Other Worlds in Space, Class 2

What about the more distant planets in the Solar System?

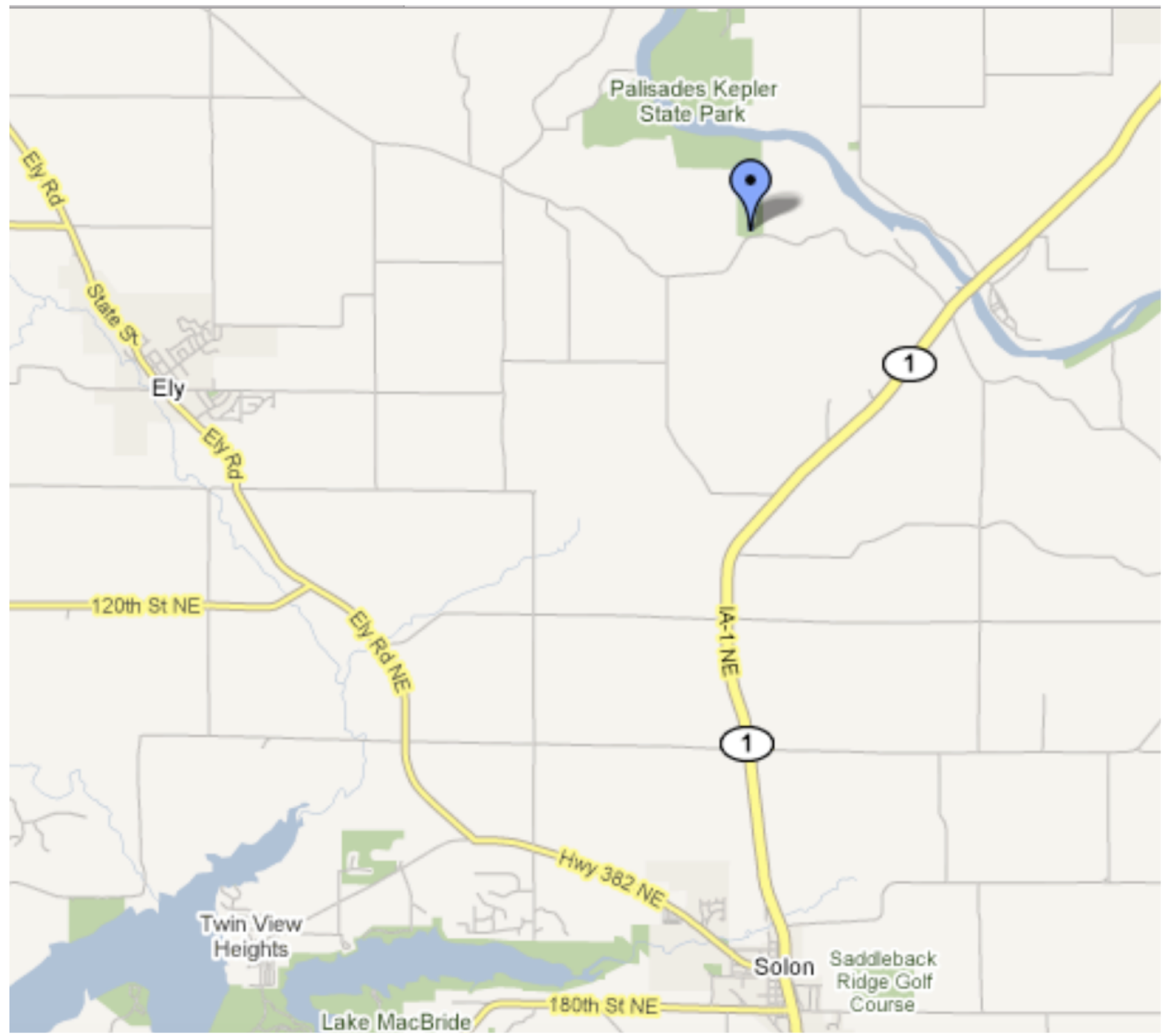
Field Trip for *Other Worlds …*

- Location: EIOLC (near Mt. Vernon)
- Prime Date: Wednesday, April 11
- Backup Date (in case of clouds): Thursday, April 12
- Time: 7:45 PM for about 2 hours
- See some of the things we talk about (e.g. Venus)

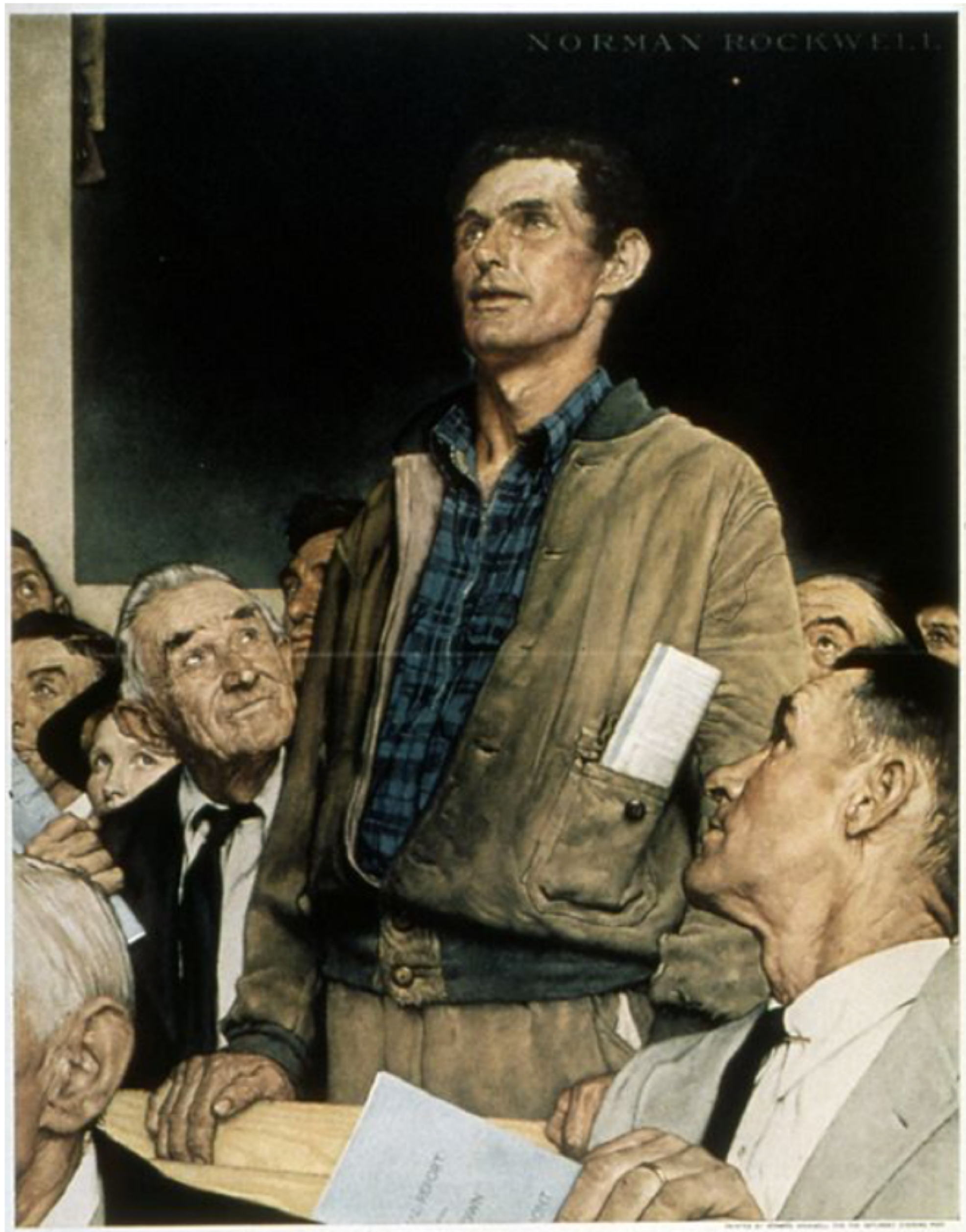
The Eastern Iowa Observatory and Learning Center at Palisades-Dows Preserve.

Field Trip (continued)

- Carpooling good
- Think about it now
- Will ask for a show of hands next time to judge participation
- Further details next week

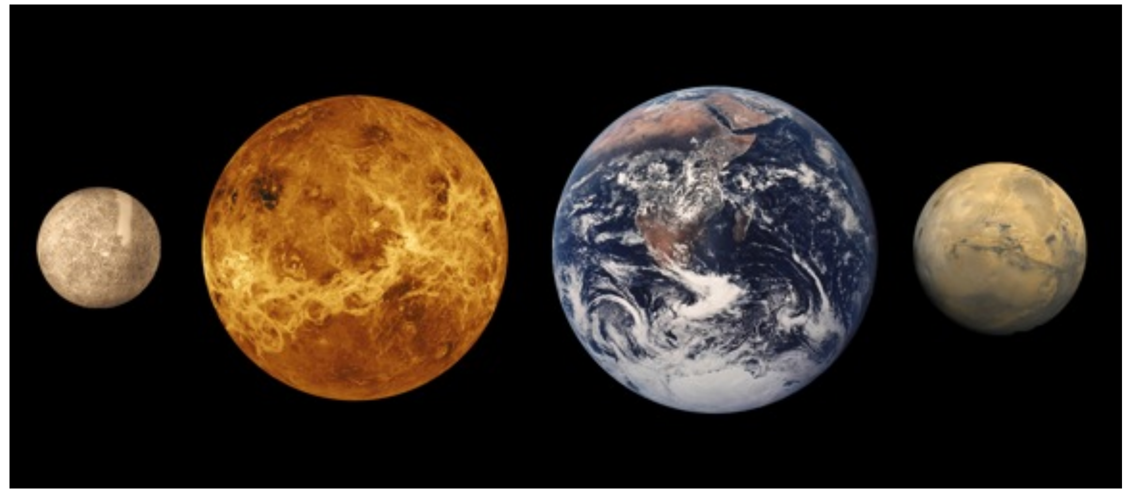


Questions from last time?



Summary of last time; the terrestrial planets

- Earthlike (sort of) planets in the inner solar system
- Venus is Earthlike in size and mass, totally different in temperature
- Mars less Earthlike in size and mass, but may have had similar surface conditions billions of years ago



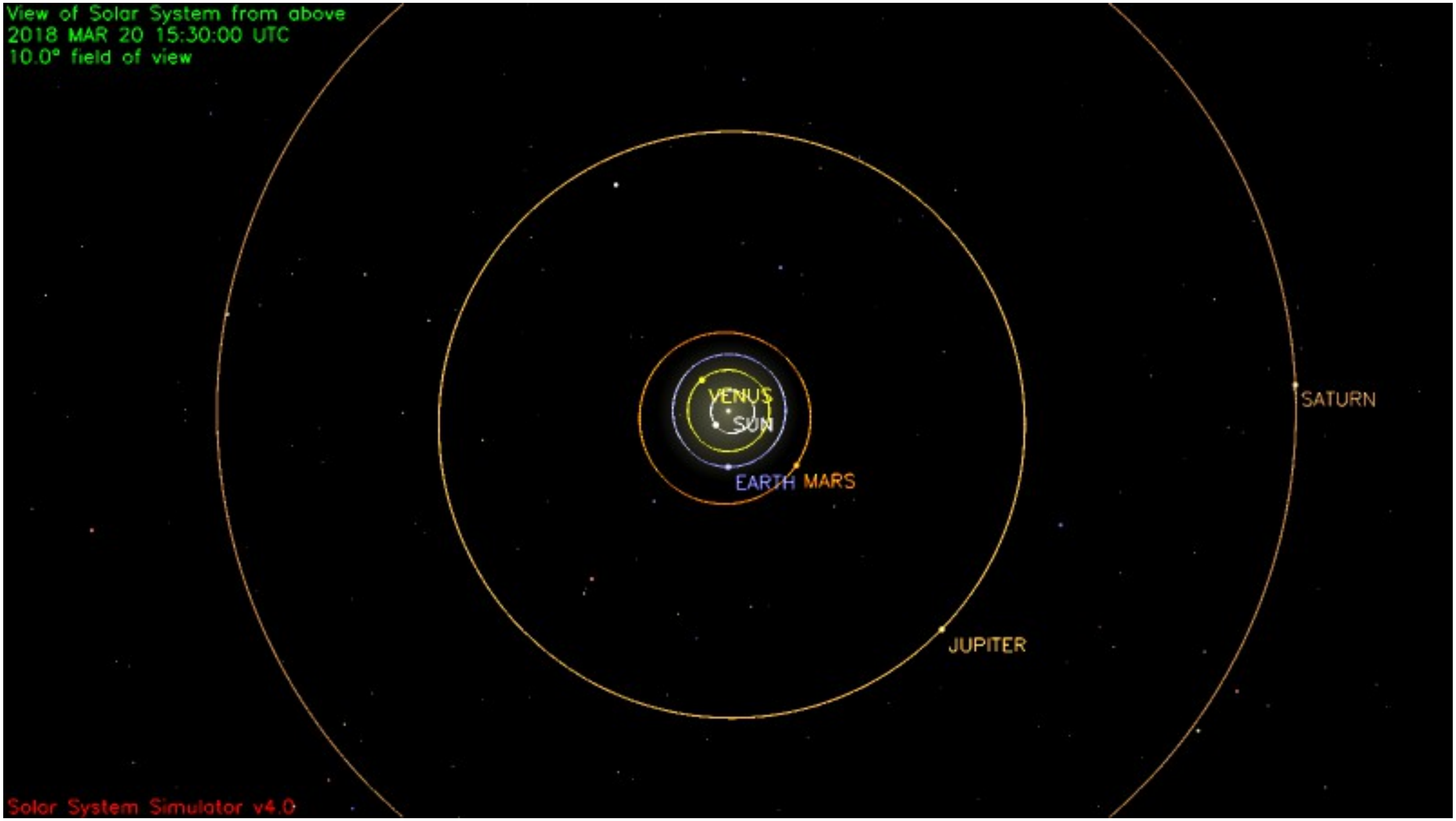
Earth unique among this set of planets

We are almost guaranteed to learn more about Mars in the next decade or two

What about the more distant planets in the Solar System?

What can they tell us about how planets formed, the nature of other solar systems?

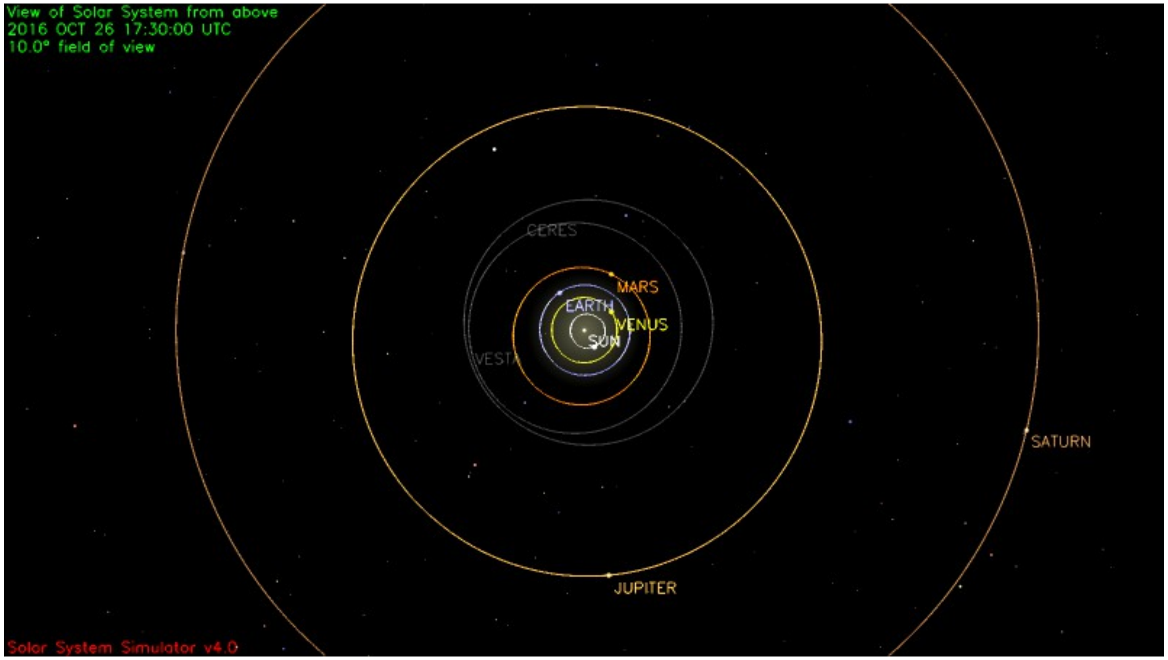
Exploring further out in the Solar System



Jupiter, Saturn, and friends

Jupiter and Saturn: orbital characteristics

Planet	a (AU)	P (yrs)	ecc	Incl (deg)
Jupiter	5.20	11.9	0.049	1.3
Saturn	9.58	29.4	0.057	2.5



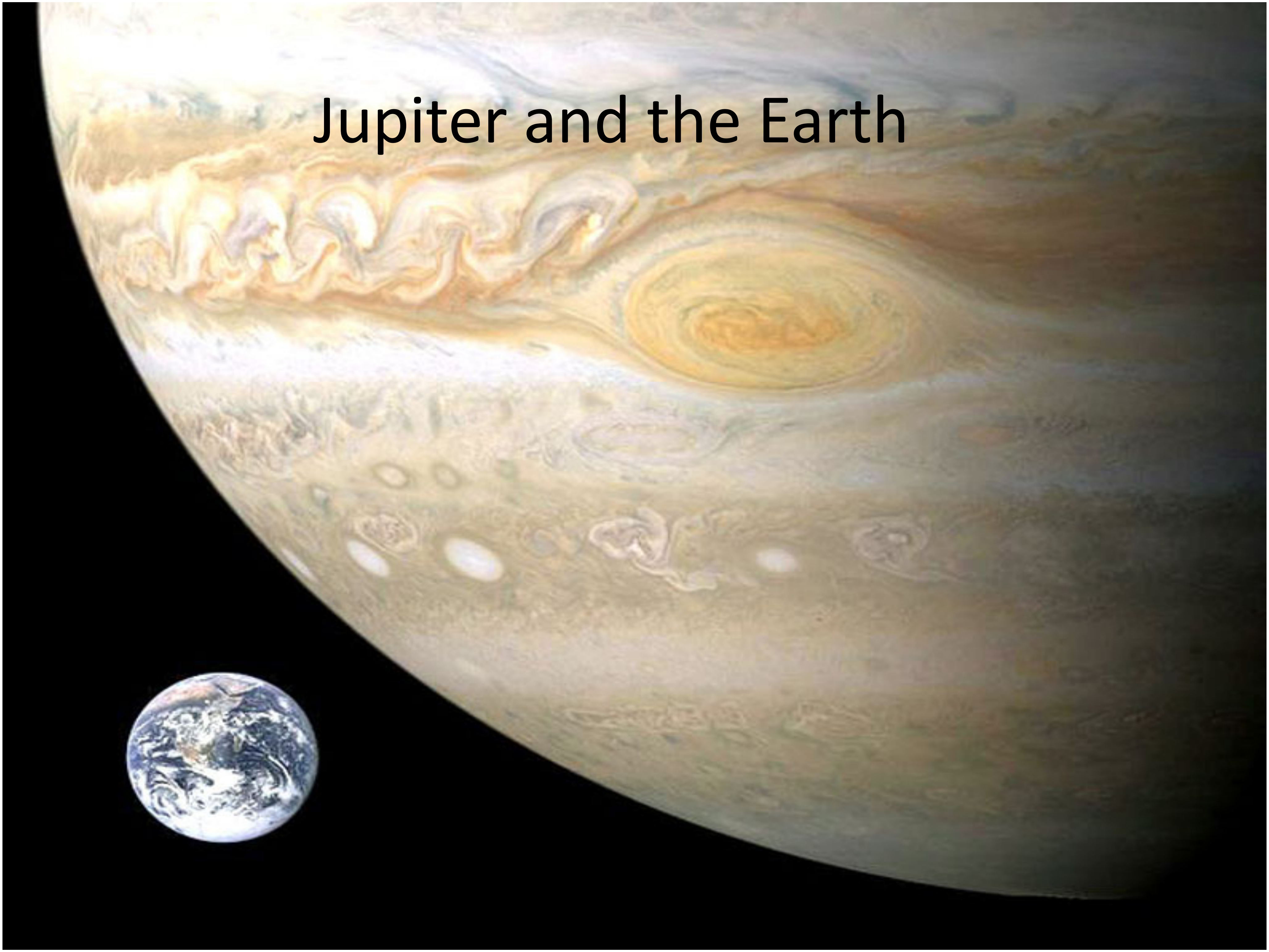
What do they look like? Let’s start with Jupiter

