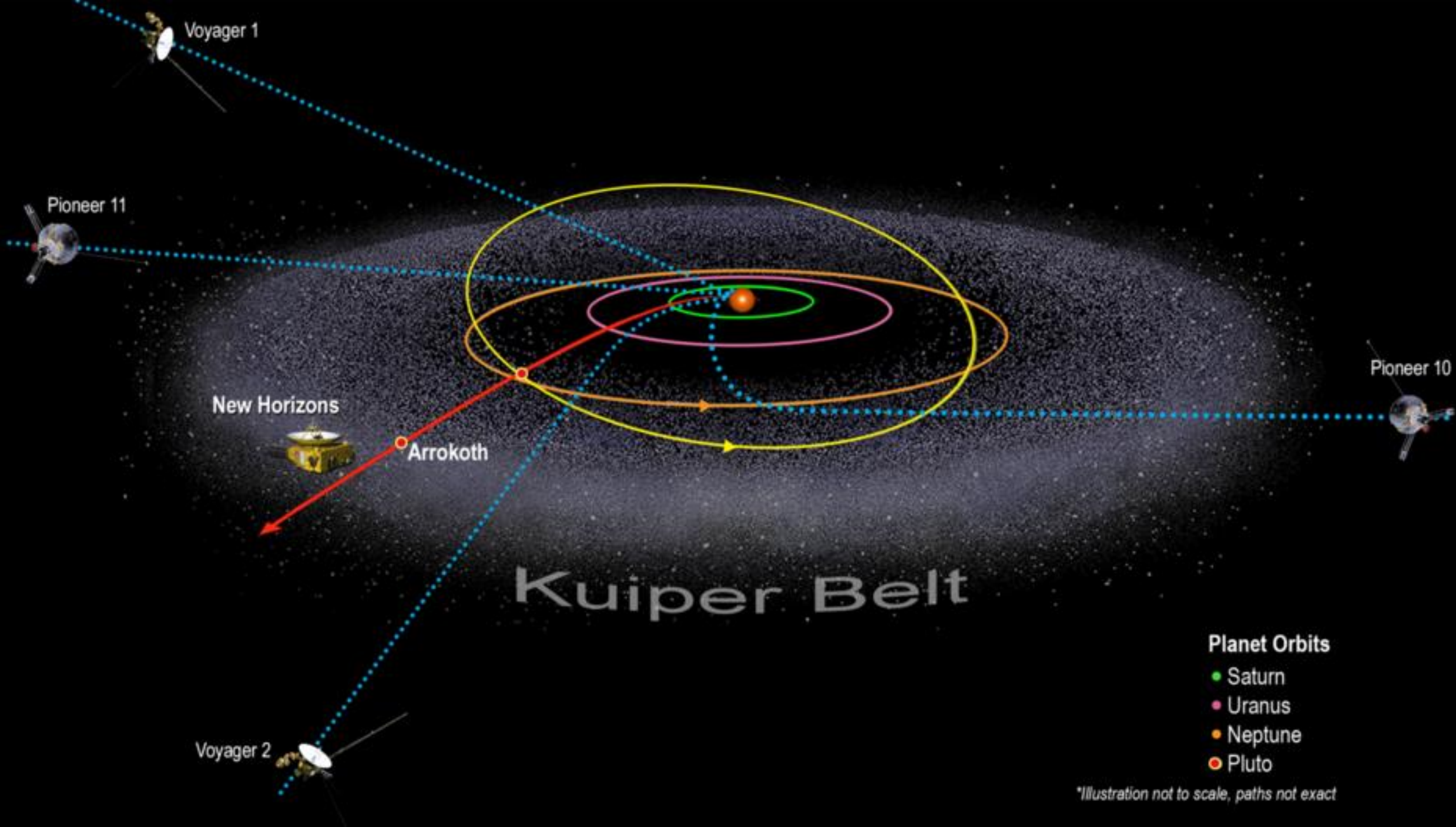
A captured moon?





