Exploring Space – Feb 2016

with Jim Paradise

Image Credit: NASA

Solar System Tour

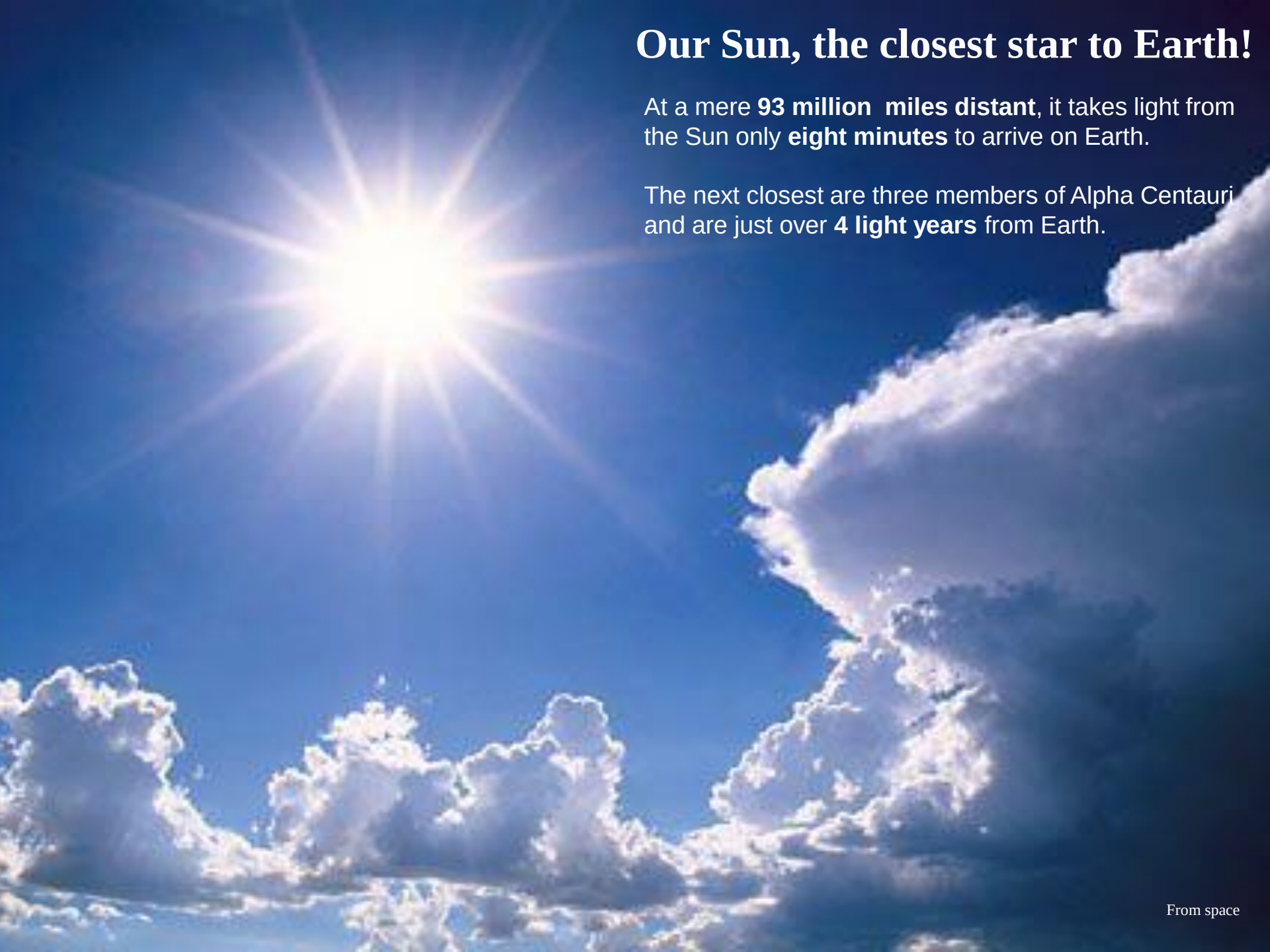
Starting in the center…

sun

Our Sun, the closest star to Earth!

At a mere **93 million miles distant**, it takes light from the Sun only **eight minutes** to arrive on Earth.

The next closest are three members of Alpha Centauri and are just over **4 light years** from Earth.