Jupiter…largest planet in the solar system

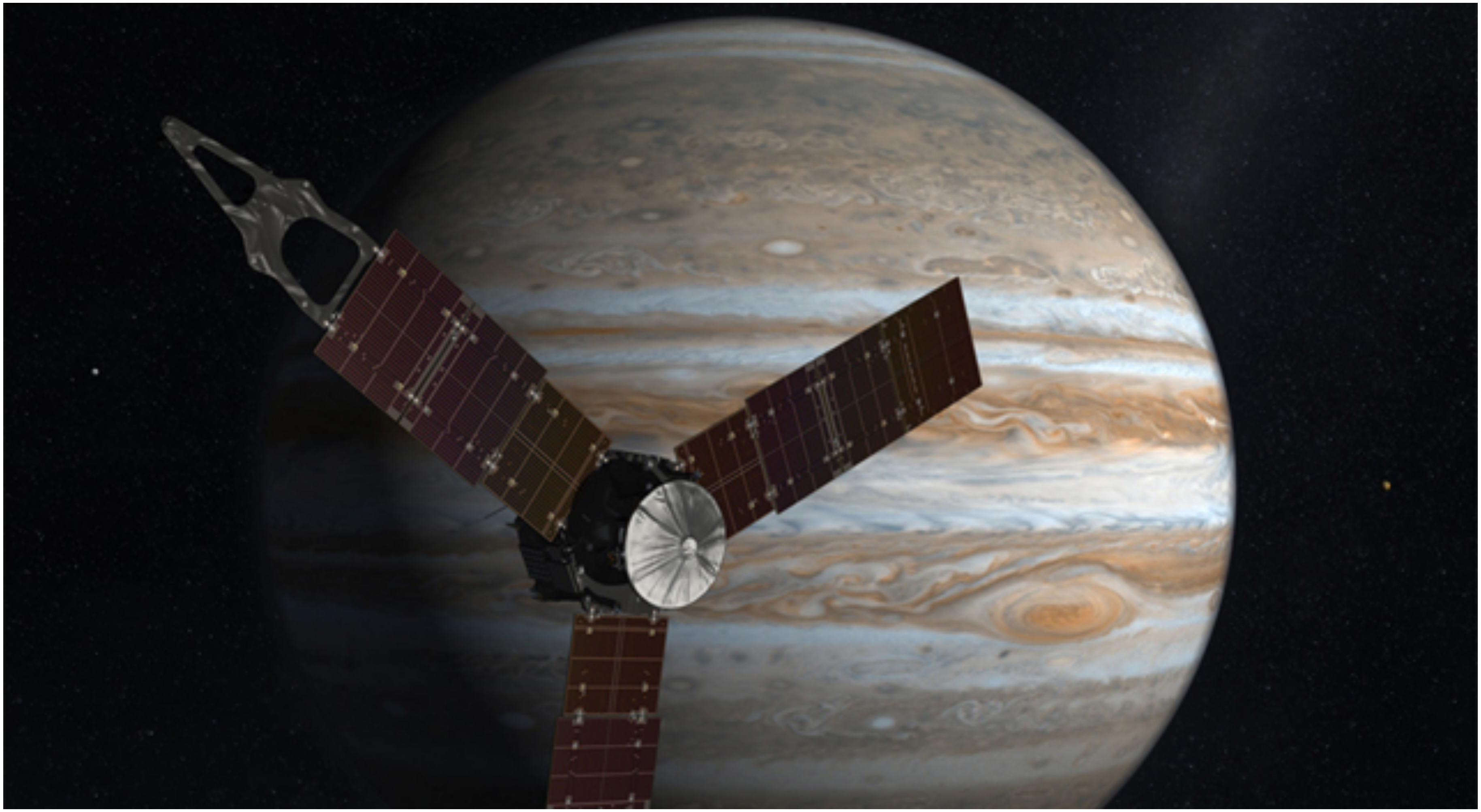
Basic properties of Jupiter and Saturn

- Jupiter: 11.2 X diameter of Earth and 318 X mass
- Saturn: 9.5 X diameter of Earth and 95 X the mass
- Jupiter and Saturn: the "giant planets"
- Jupiter and Saturn are "all atmosphere", and mainly hydrogen and helium

Jupiter and the Earth



The future exploration of Jupiter… Juno (arrived last summer)



Launch: August 5, 2011…   Arrival at Jupiter: July 4, 2016

National Aeronautics and
Space Administration

Juno Spacecraft

SPACECRAFT DIMENSIONS

Diameter: 66 feet (20 meters)
Height: 15 feet (4.5 meters)

For more information:
missionjuno.swri.edu &
www.nasa.gov/juno

Juno's Instruments

Gravity Science and Magnetometers
Study Jupiter's deep structure by mapping the planet's gravity field and magnetic field

Microwave Radiometer
Probe Jupiter's deep atmosphere and measure how much water (and hence oxygen) is there

JEDI, JADE and Waves
Sample electric fields, plasma waves and particles around Jupiter to determine how the magnetic field is connected to the atmosphere, and especially the auroras (northern and southern lights)

UVS and JIRAM
Using ultraviolet and infrared cameras, take images of the atmosphere and auroras, including chemical fingerprints of the gases present

JunoCam
Take spectacular close-up, color images

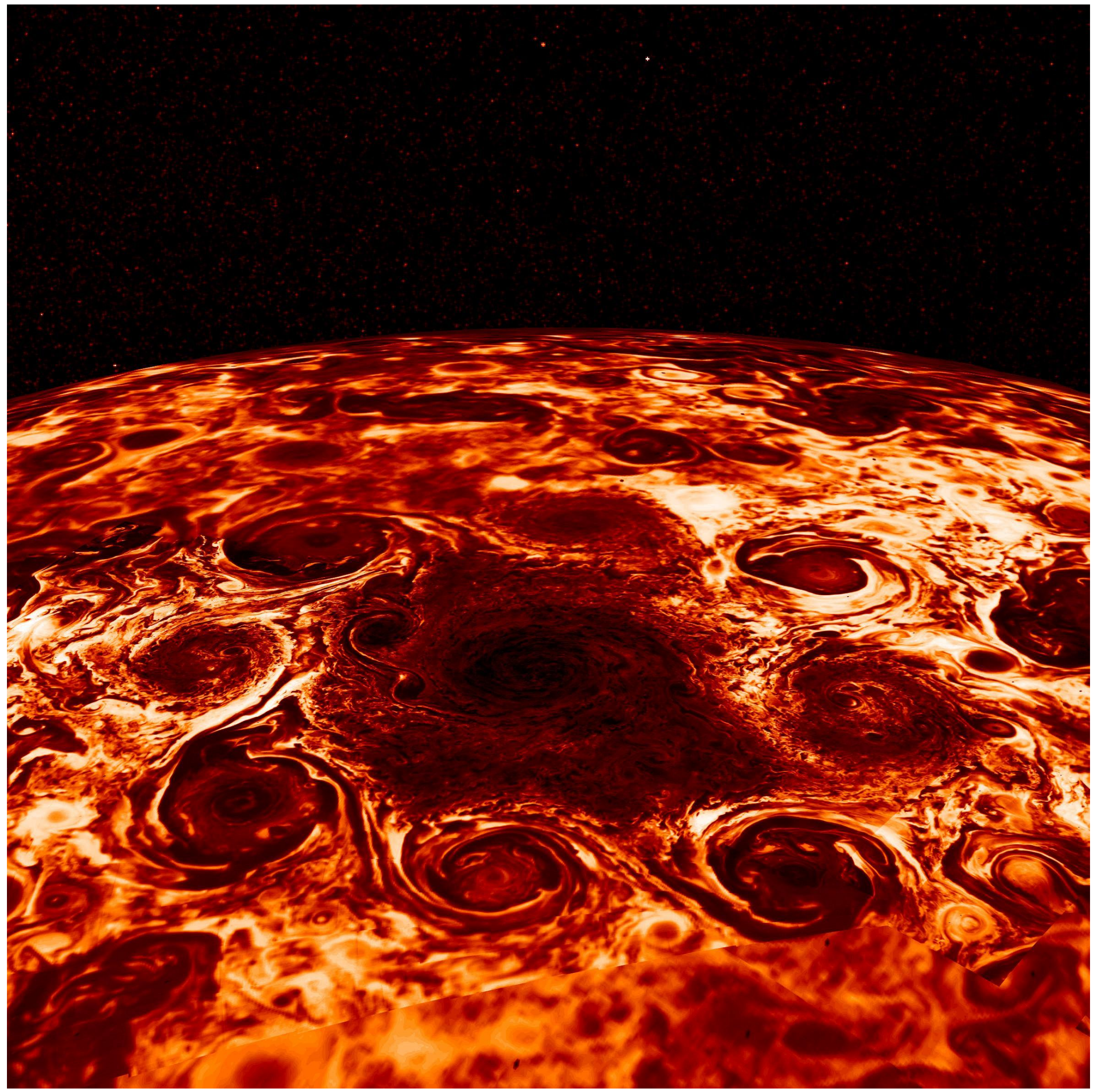
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

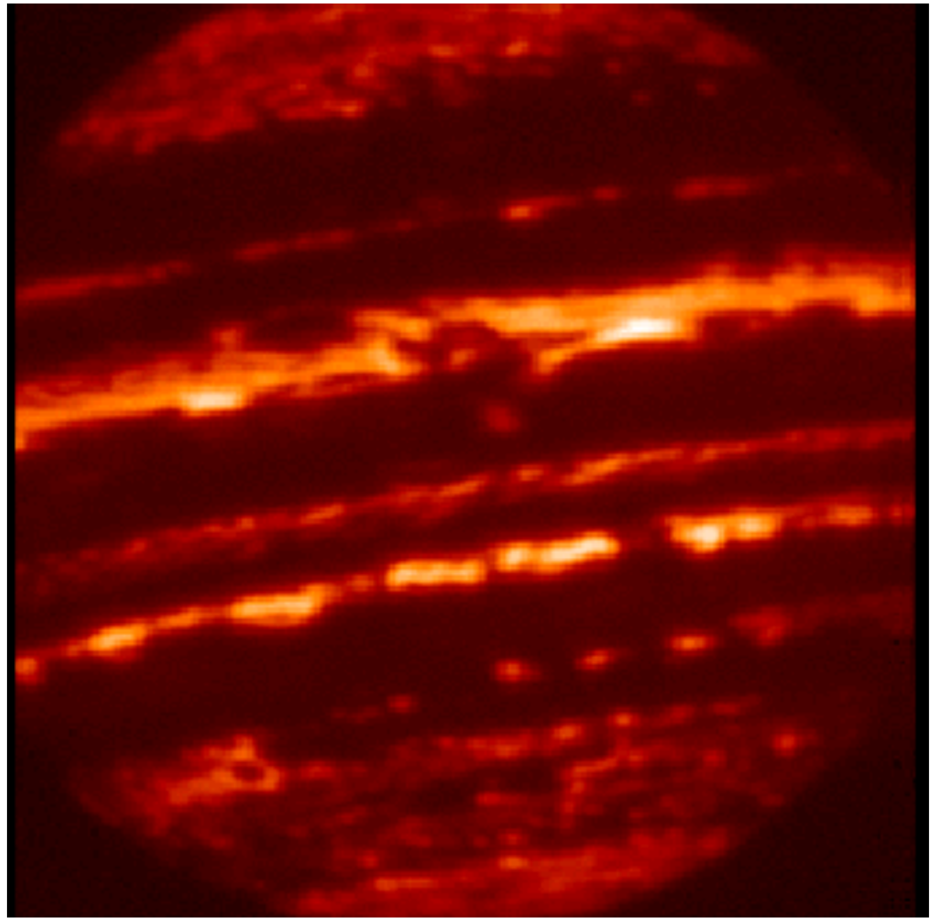
The Juno spacecraft is giving us new insights into Jupiter

There is really no surface on Jupiter; the gas density and pressure get larger and larger, matter weirder and weirder



Are Jupiter and Saturn planets or stars?

Jupiter as seen at infrared wavelengths



Jupiter emits 70% more radiation to space than it receives from the Sun. It has an "engine" inside

The Moons of Jupiter…a new wrinkle for the outer planets

Jupiter has many moons

- 12 when I started studying astronomy
- A standard textbook lists 38
- Most important are the 4 **Galilean** satellites, Io, Europa, Ganymede, Callisto

From Earth, it is difficult to learn too much about the Galilean satellites

At **opposition** of Jupiter, the angular diameter of Ganymede is 1.7 arcseconds

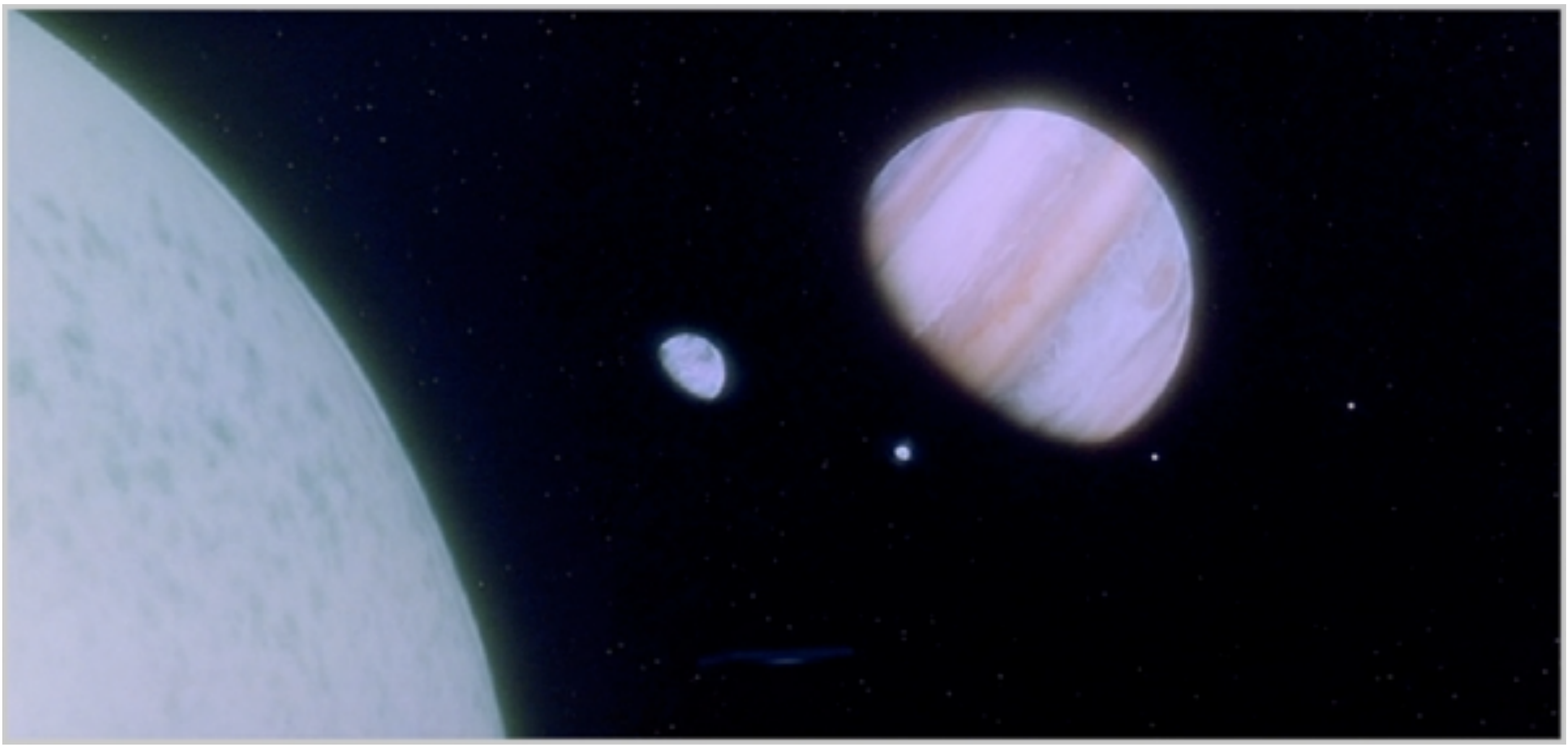
Pre space-age telescope observations revealed a little bit about size, reflectivity (albedo), and surface features

Basic data on the Galilean satellites

moon	a (km)	P (days)	D (km)
Io	422,000	1.769	3630
Europa	671,000	3.551	3130
Ganymede	1,071,000	7.155	5280
Callisto	1,884,000	16.689	4840
MOON	384,000	27.32	3476

The largest Moon, Ganymede, has a diameter about 50 percent larger than our Moon

What are the moons of Jupiter like? Would do they look like “up close”?

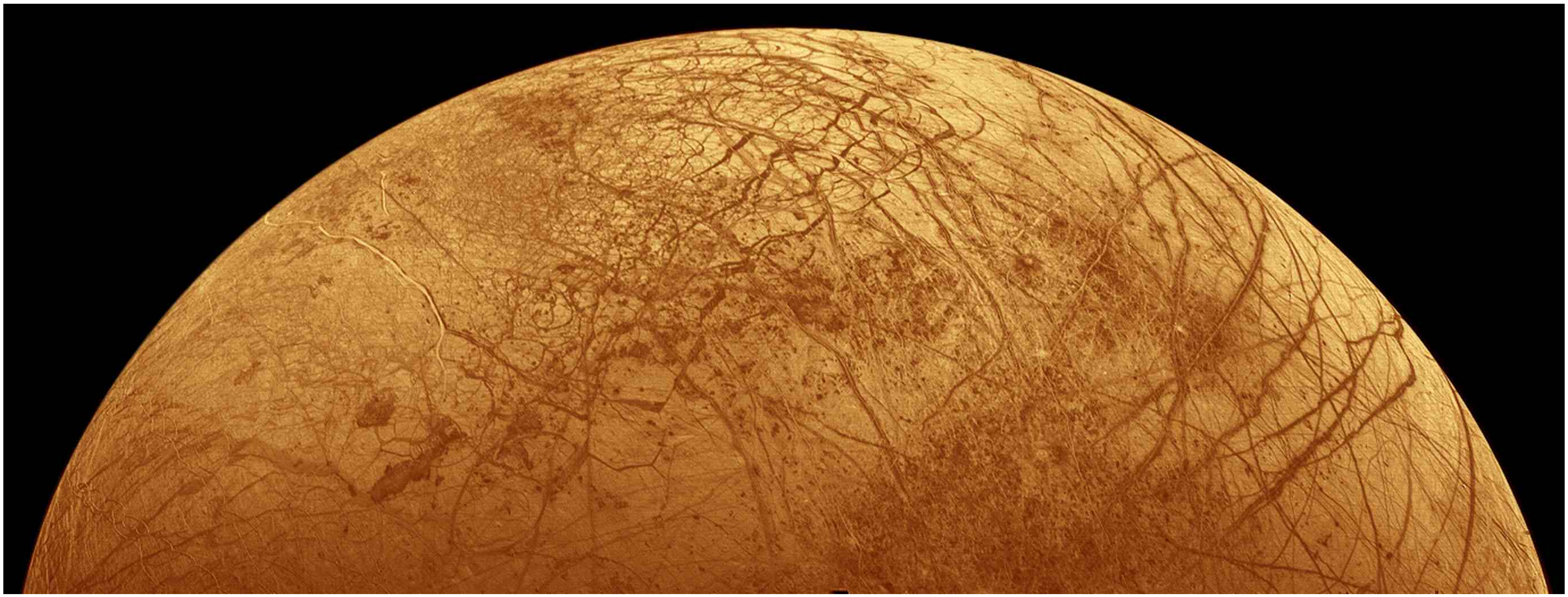


The 1968 movie “2001 A Space Odyssey” has them similar and looking like our Moon

All of them together (sibling portrait)

Images scaled to give correct relative sizes

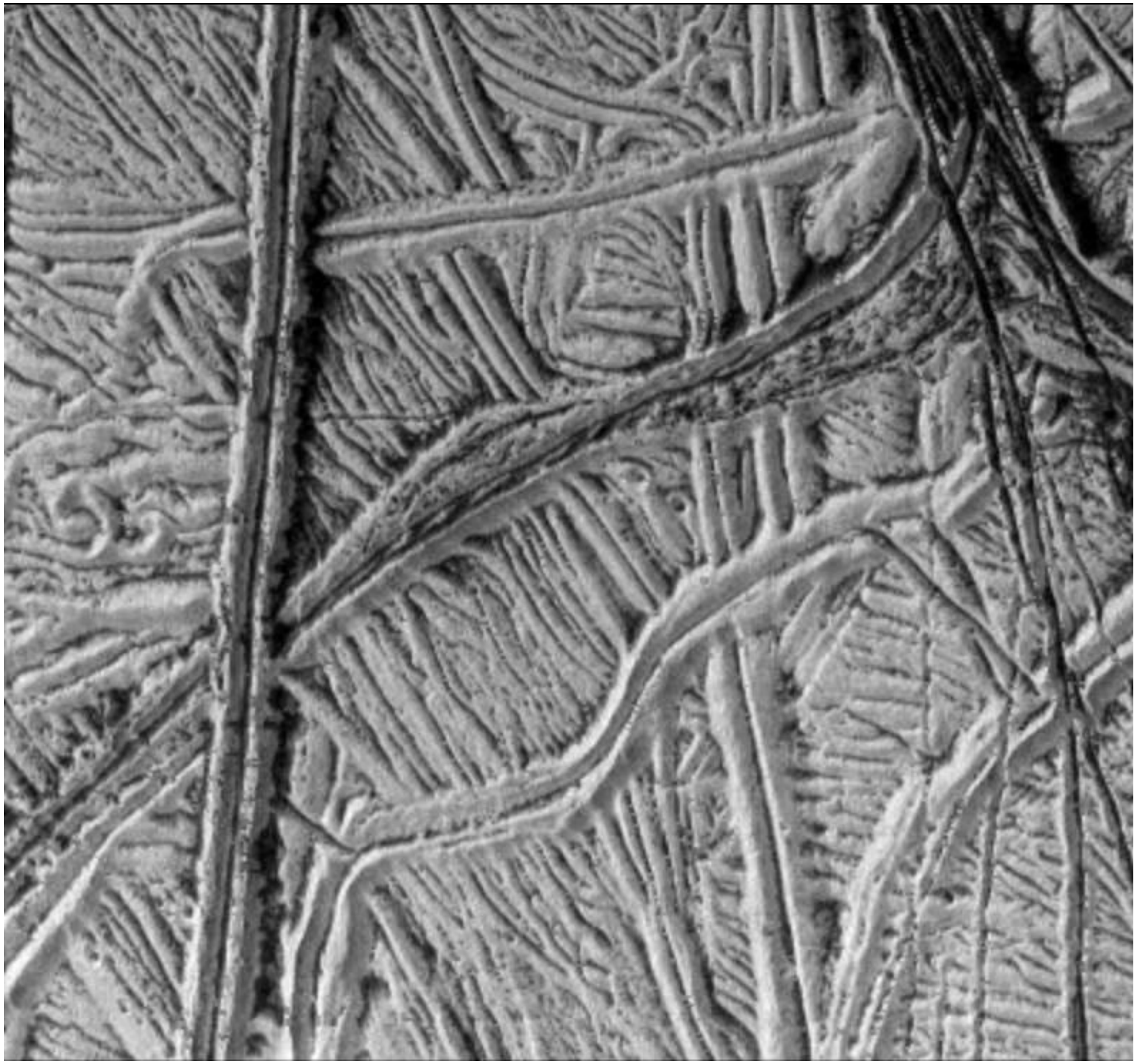
Exploring Europa



What is under its ice-covered plains?