Goodbye to Neptune and Triton

The Present Day



Outside planetary orbits – decades ago

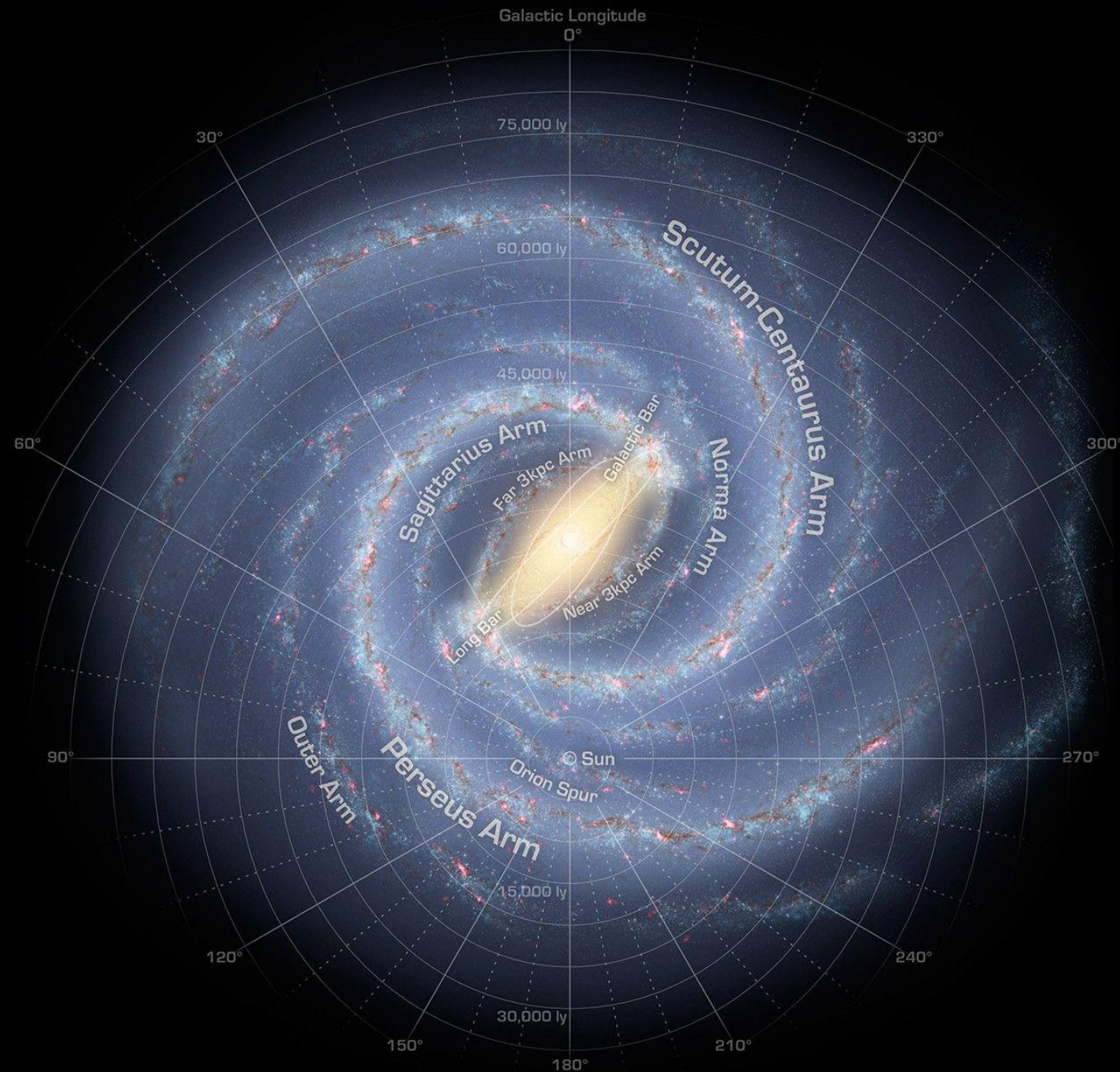
Beyond heliosphere – 2012 and 2018

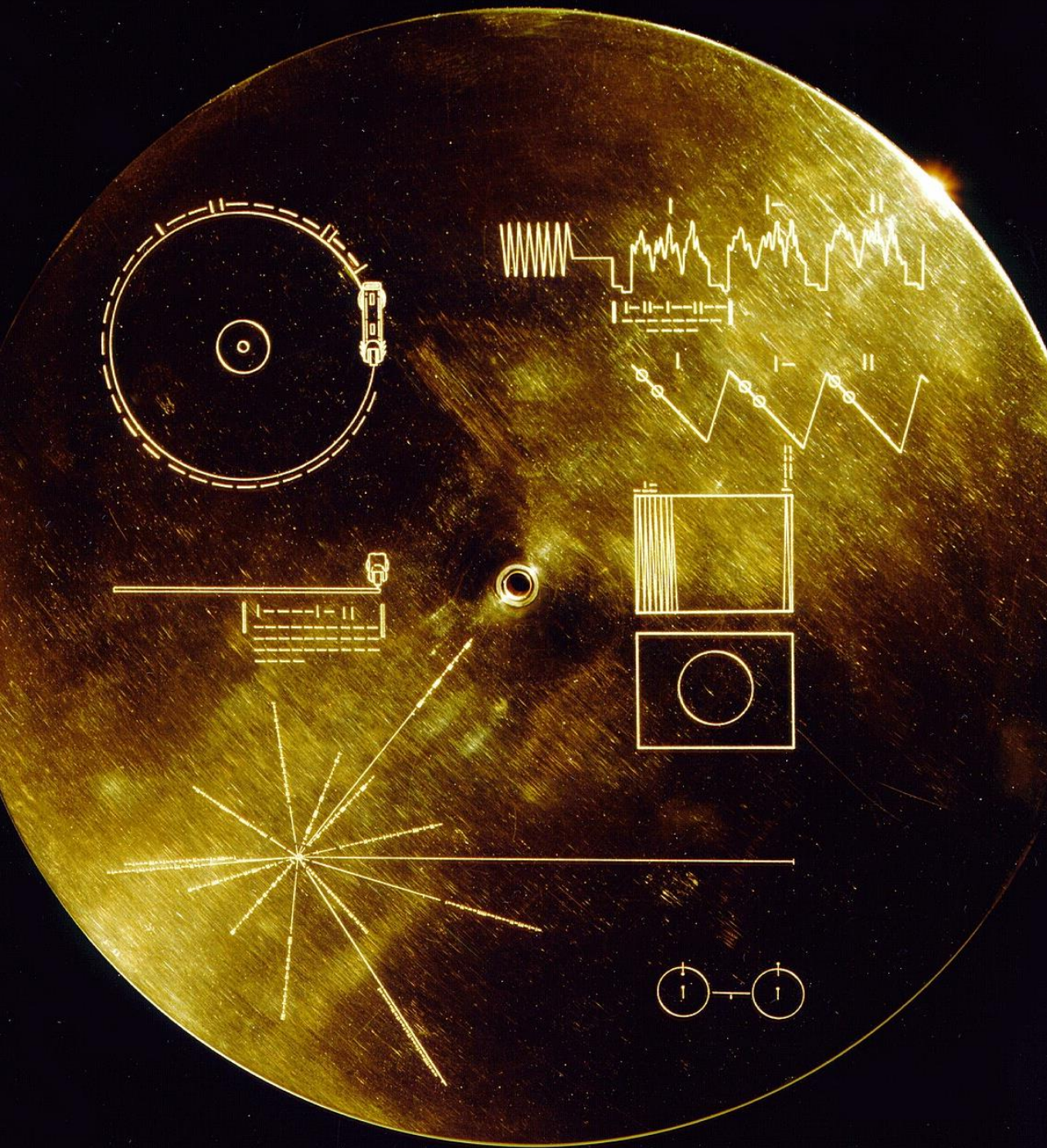
Sun's gravitational system – 30,000 years

Visit other stars – around 40,000 years

Distance of around 1.7 light years

Other side of the galaxy – 2 billion years?







One last look home...

Thank you