From space

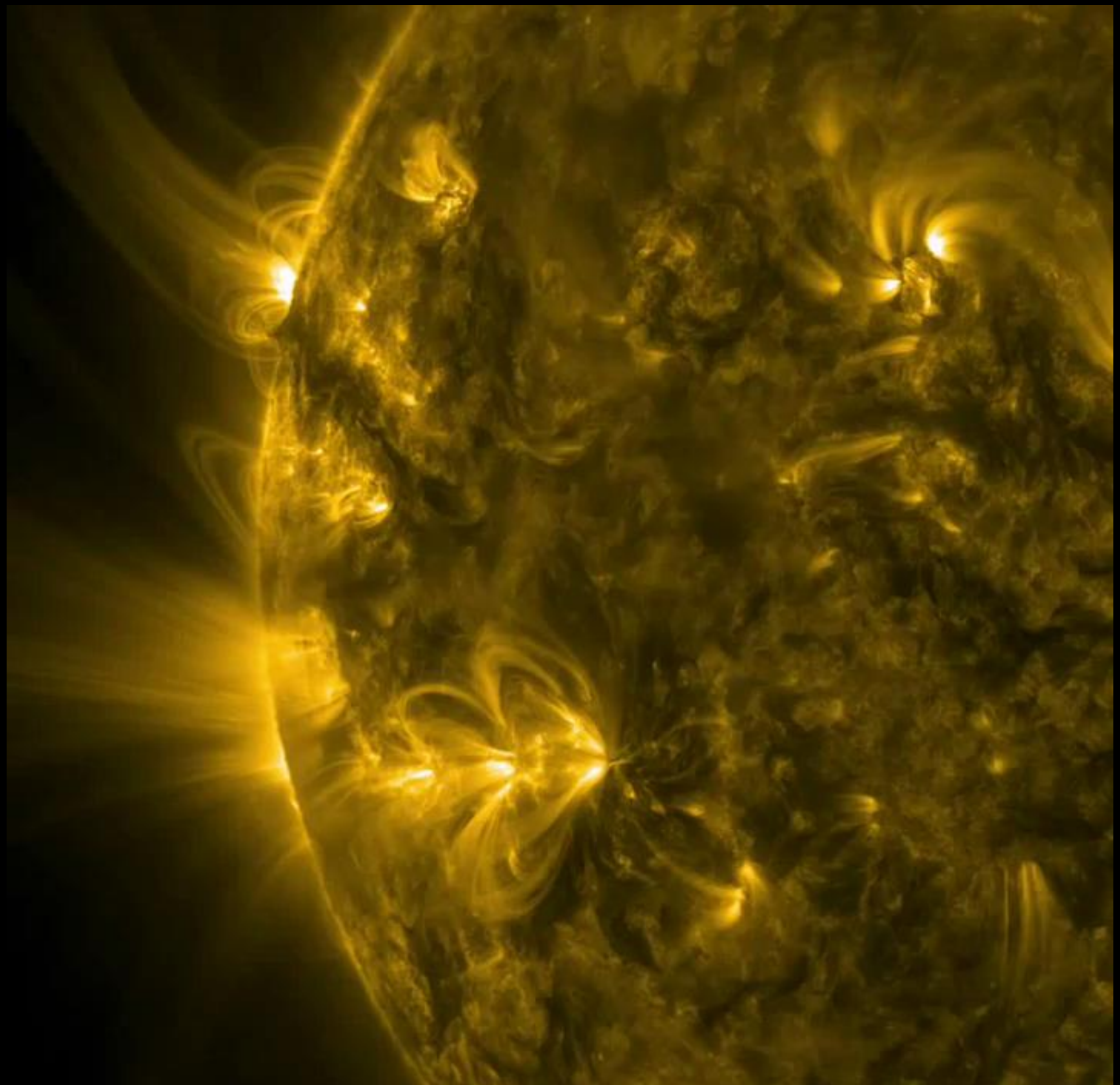
This is what our sun looks like from space

Image credit: NASA/JPL-Caltech

SDO


Solar Dynamics Observatory (SDO)
Launched Feb 11, 2010
Sun in ultraviolet

Ionized Iron and Magnetic Fields on surface of the Sun (SDO)