Europa is slightly smaller and less massive than our Moon. It is of interest because the entire moon is encased in ice. There are cracks and other features that hint at liquid water at some point below the surface,

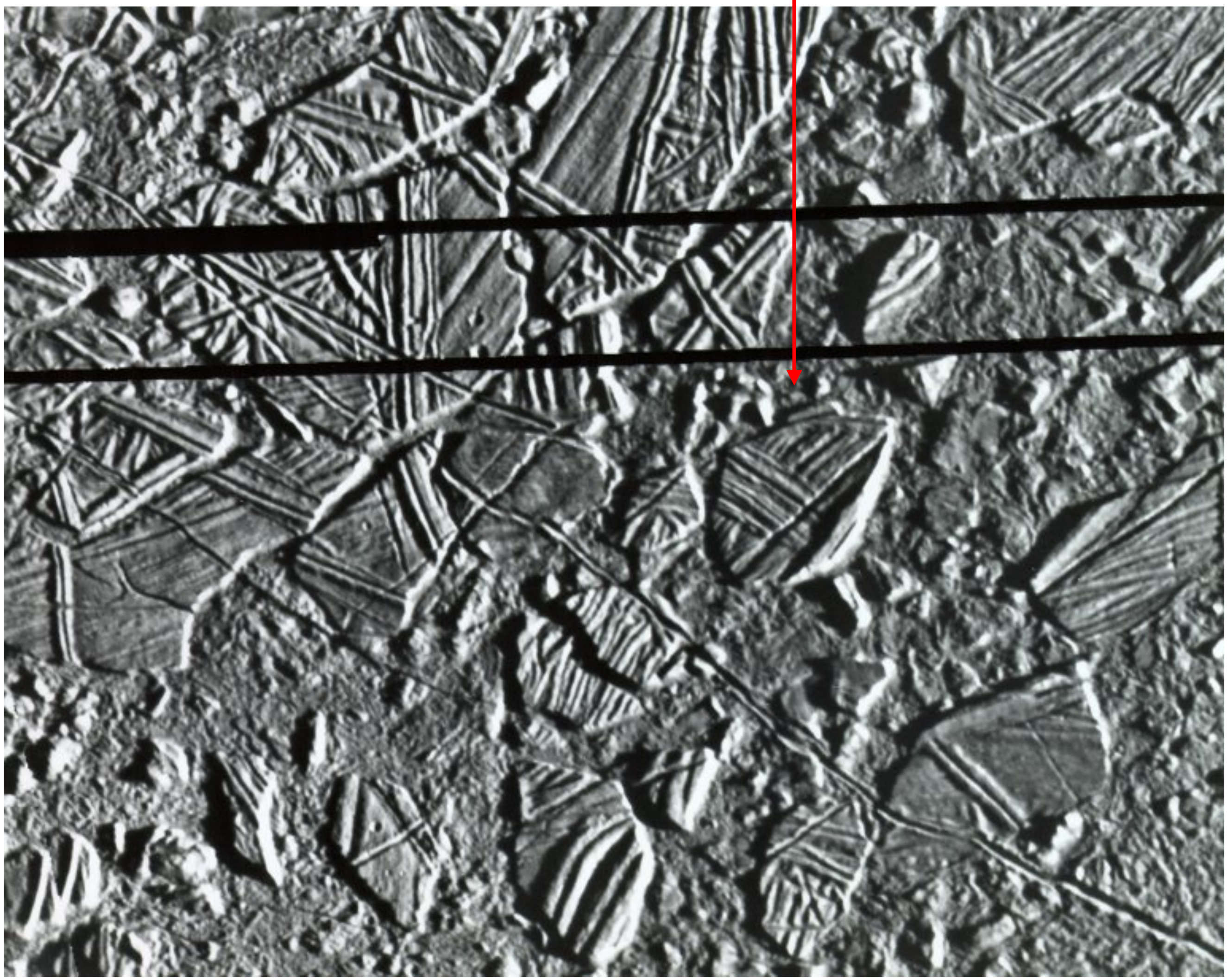
Views of the cracks from Galileo



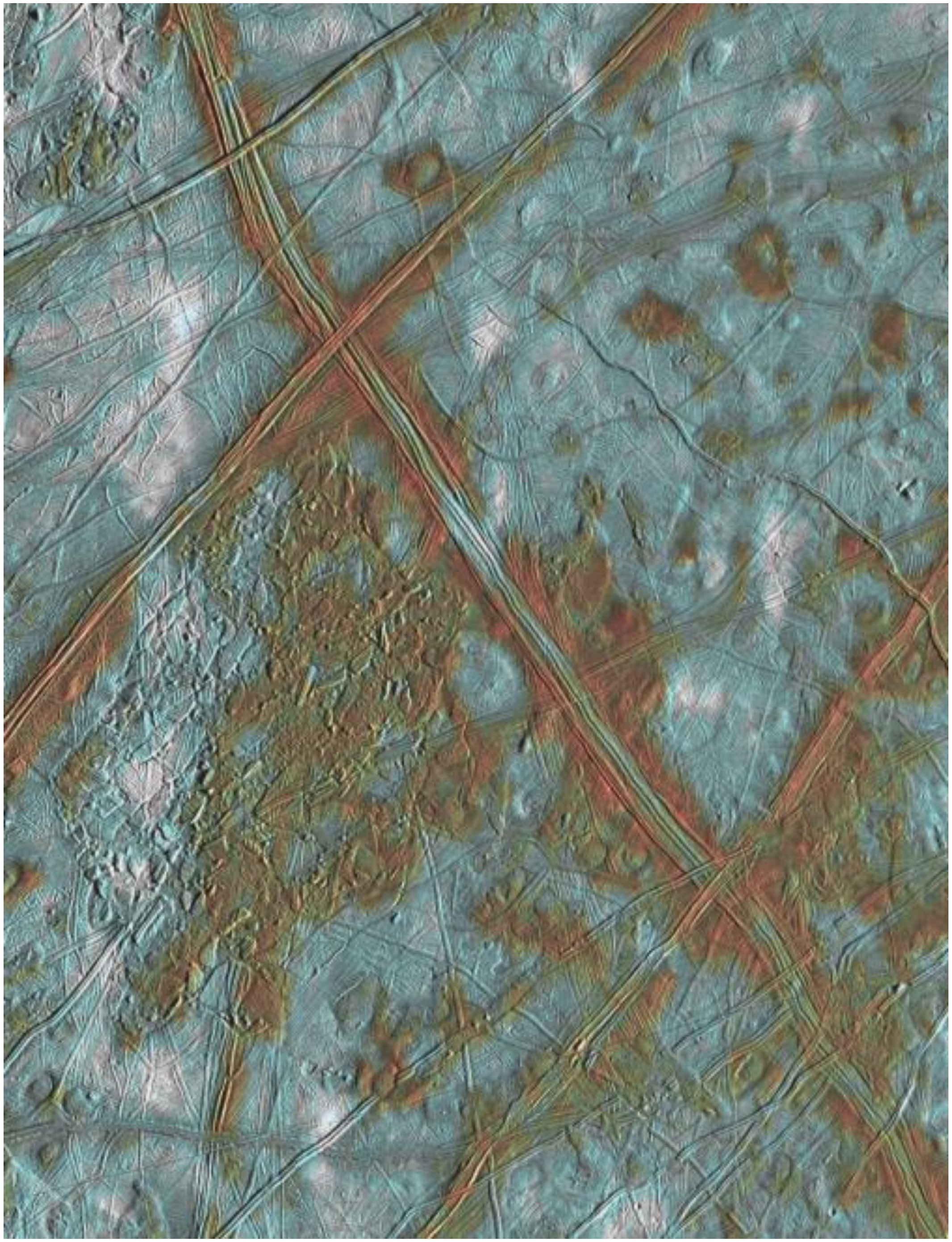
Picture about 100 miles on a side

A related phenomenon. The ice rafts of Europa

Similar features seen in arctic ocean and are due to flows of ocean underneath



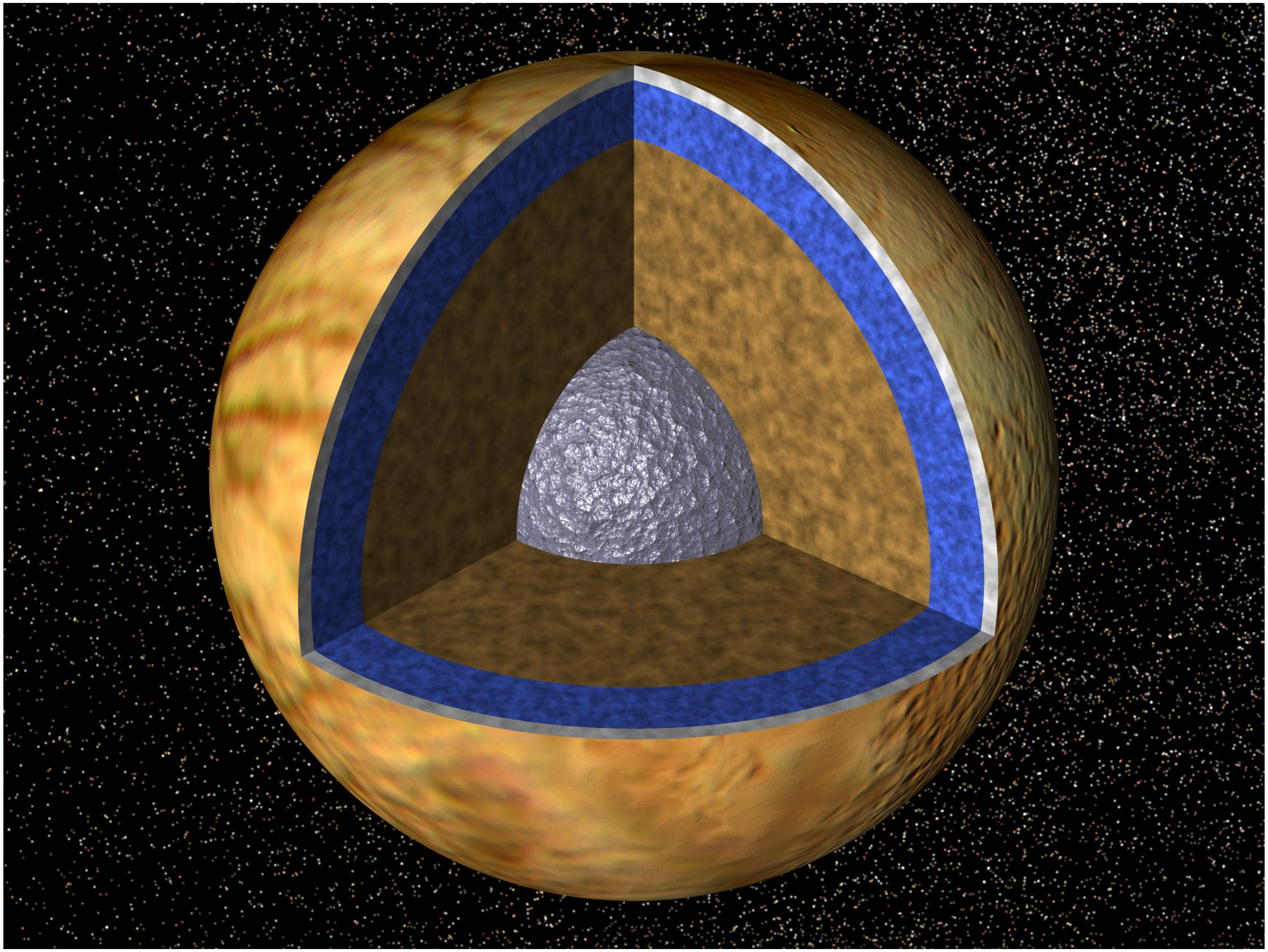
Evidence for flows from beneath the surface of Europa



There is evidence (circumstantial) for liquid water under the surface, but how far down is it? What is below the water?

Spacecraft missions to Europa over the next few decades might tell us

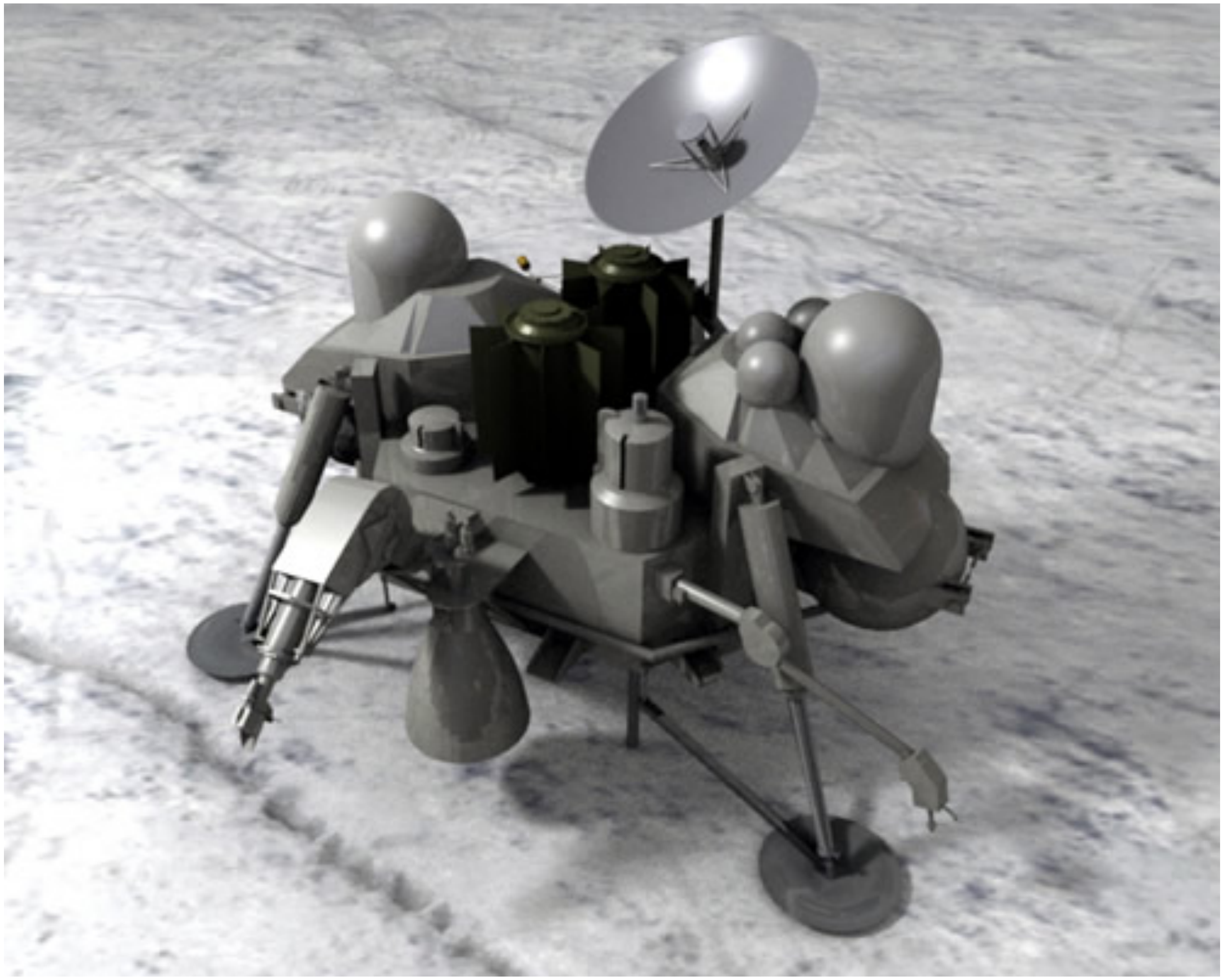
Speculations on interior structure of Europa



A summary of what we know about Europa

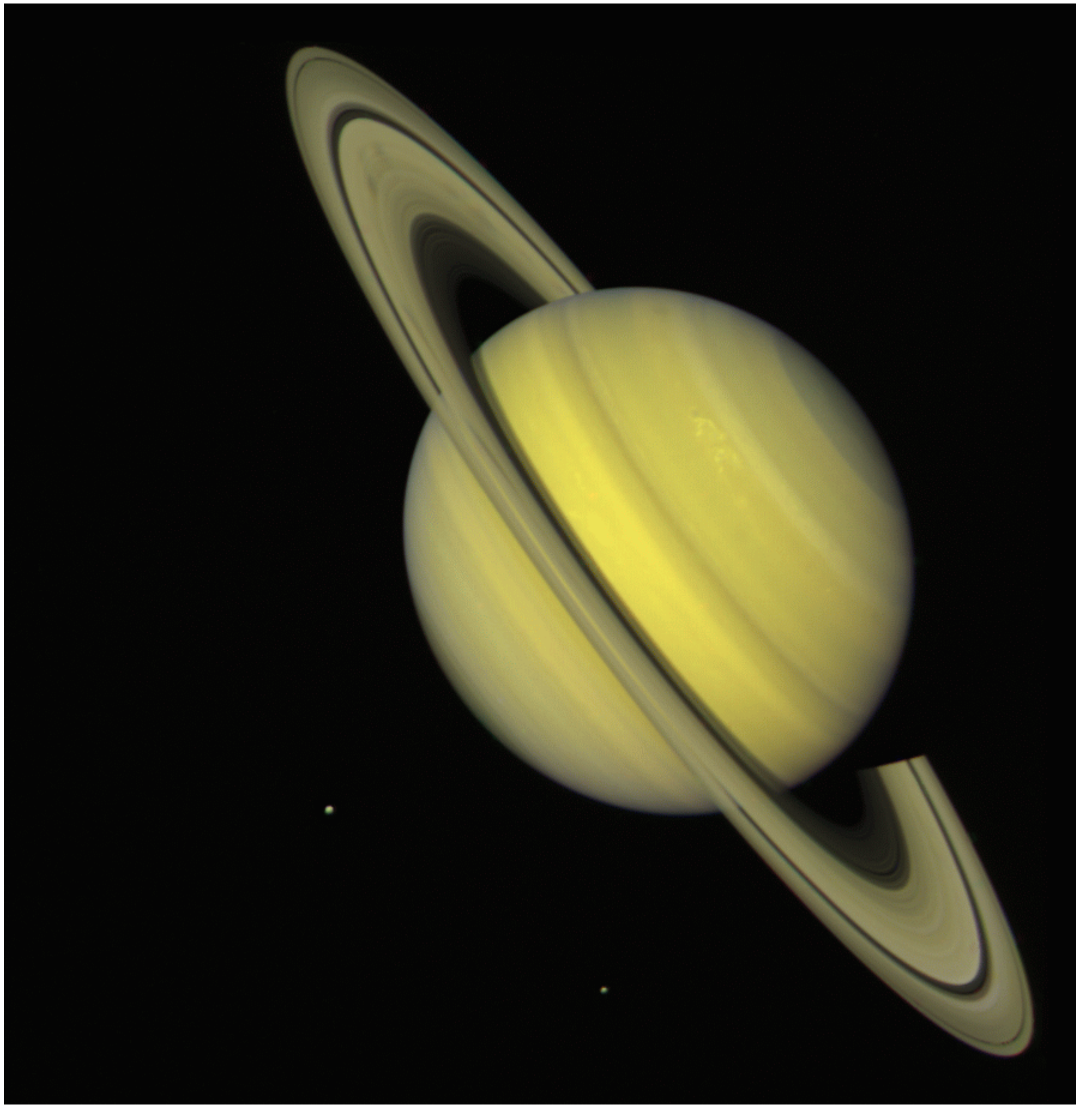
- Slightly smaller in mass and diameter than the Moon
- Surface covered with water ice casing
- Evidence for surface “activity” from cracks and grooves, and ice rafts
- Small numbers of craters implies surface has reformed in last 100 million years
- Estimates that liquid layer, “sealed ocean” is between 10 - 50 kilometers below the surface, with possible rocky sea floor

A future Europa Lander could tell us much about the possible subsurface ocean of Europa



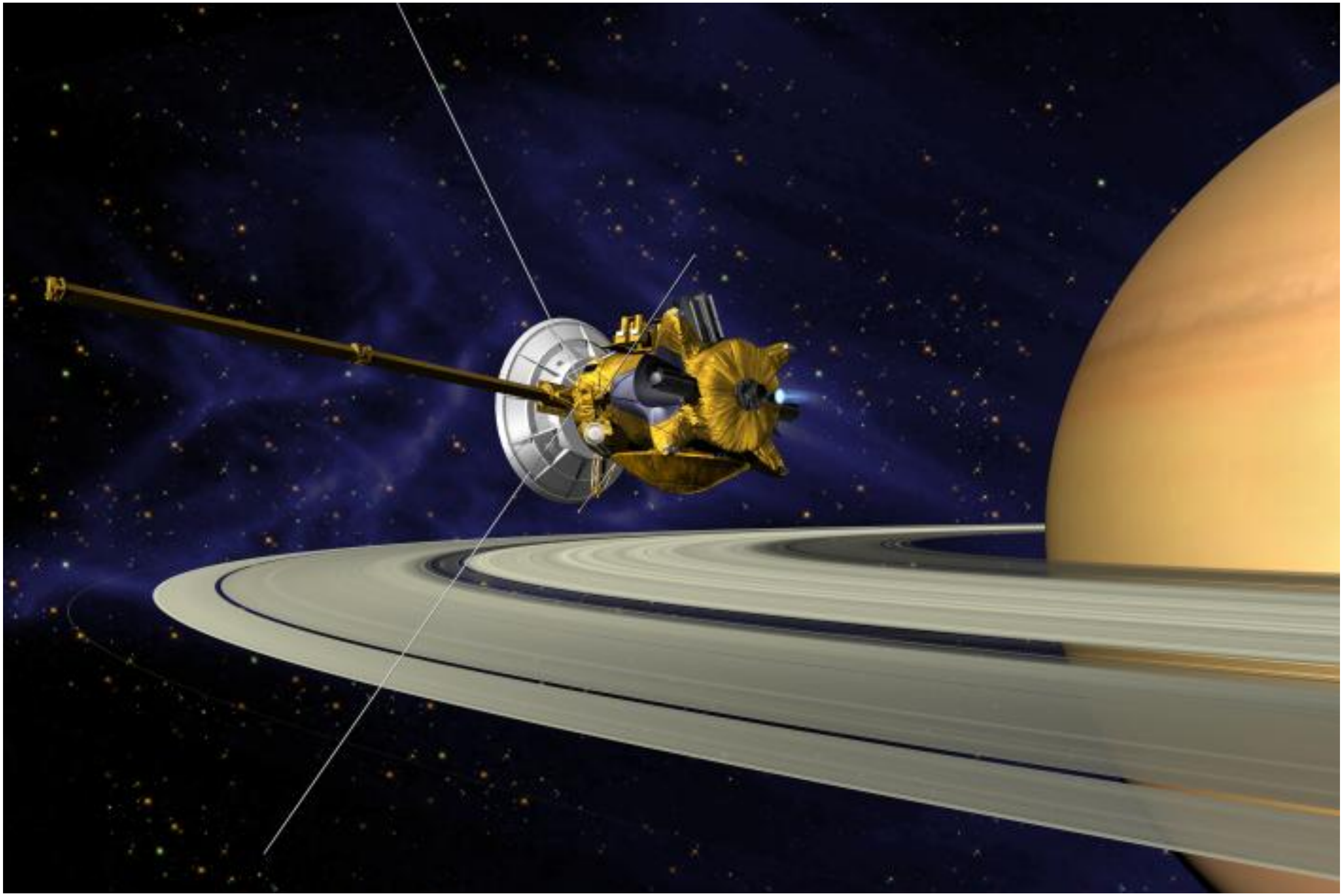
Europa Clipper launch 2022, arrival 2024

What about Saturn and its moons?

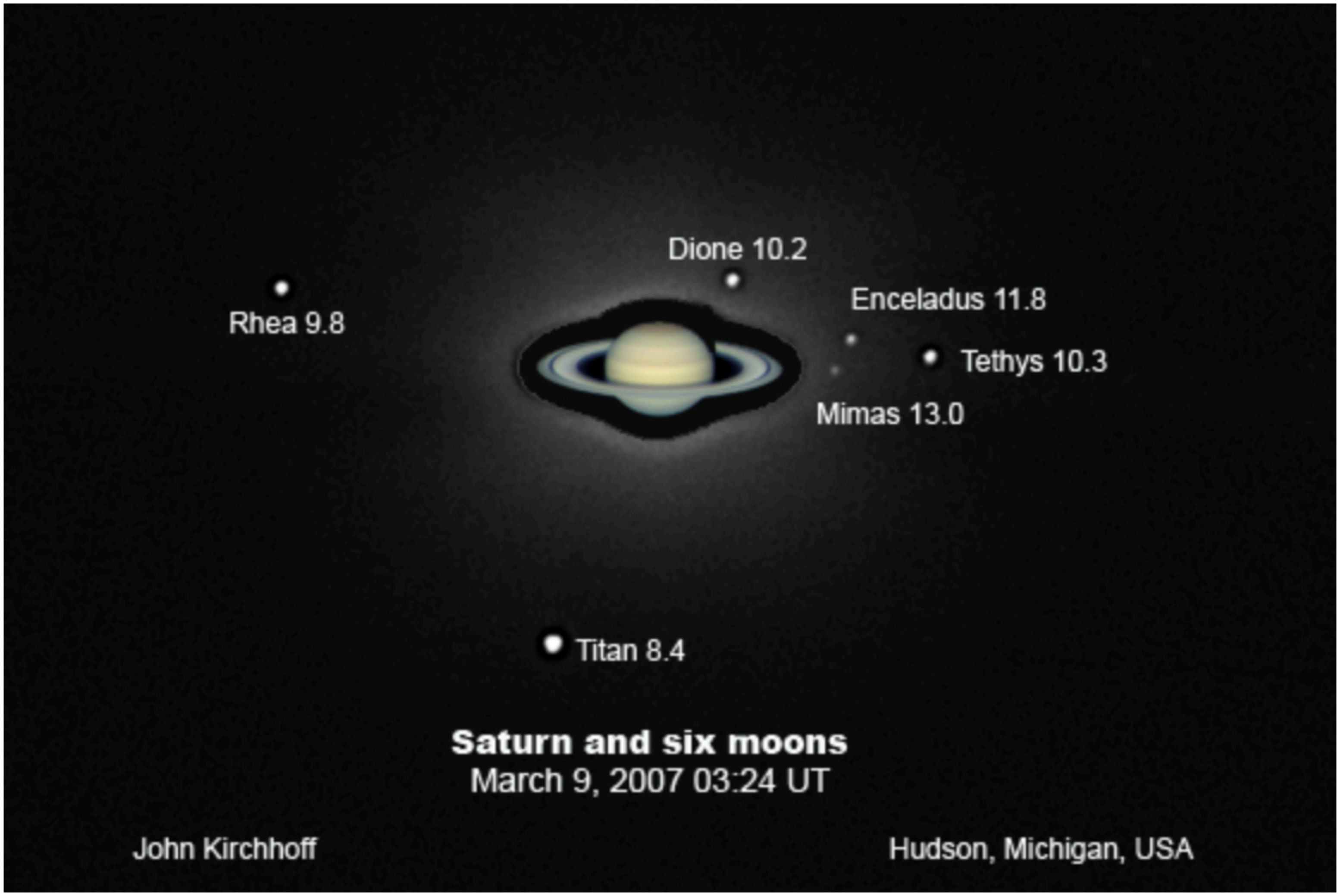


Most distant known planet in solar system before invention of telescope

Exploration of the moons of Saturn



Saturn’s moons

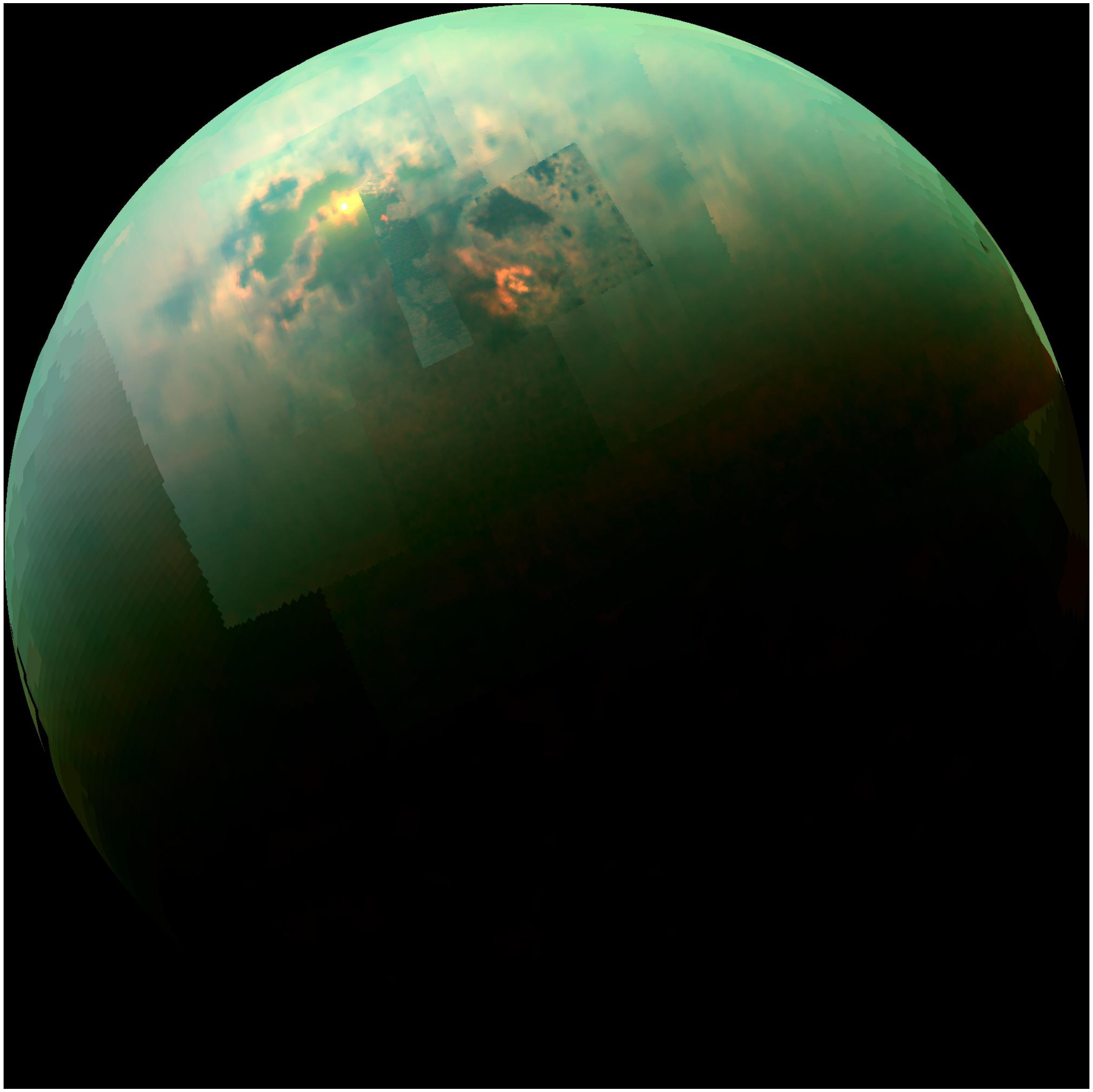


The view through an amateur telescope

A "family portrait" of the larger moons of Saturn

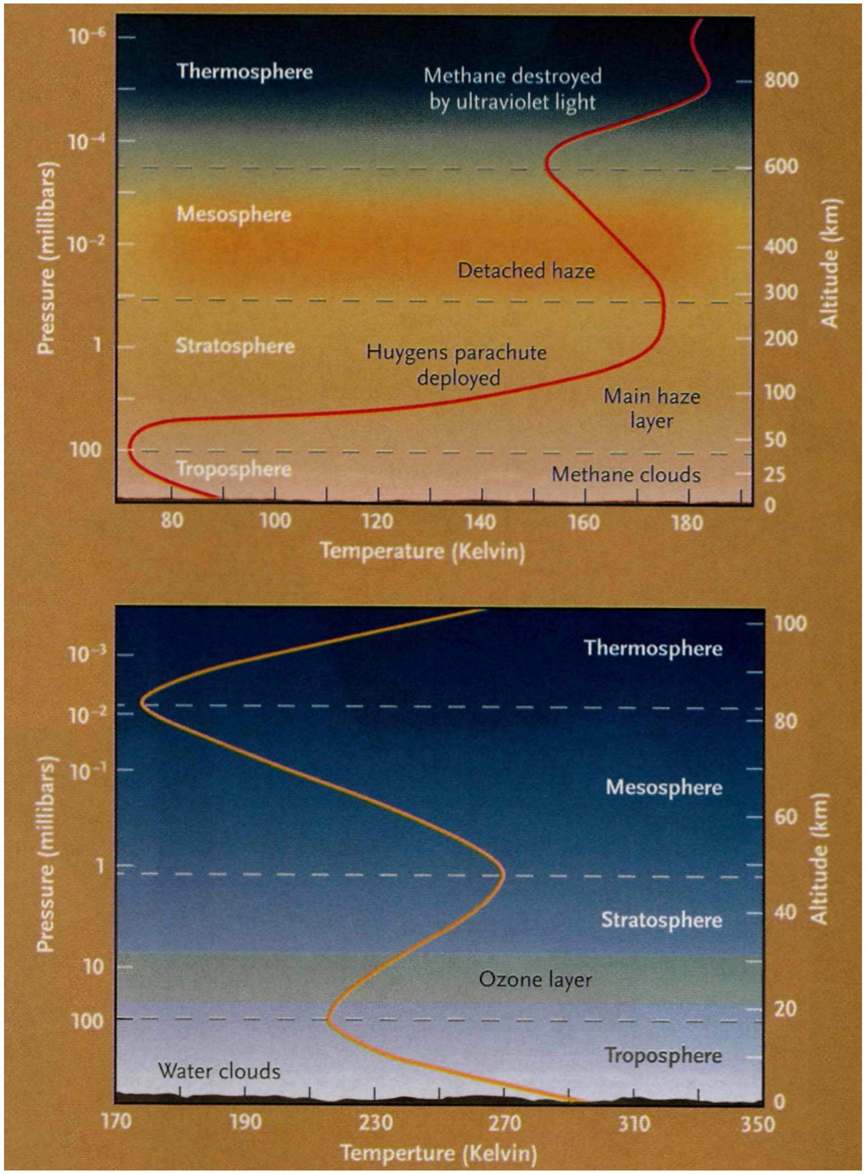
One large one (Titan) in a class by itself

We have learned much about Titan in the last decade



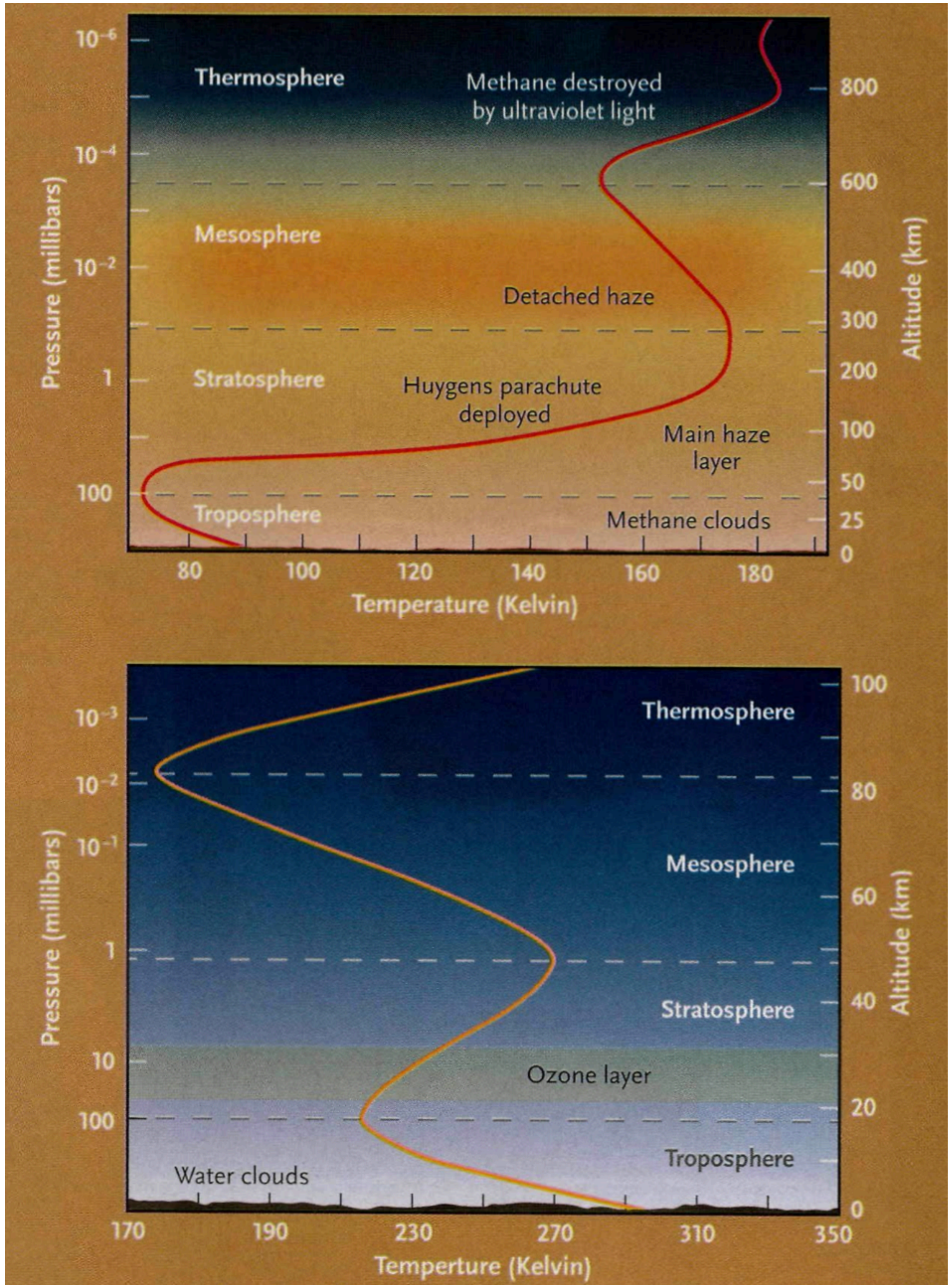
What we knew before the arrival of Cassini, July 2004