IRIS

Mercury

- Distance From Sun:
  36 Million Miles
- Average Temp: 332°F
  - Low: -270°F
  - High: +800°F
- Diameter: 3,000 miles
- Orbital Period: 88 days
- Rotation: 58 days
- Atmosphere: trace
- Moons: 0

Image credit: NASA/JPL-Caltech

Messenger

MESSENGER

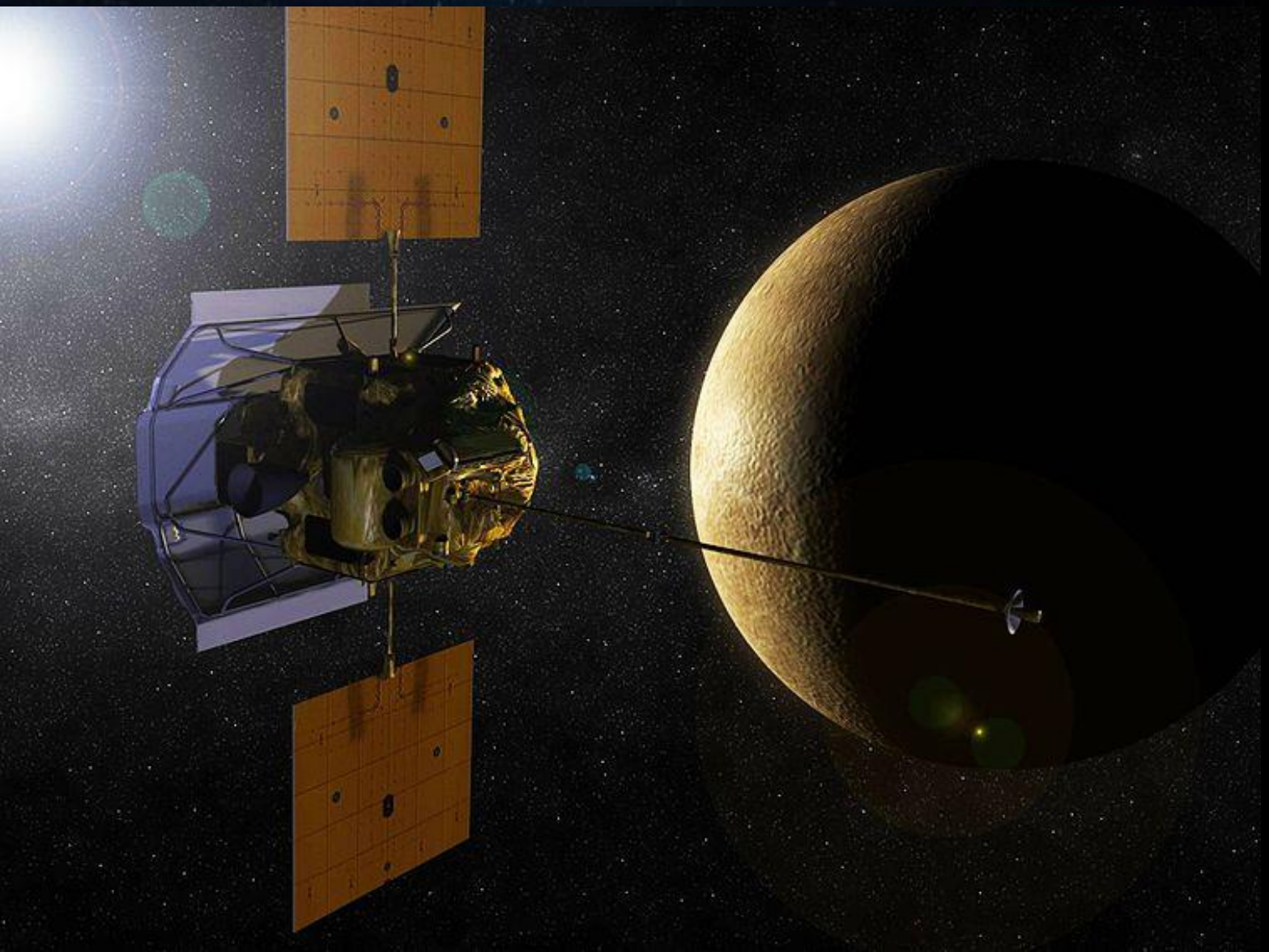