A lot. Titan has a thick atmosphere, unique among moons



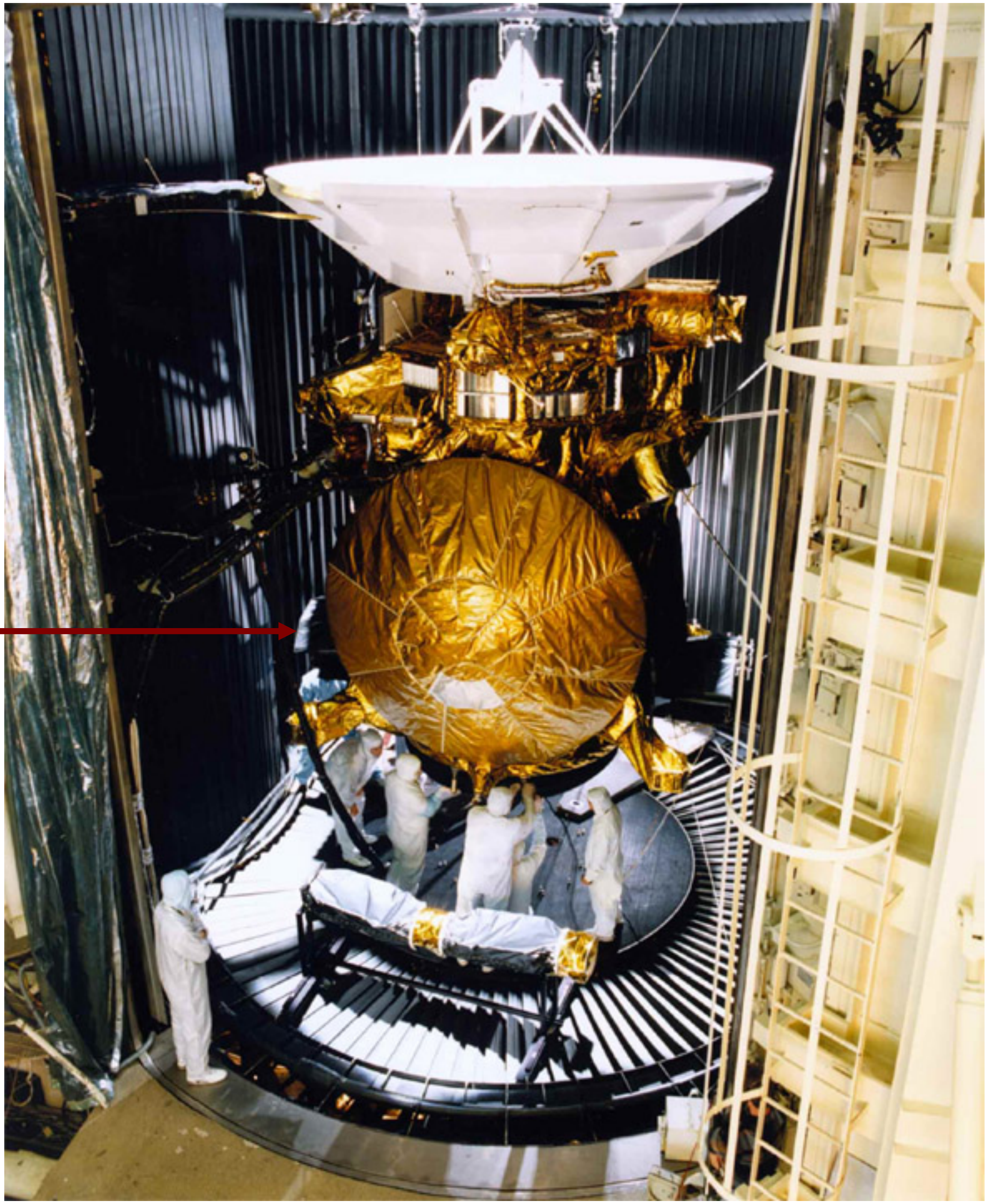
A closer look

Primary atmospheric constituent is molecular nitrogen N2 (like Earth). Methane CH4 at about same proportion as water in Earth's atmosphere. Ethane C2H6 also present

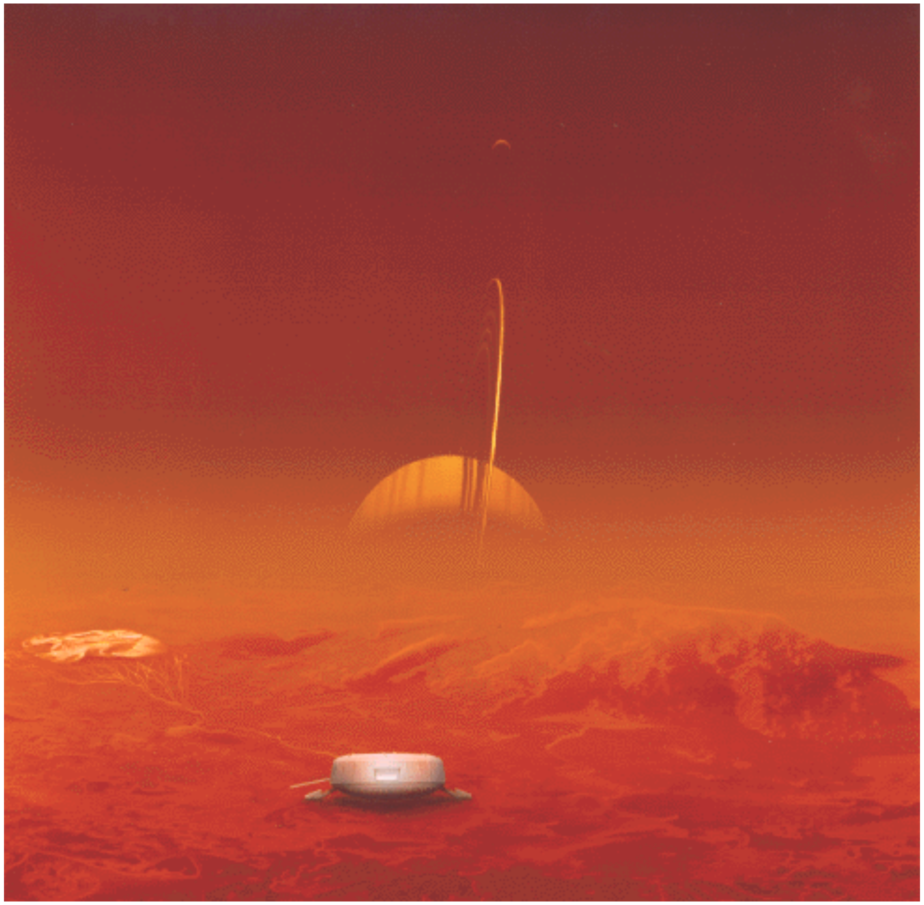


The Cassini and Huygens spacecraft

The Huygens lander



Concept of the Huygens lander…an artist' s conception



Pictures of Titan from the approaching Cassini spacecraft

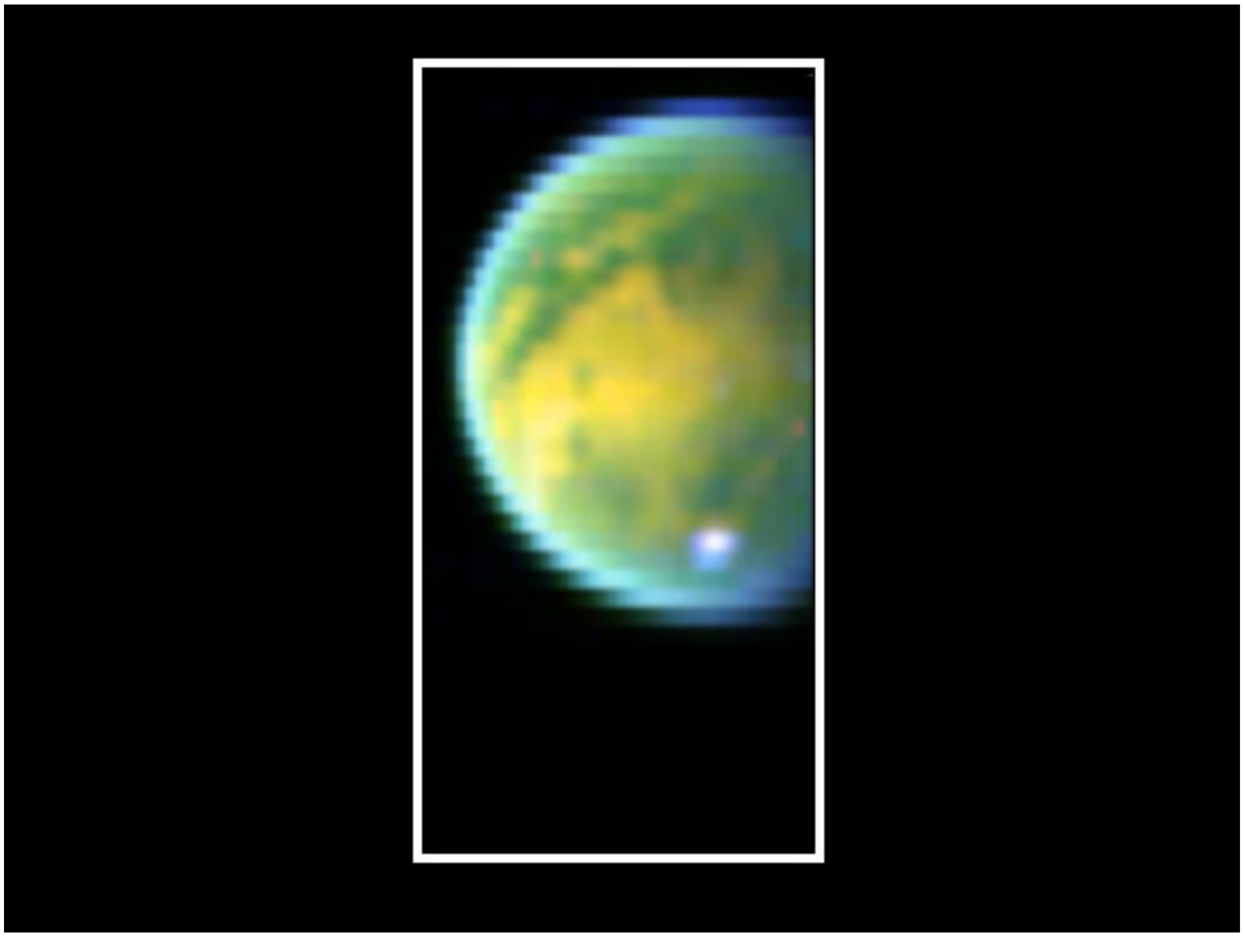
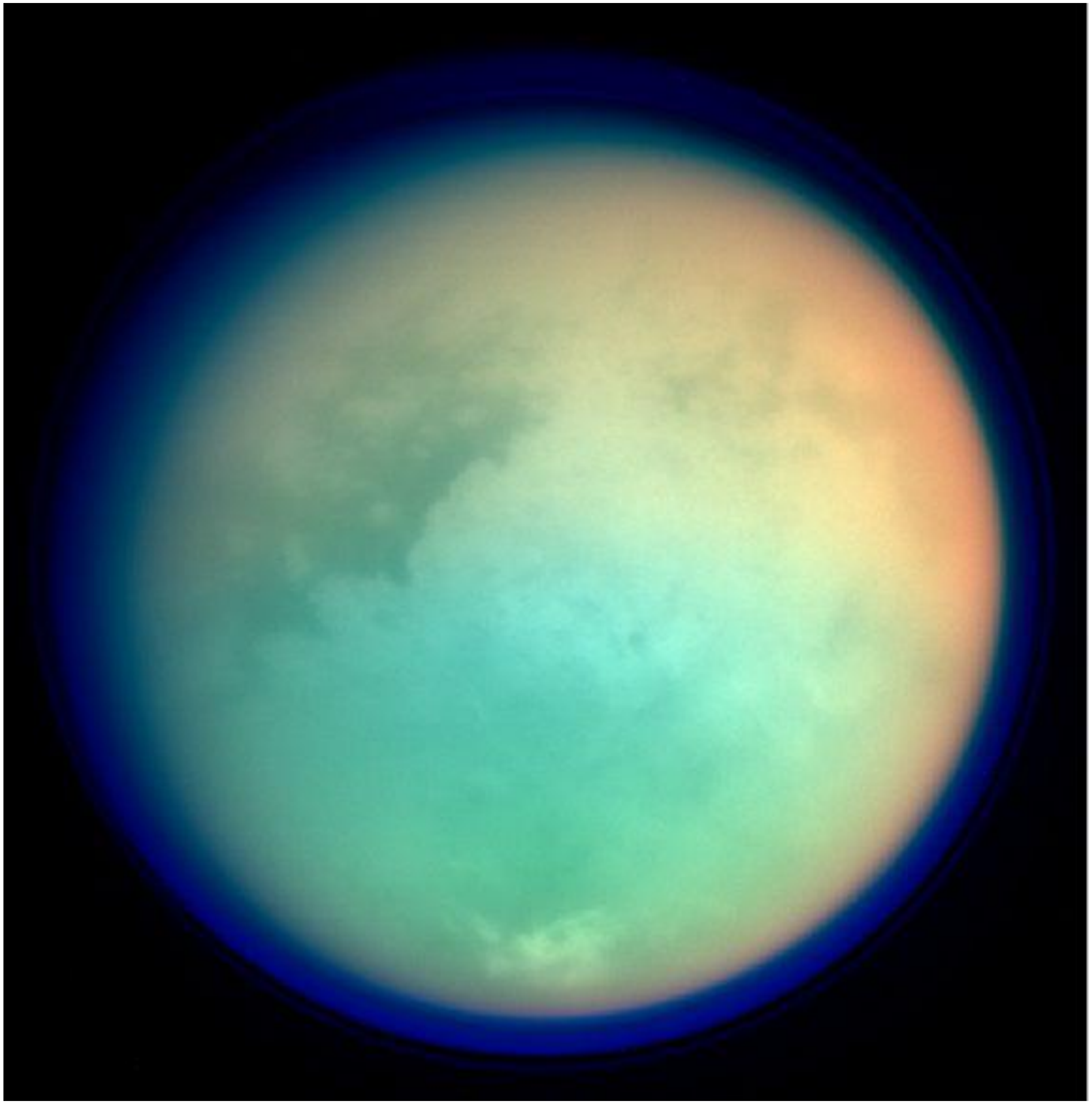
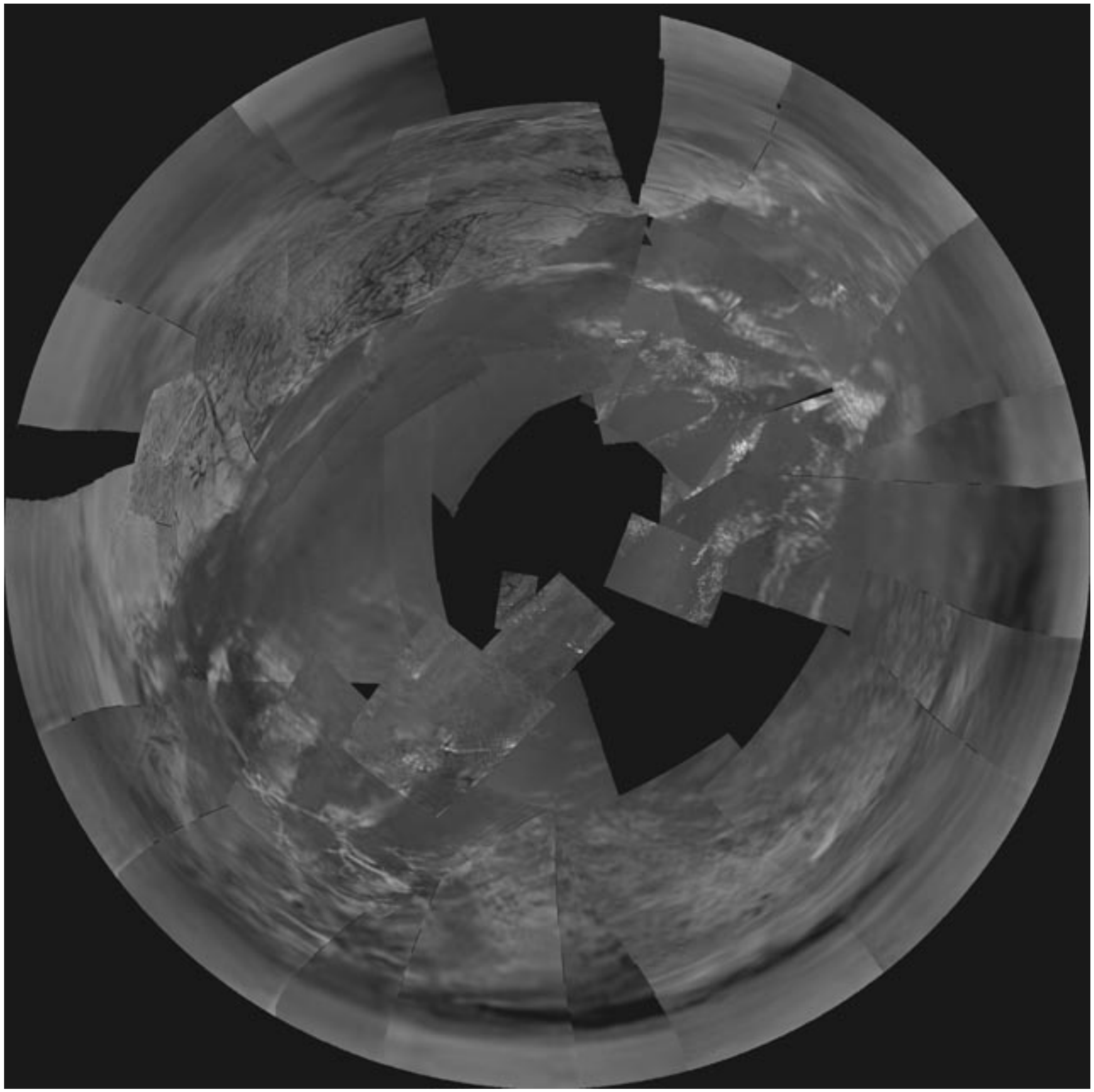


Image at infrared wavelengths

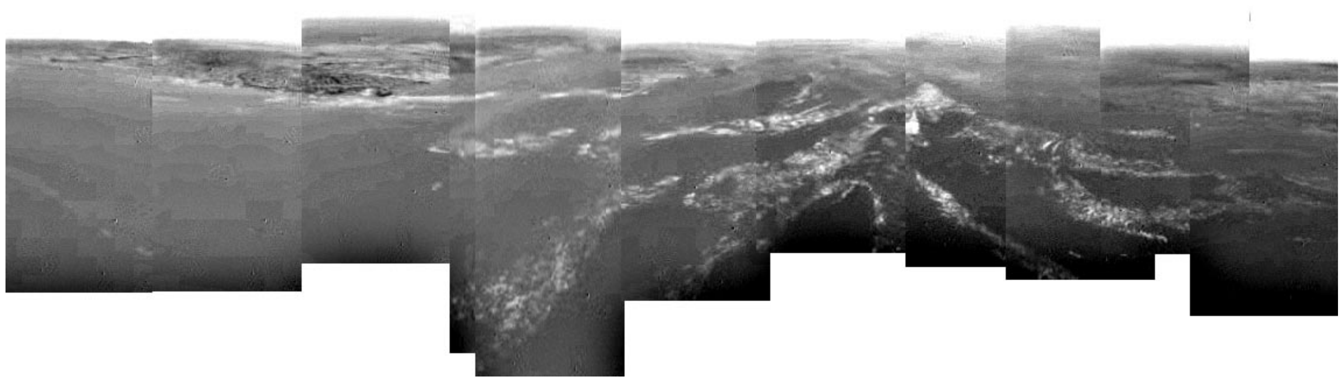
A new view of Titan (from close up)



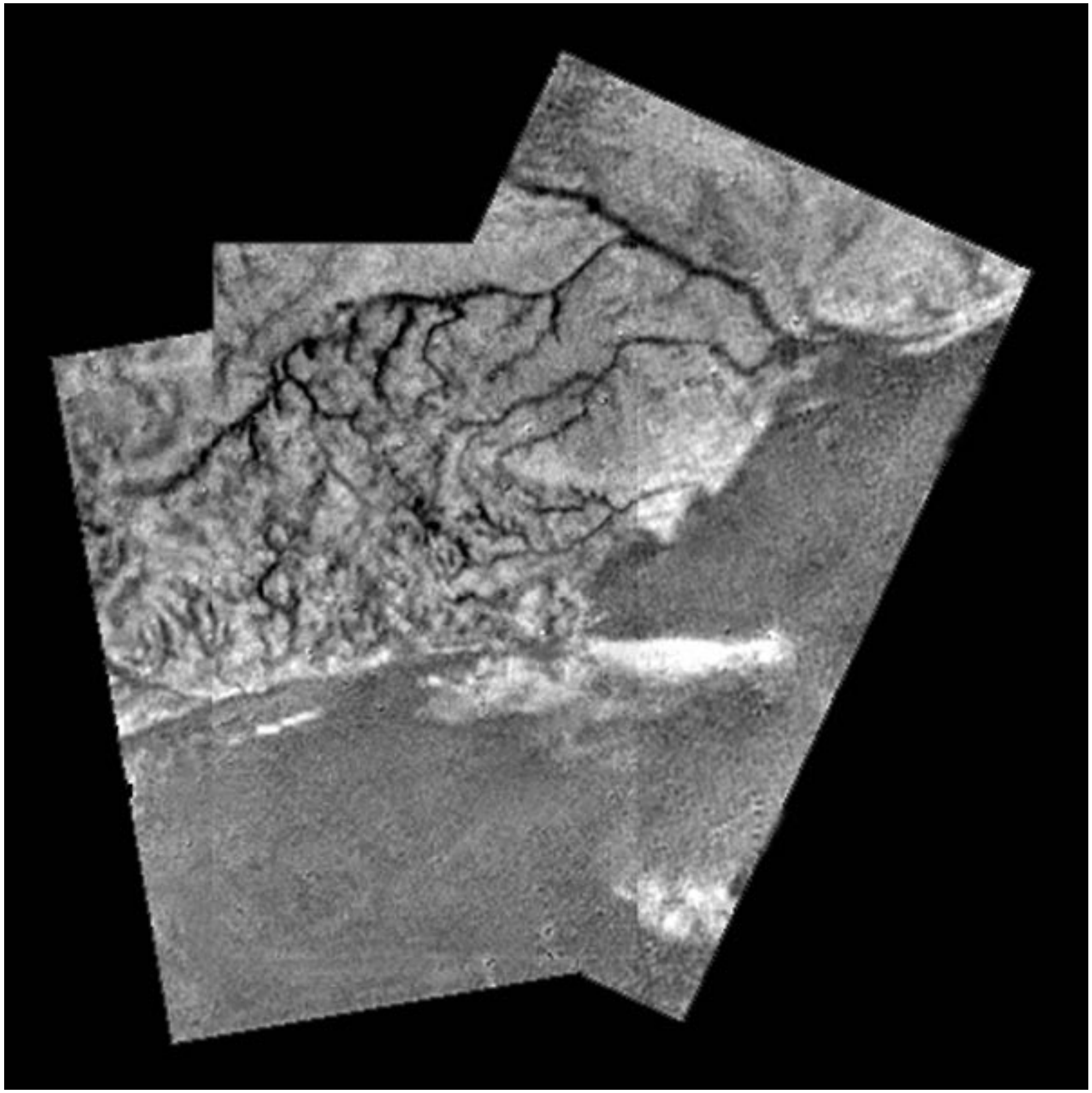
The view from Huygens on the way down



Closer to the surface



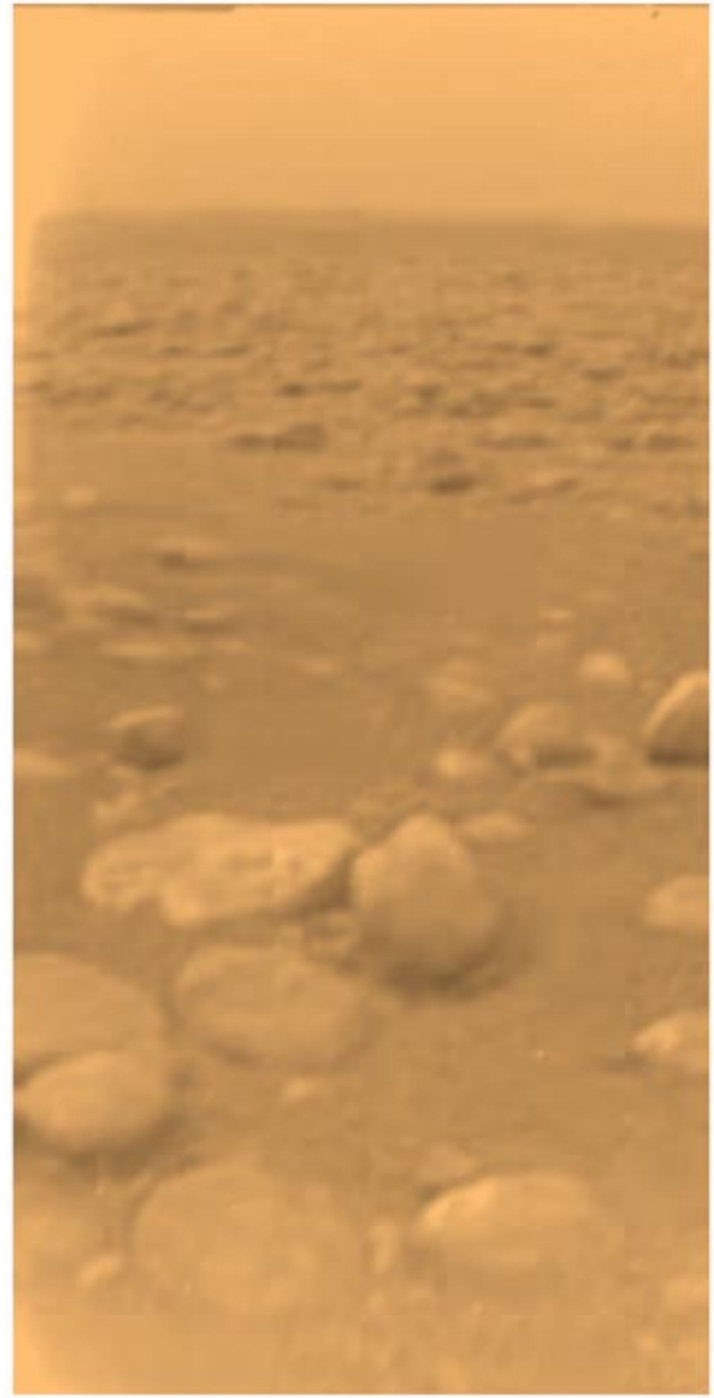
Titan has flow channels, too



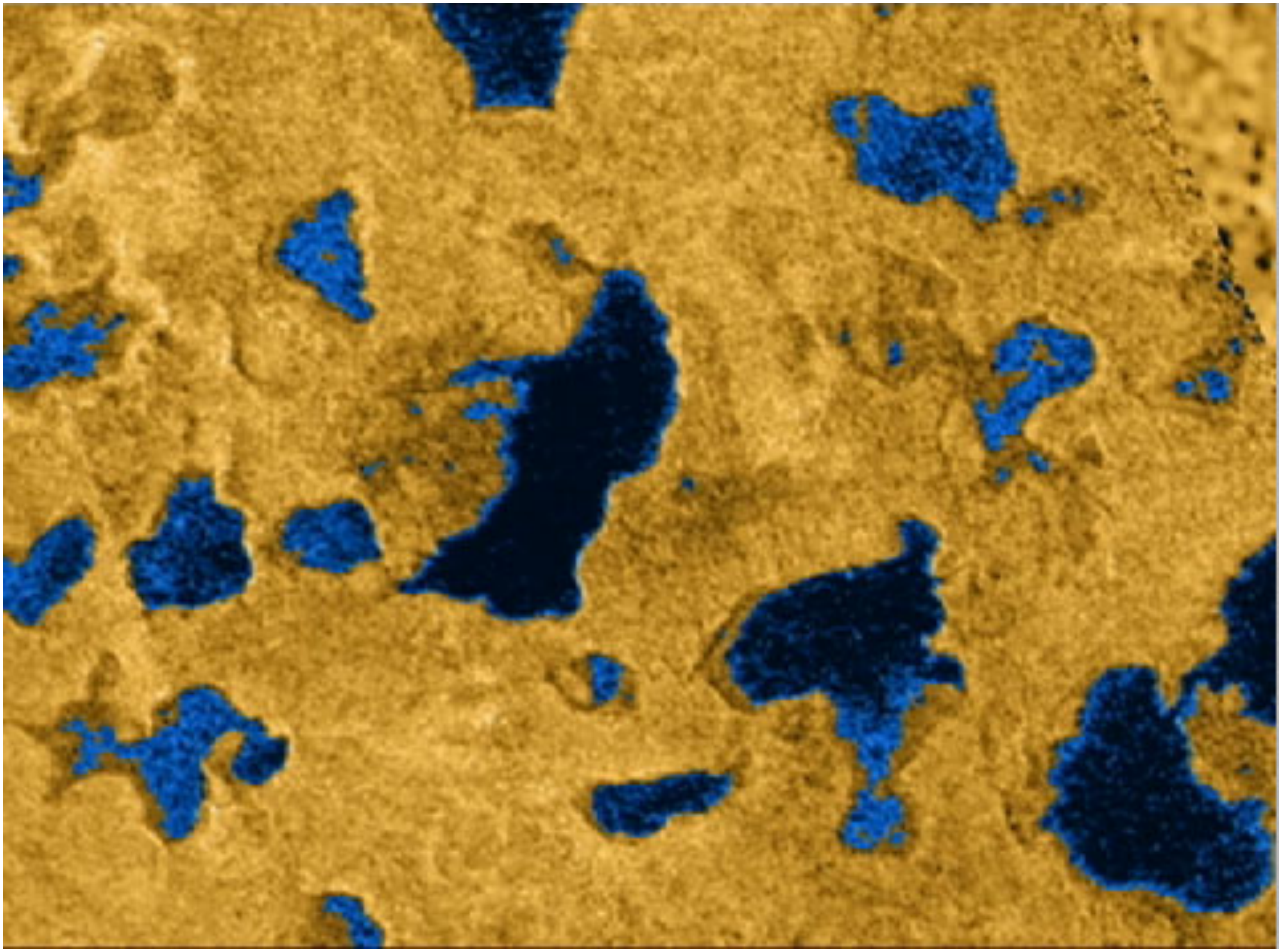
On the surface

“rocks” are blocks of ice

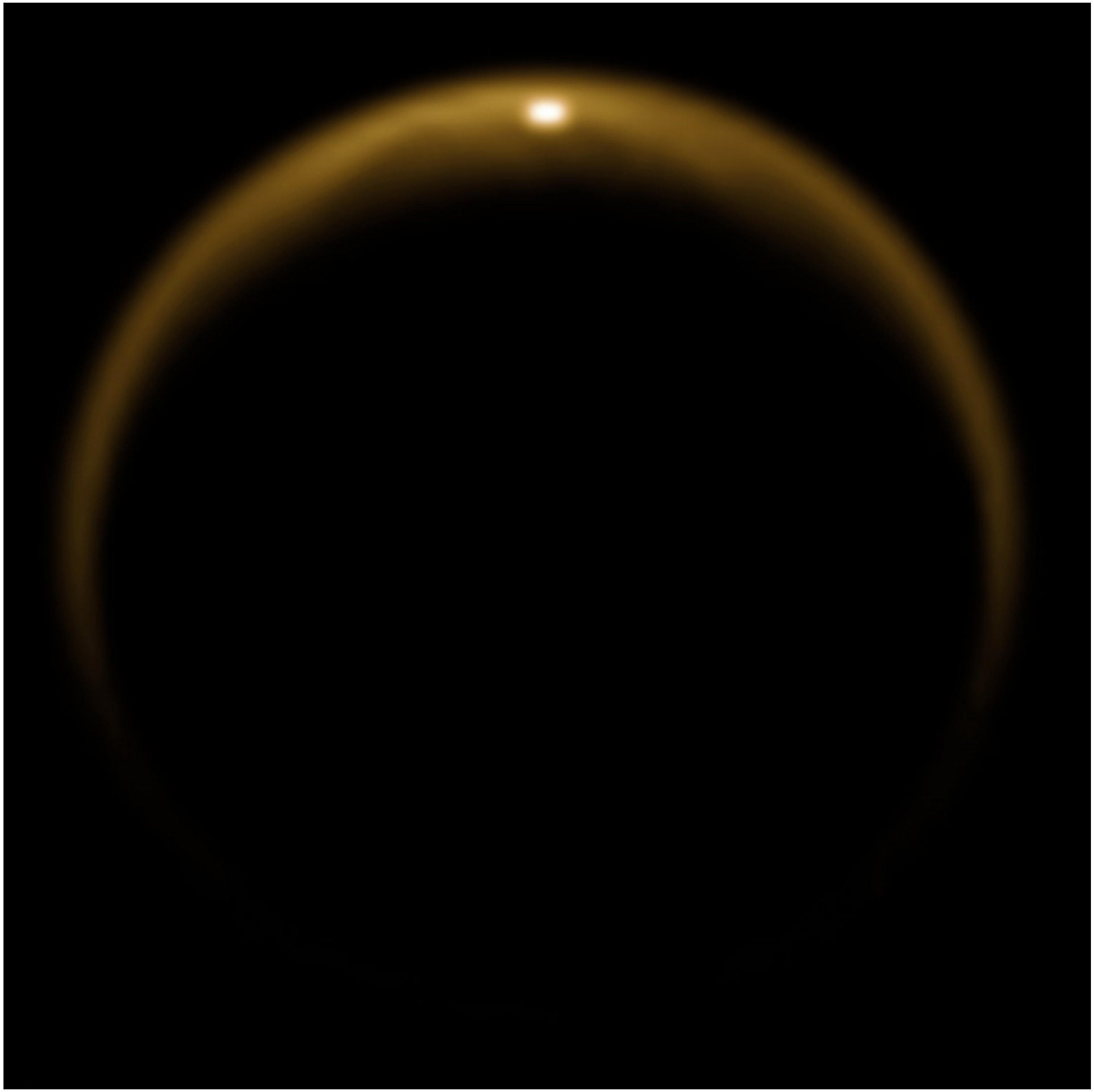
The most remote human “base” in the universe: nearly a billion miles from the Sun



Cassini radar shows lakes of methane



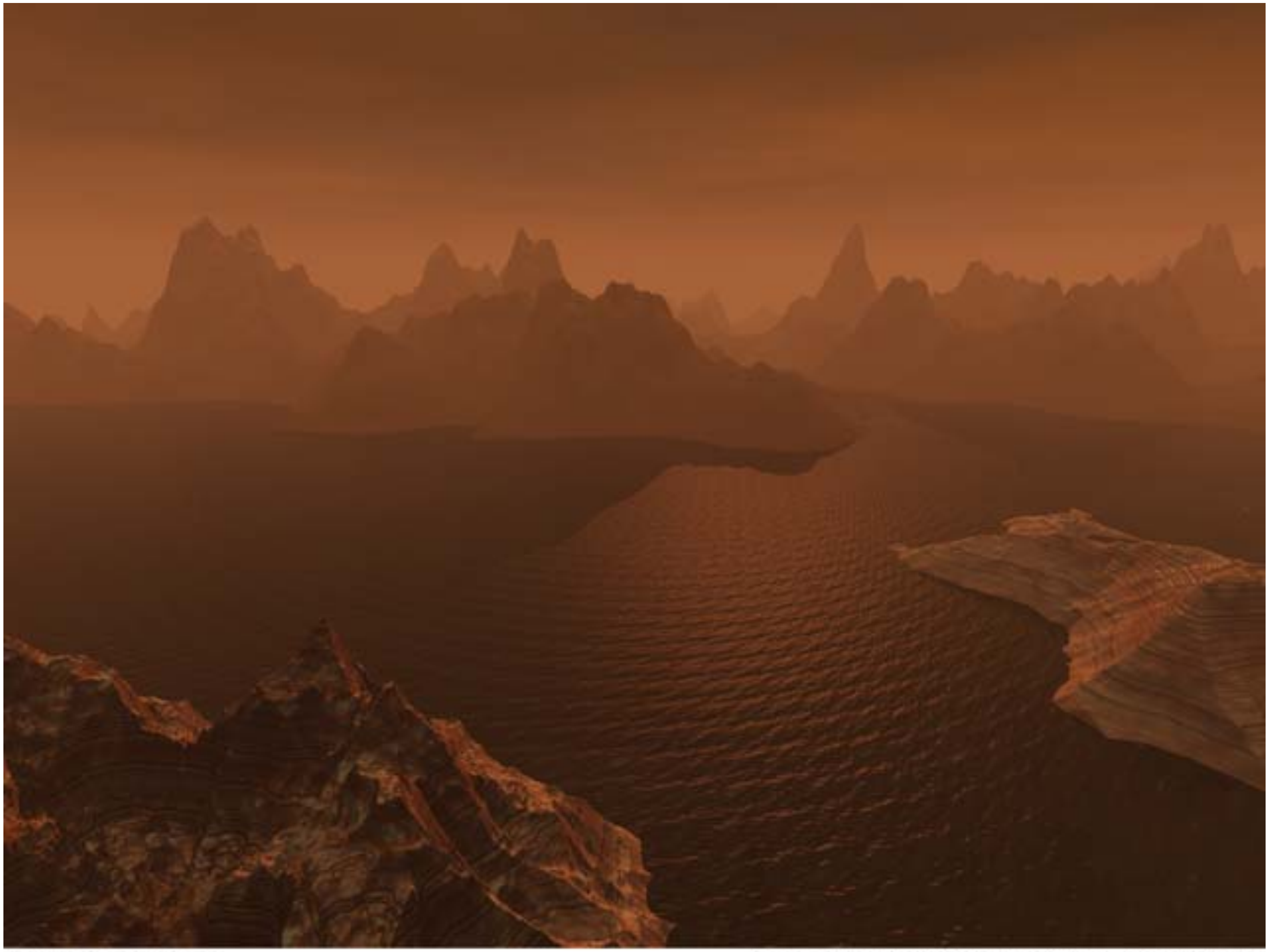
Other observations from Cassini show different manifestation of methane lakes: sunlight glints from the lake surfaces



Reasons for the interest and importance of Titan: it has a dense atmosphere and a "hydrological cycle" based on another compound. Despite its alien nature, in some ways it is the most Earth-like object in the solar system

A more general reason of interest is that Titan may be a showcase for the organic chemistry which can occur in outer space, even if that organic chemistry never developed to the point of forming life. Finally, it is possible, although only remotely possible, that a form of life has evolved on Titan in which liquid methane and ethane play the role of water for life here on Earth. One of the many arguments against this is that the extreme cold of Titan means that chemical reactions would go very slowly.

The surface of Titan: an artist's view



Titan's Lakes

Another moon of Saturn: Enceladus

- Diameter=500 km
- Mass = 0.0012 that of Earth's Moon
- Orbital period=1.37 days
- Semimajor axis of orbit=238,000 km
- Semimajor axis of orbit = 4.0 X radius of Saturn

Solar system astronomy in the news

SPACE & COSMOS

Under Icy Surface of a Saturn Moon Lies a Sea of Water, Scientists Say

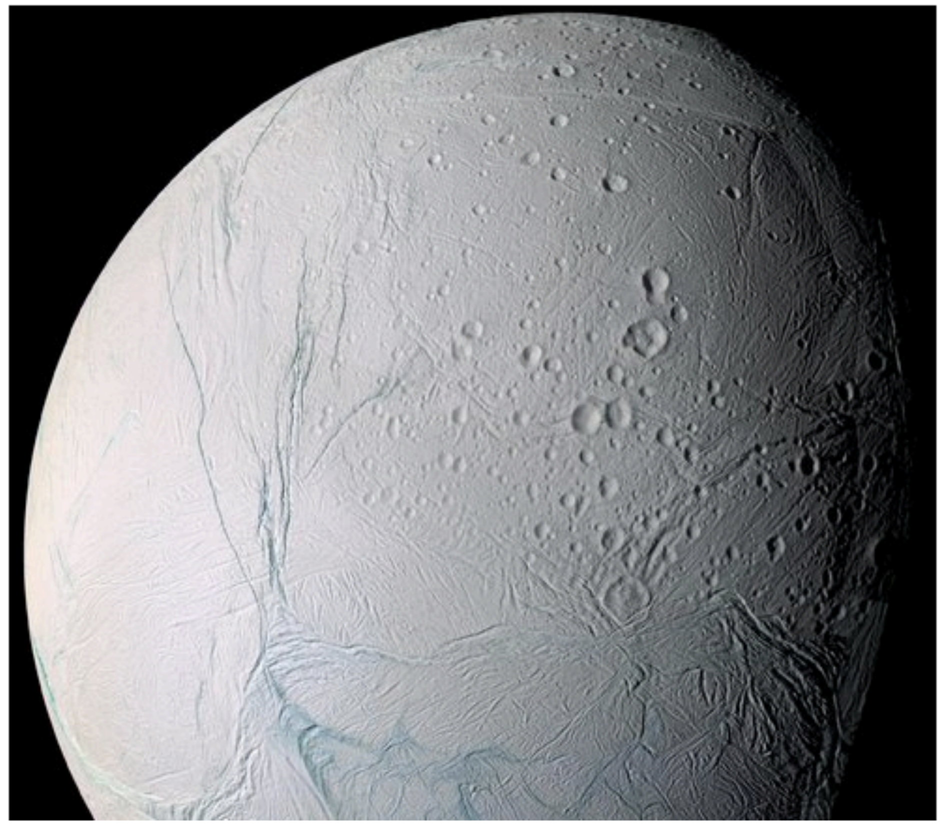
By KENNETH CHANG APRIL 3, 2014

Inside a moon of Saturn, beneath its icy veneer and above its rocky core, is a sea of water the size of Lake Superior, scientists announced on Thursday.

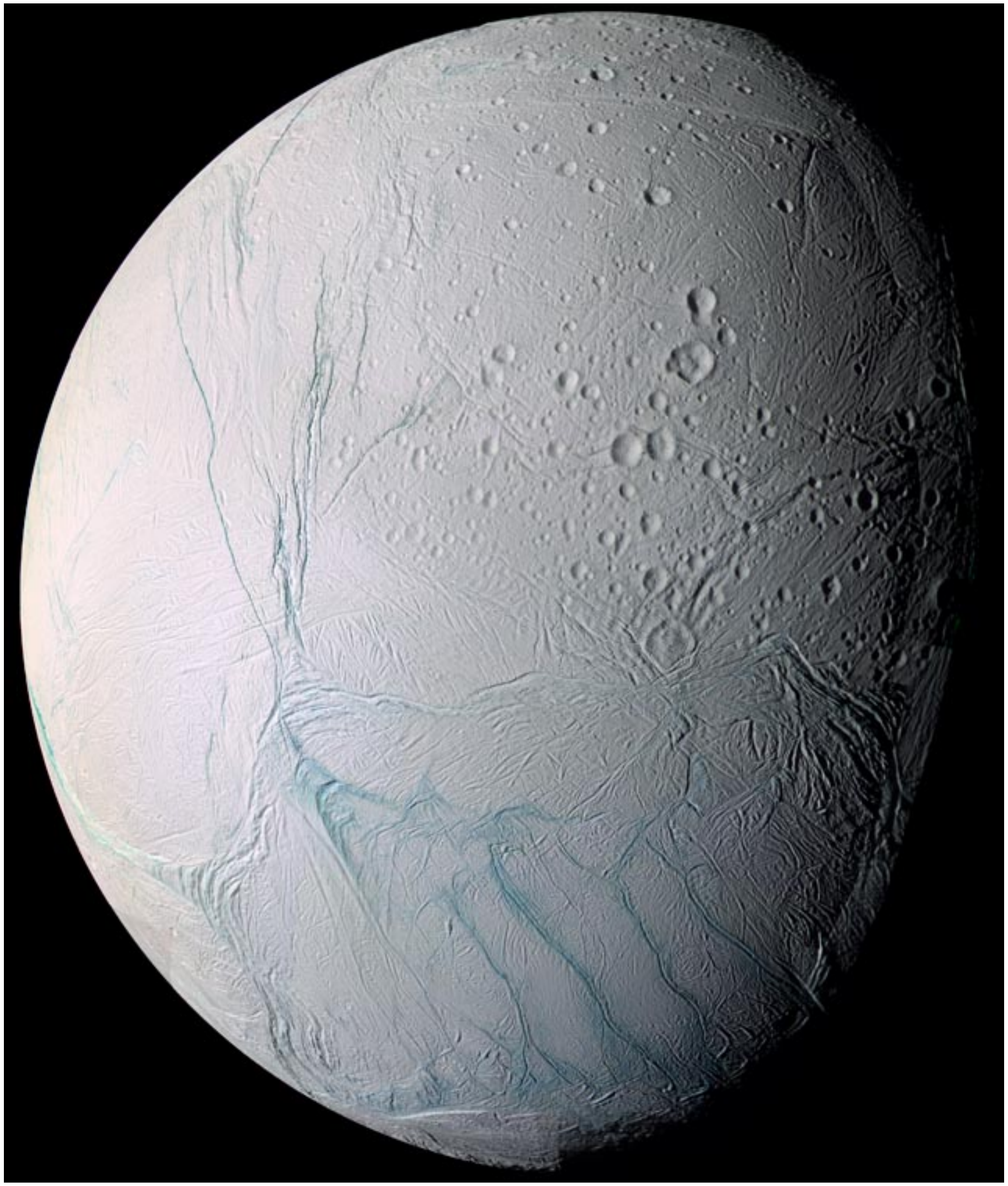
The findings, published in the journal Science, confirm what planetary scientists have suspected about the moon, Enceladus, ever since they were astonished in 2005 by photographs showing geysers of ice crystals shooting out of its south pole.

“What we’ve done is put forth a strong case for an ocean,” said David J. Stevenson, a professor of planetary science at the California Institute of Technology and an author of the Science paper.

For many researchers, this tiny, shiny cue ball of a moon, just over 300 miles wide, is now the most promising place to look for life elsewhere

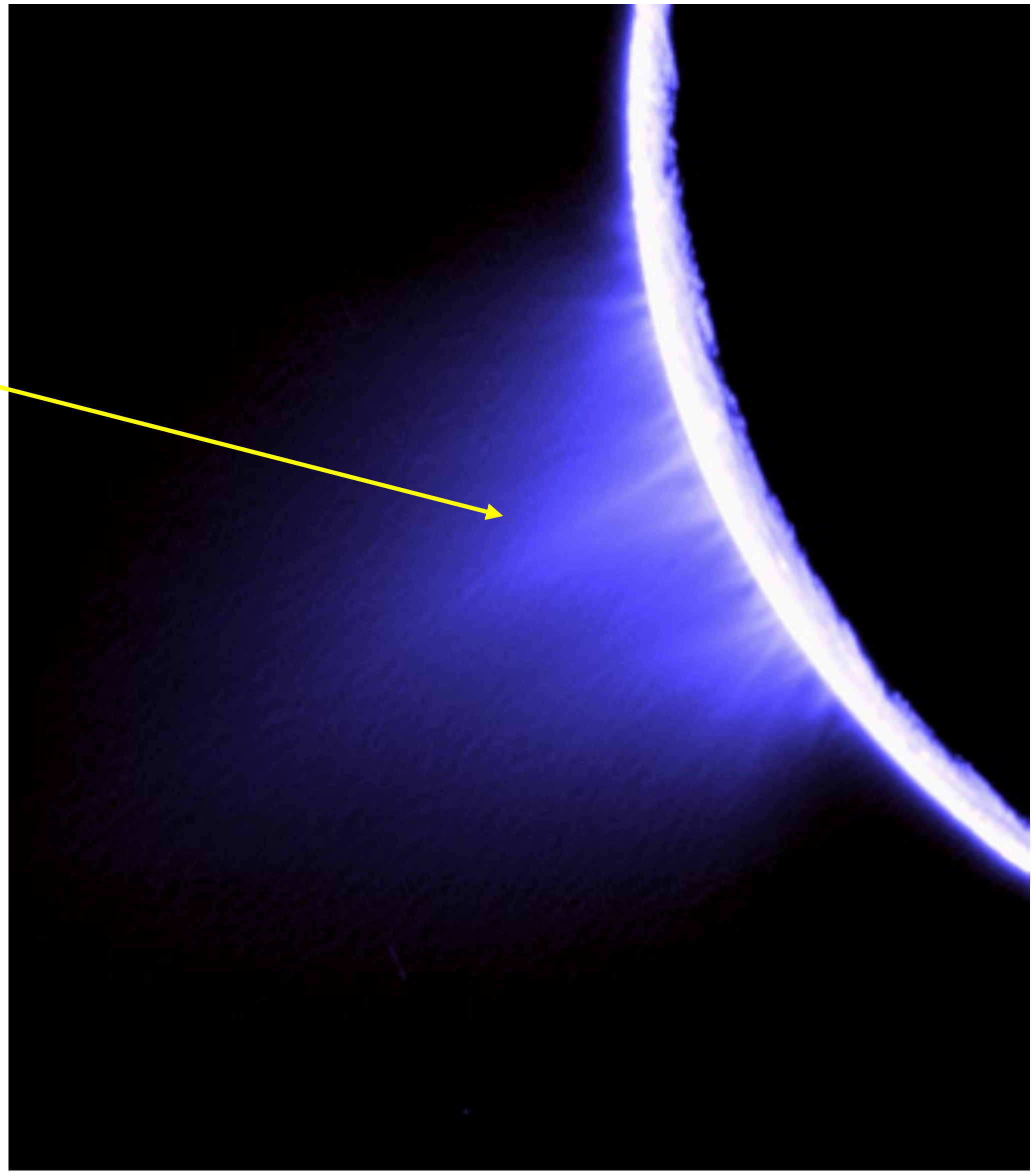


Cassini gives a closeup view of Enceladus



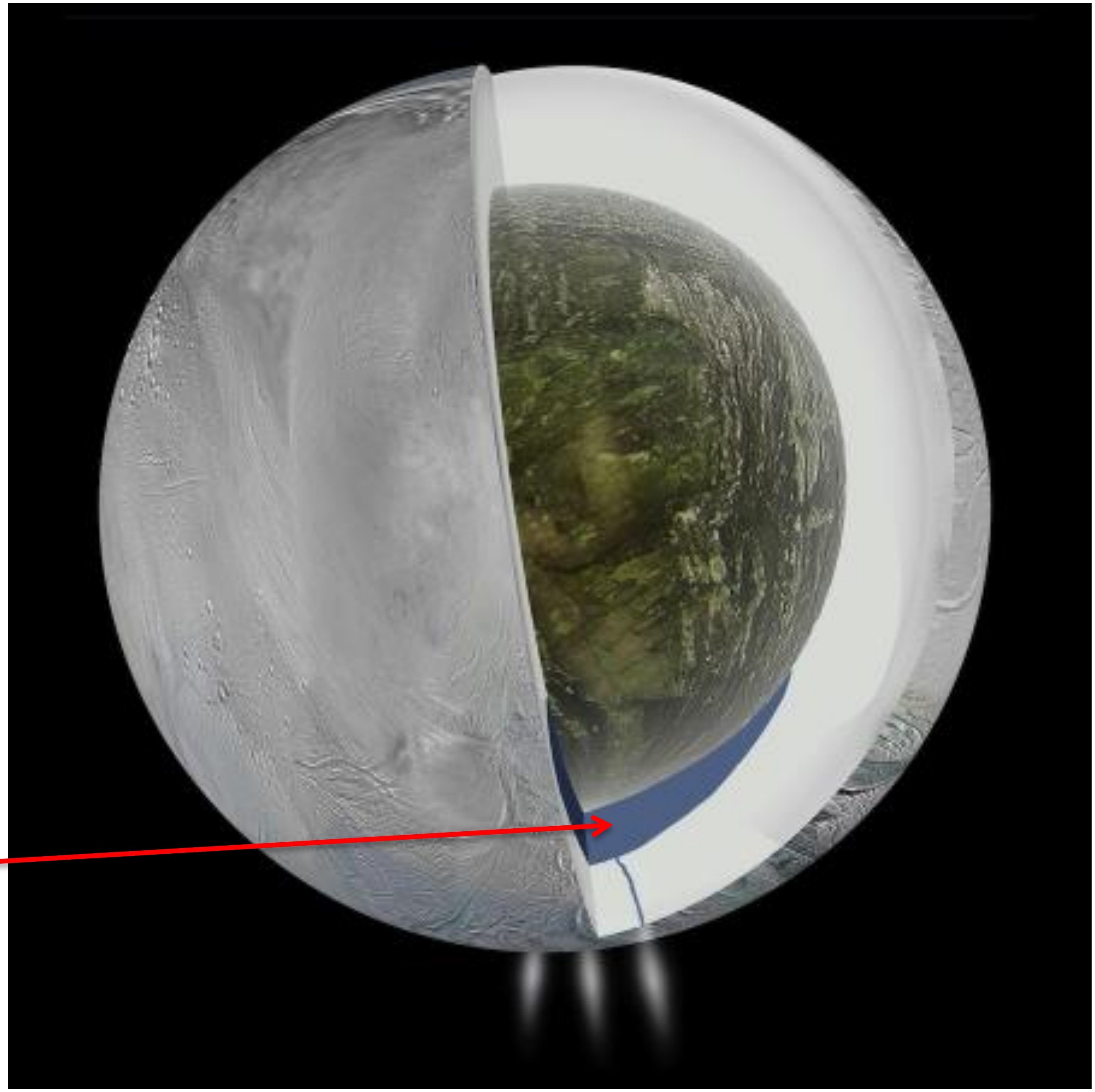
Why Enceladus is of interest

Water geysers coming from the "tiger stripes"



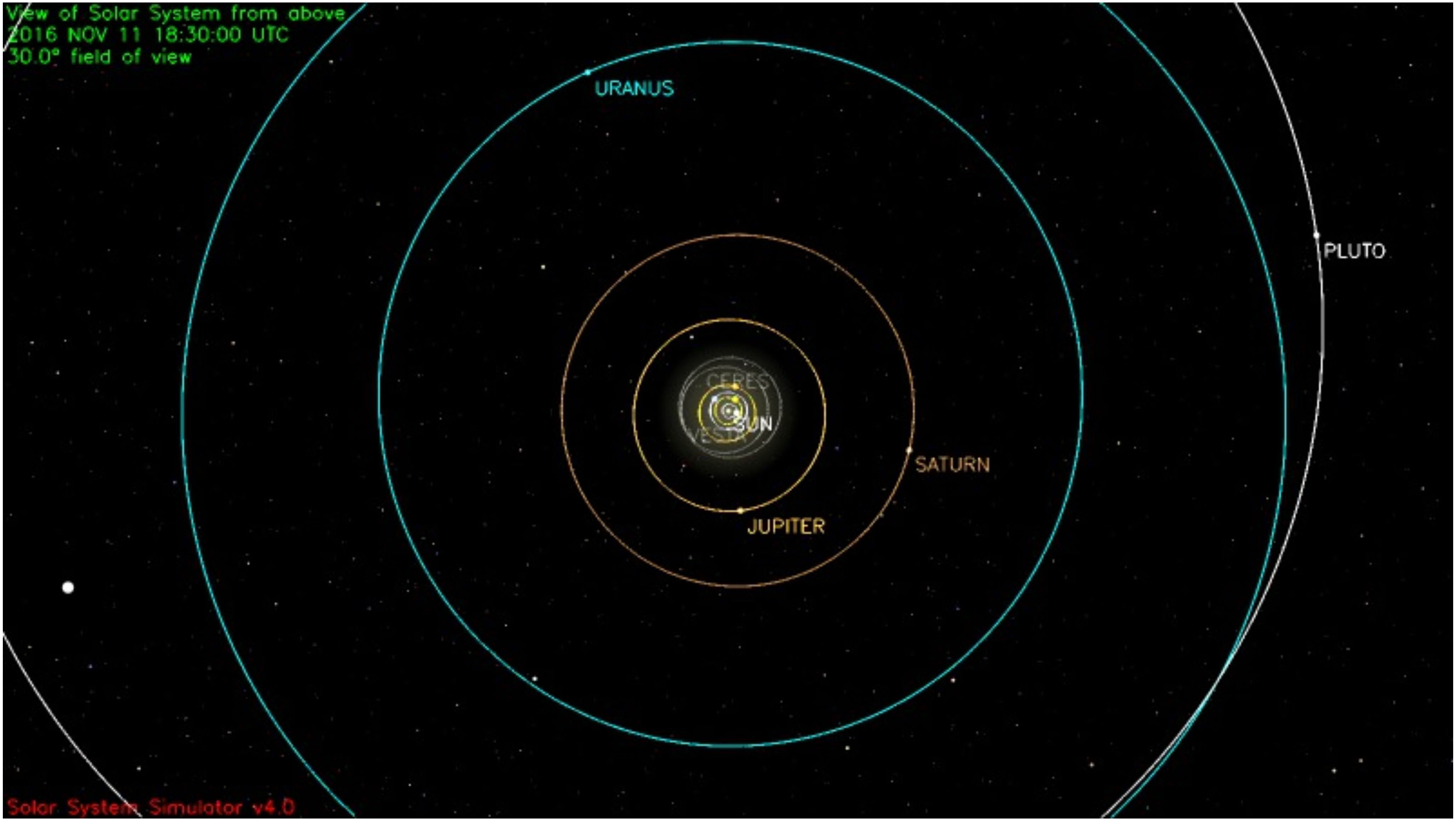
Now, recent report that there is a subsurface ocean on this small object

Recent measurements of gravitational field of Enceladus suggest a subsurface ocean at south pole



Summary: several moons of the outer planets, in addition to being amazing natural spectacles, may be abodes for primitive forms of life, or at least give us some insight into the astro-biochemical processes which gave rise (or didn't) to life. Future spacecraft will have much to explore. Stay tuned.

Further out…to the edge of the Solar System



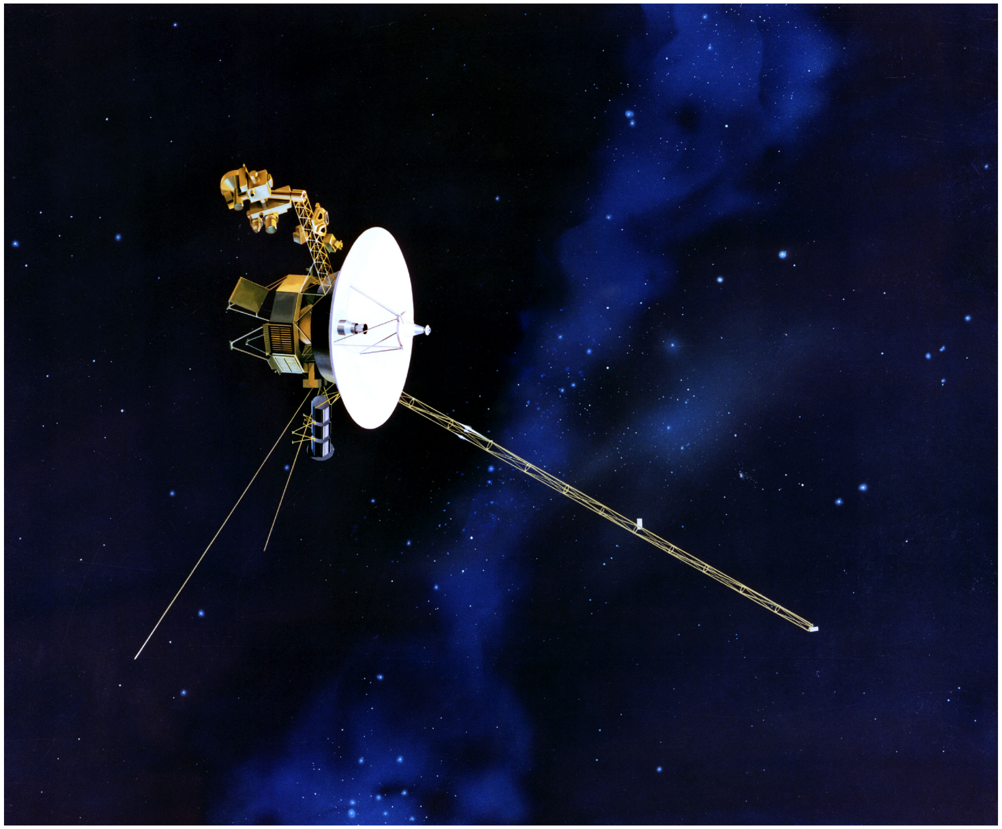
Uranus and Neptune… where are they? Let's look at a **Table!**

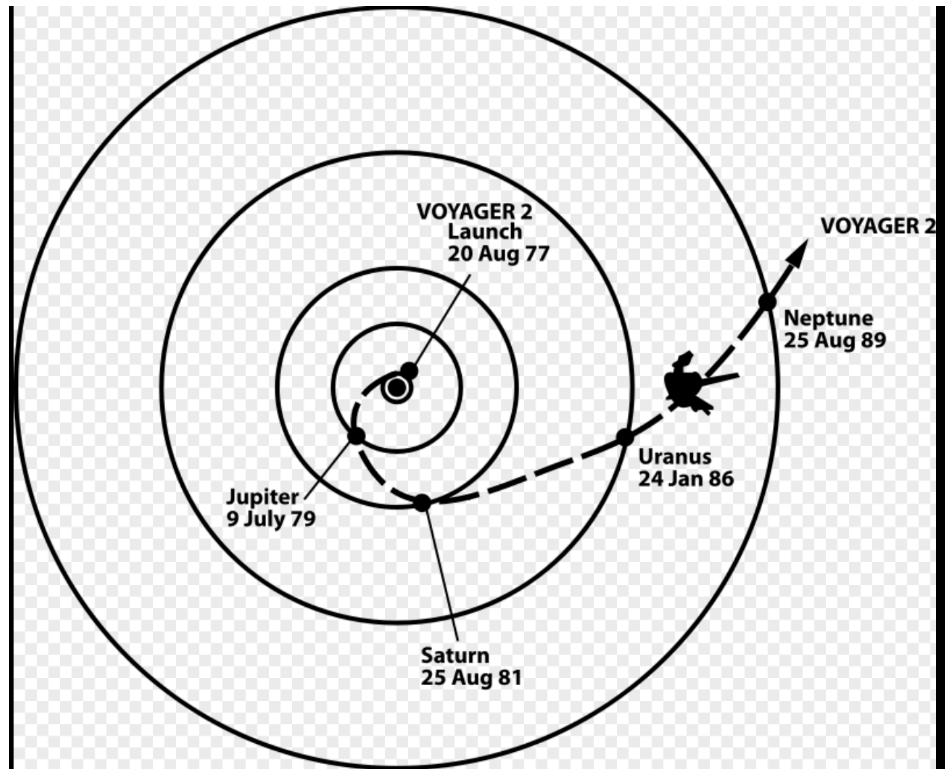
Planet	a (AU)	P(yr)	ecc	Incl (degrees)
Uranus	19.20	83.7	0.046	0.8
Neptune	30.5	163.7	0.011	1.8

Current locations: Uranus: Pisces; Neptune: Aquarius.

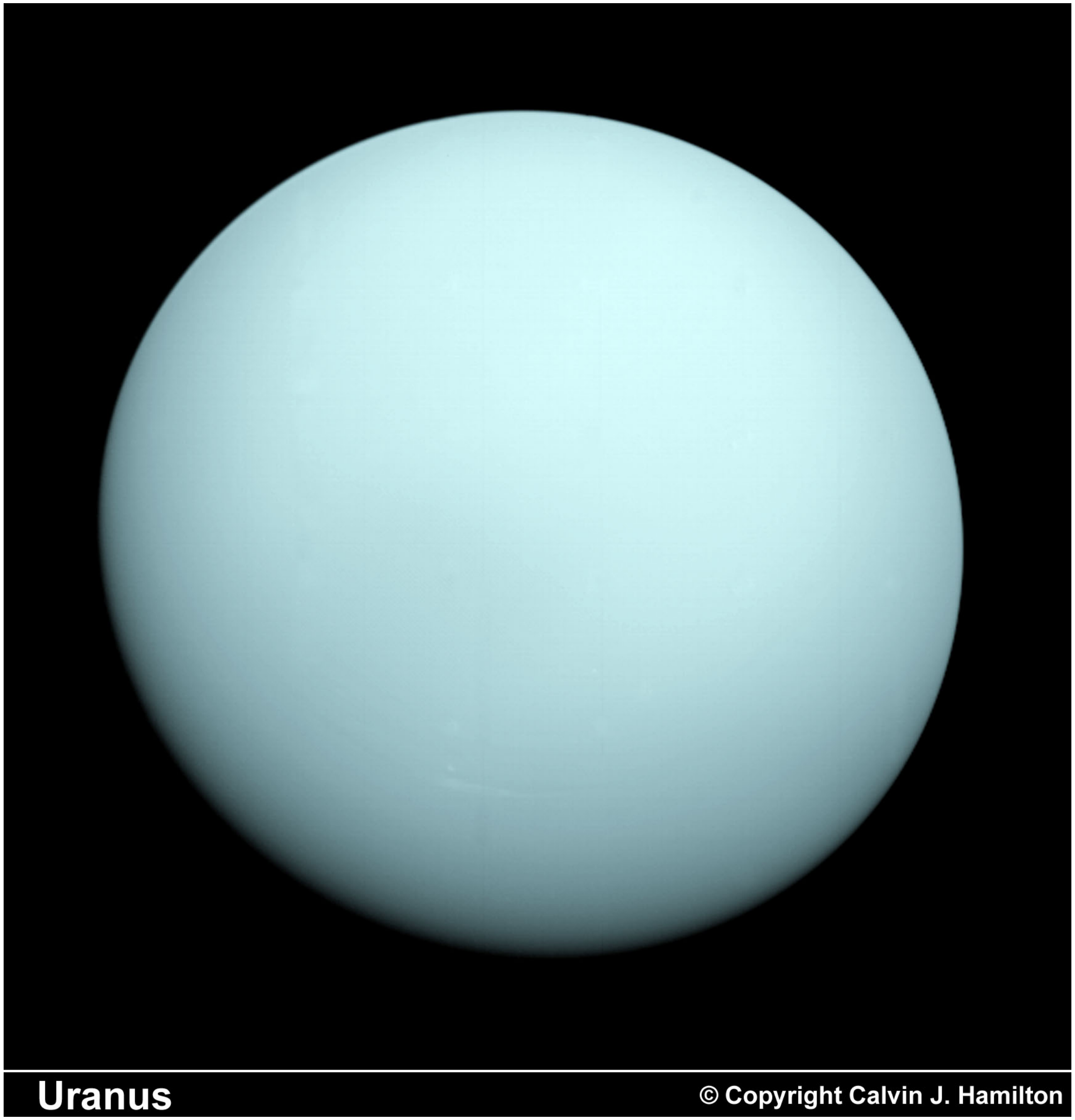
What do they look like?

Our best views (and scientific information) come from visits (flybys) of the Voyager 2 spacecraft



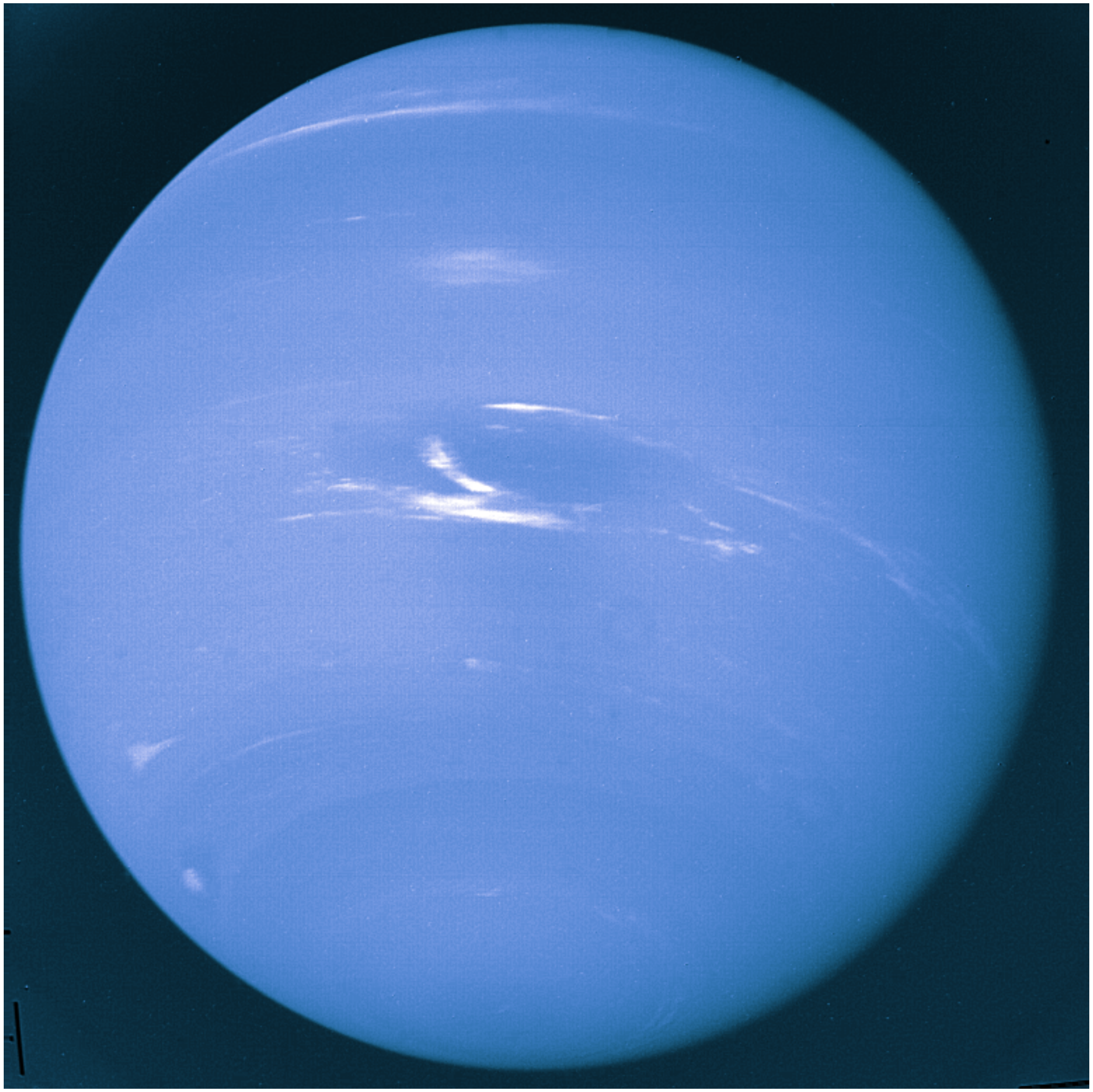


Uranus as seen by Voyager 2

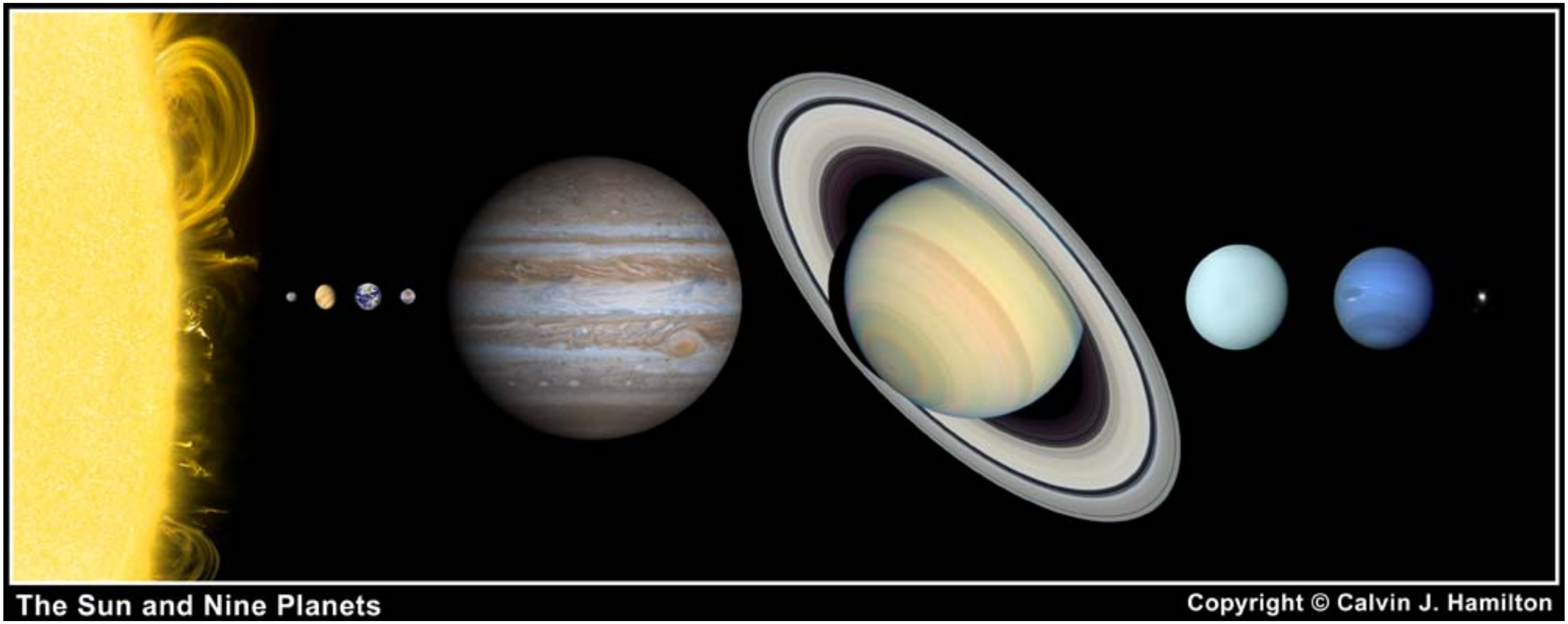


Neptune as seen by Voyager 2

They look like
“blue Jupiters”

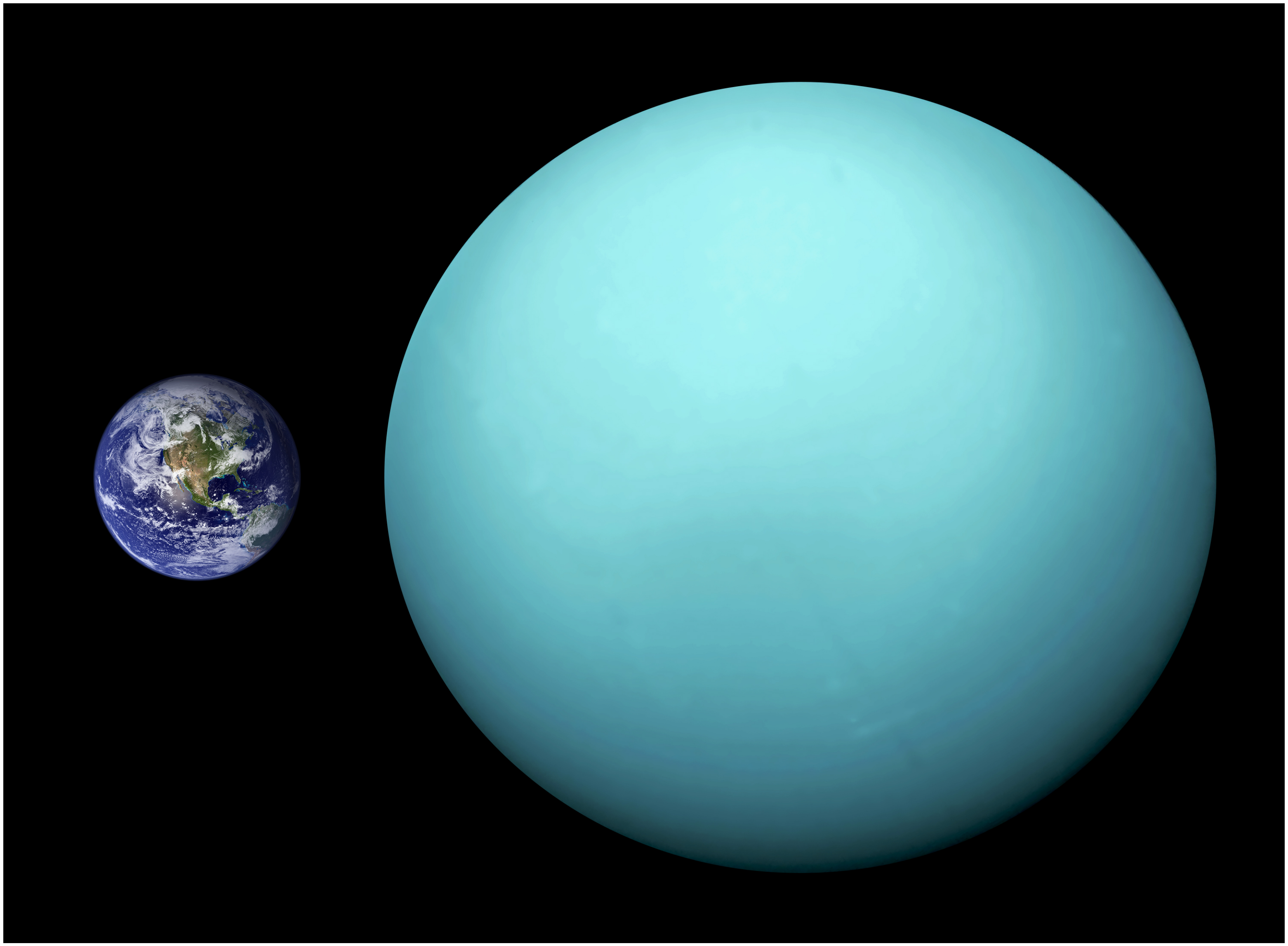


How do they match up to Jupiter and Saturn?

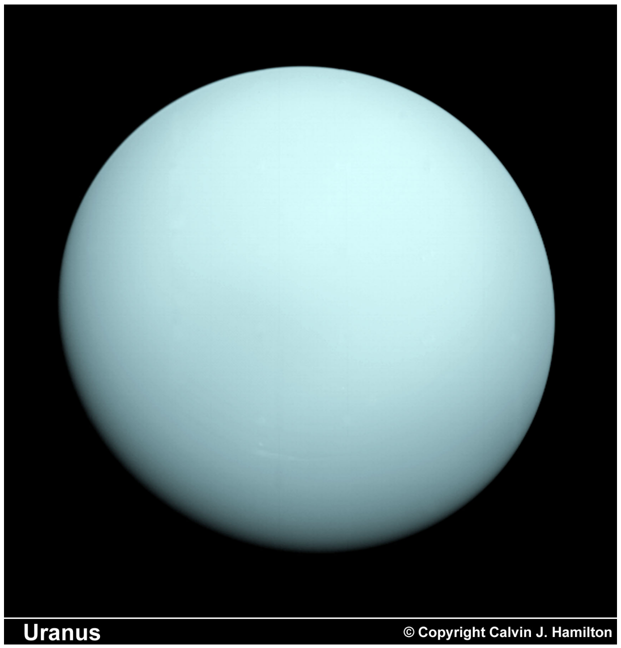


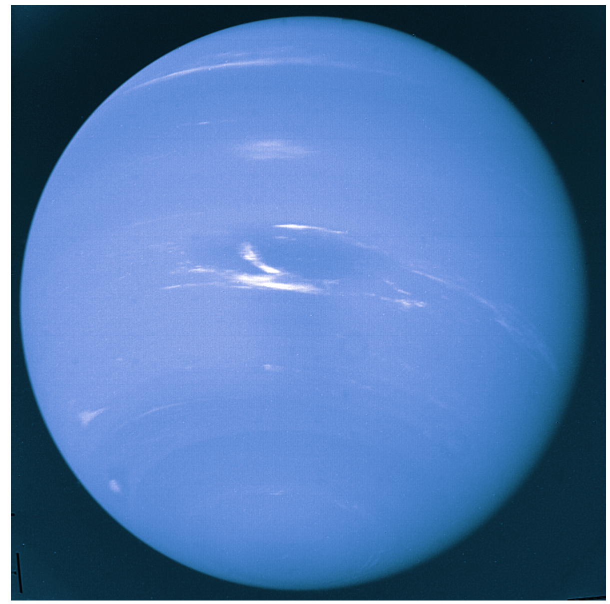
Smaller than Jupiter and Saturn; much bigger than the Earth

Uranus (and Neptune) substantially larger than Earth



Uranus and Neptune (just the facts, Ma'am)

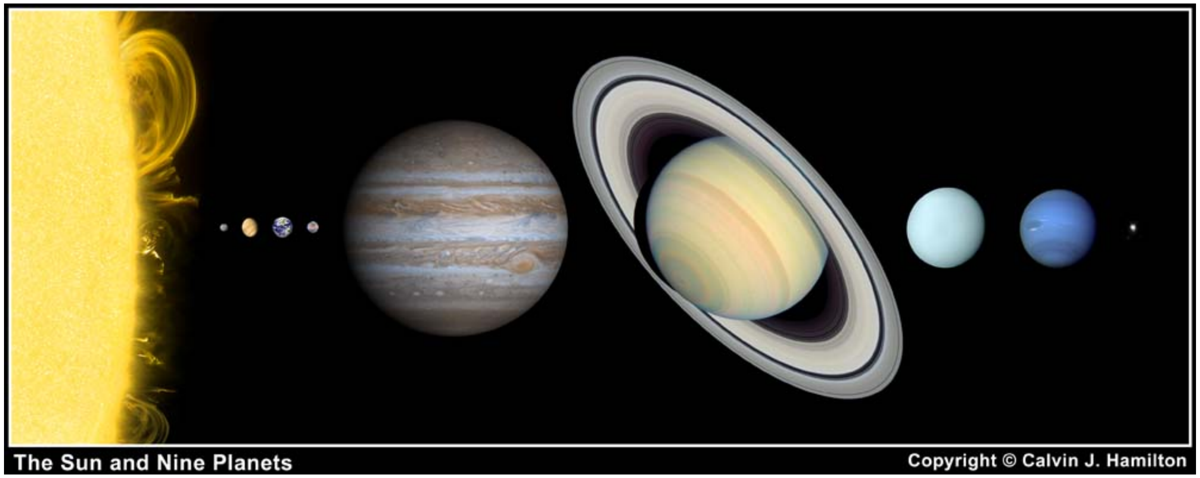




planet	D (rel to Earth)	M (rel to Earth)
Uranus	4.01	14.5
Neptune	3.88	17.1

Uranus and Neptune are relevant in the exoplanet context

How do we summarize all of this?



- The small rock planets are in close to the Sun
- The big, gaseous planets are way out, far from the Sun
- Mars *may have* had habitable conditions on its surface billions of years ago
- Moons of the outer planets (Europa, Titan) may be promising locations for life


Would solar systems around other stars be similar?