Mission to Mercury

August 2004 - Launch

March 2011 - Mercury Orbit

- 100% of Mercury imaged

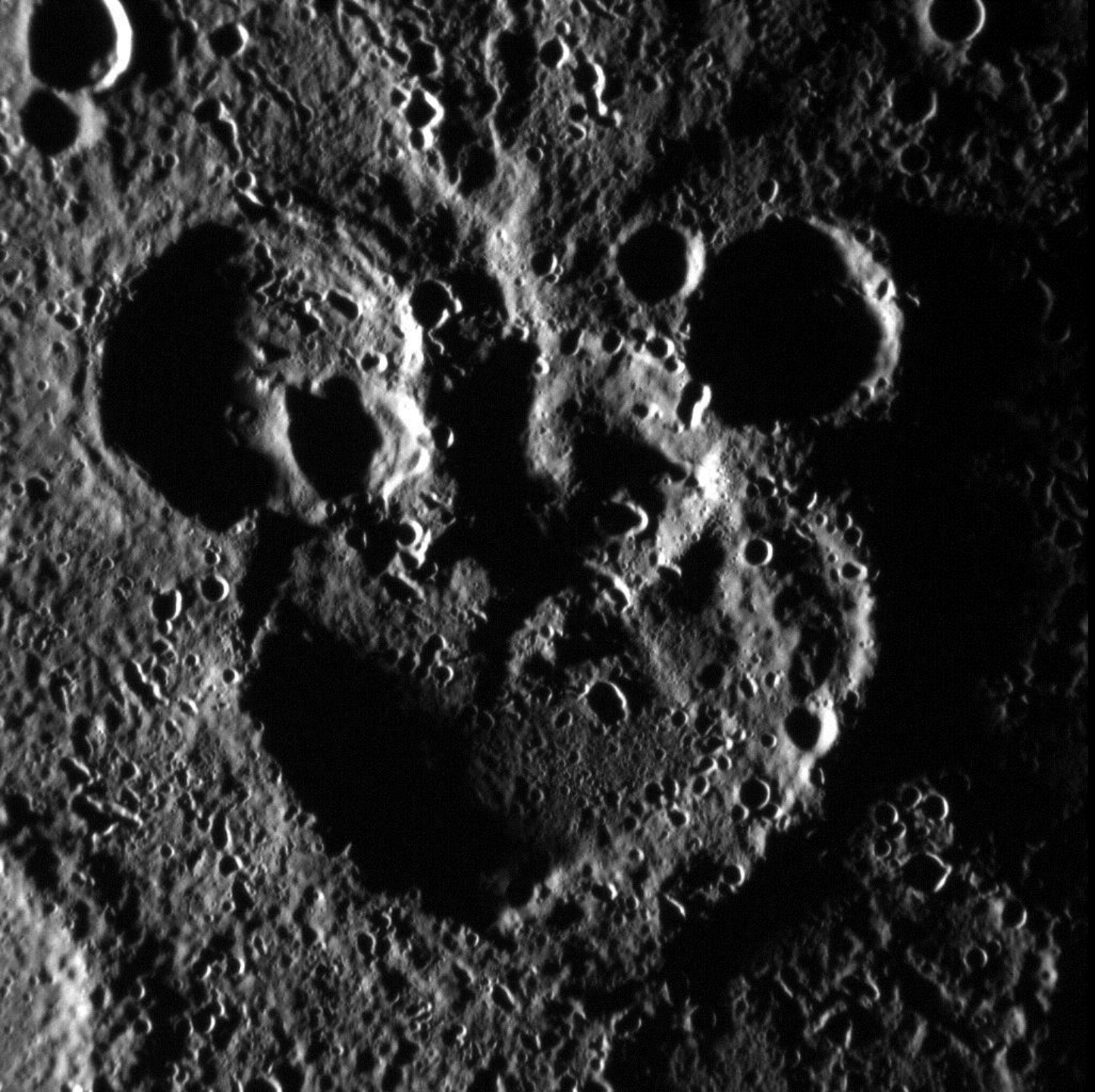
Now – Awaiting 2nd mission extension



High Rez

Mercury - High Resolution Mapping in Progress

Mickey Mouse Crater



Venus

Venus (in visible light)

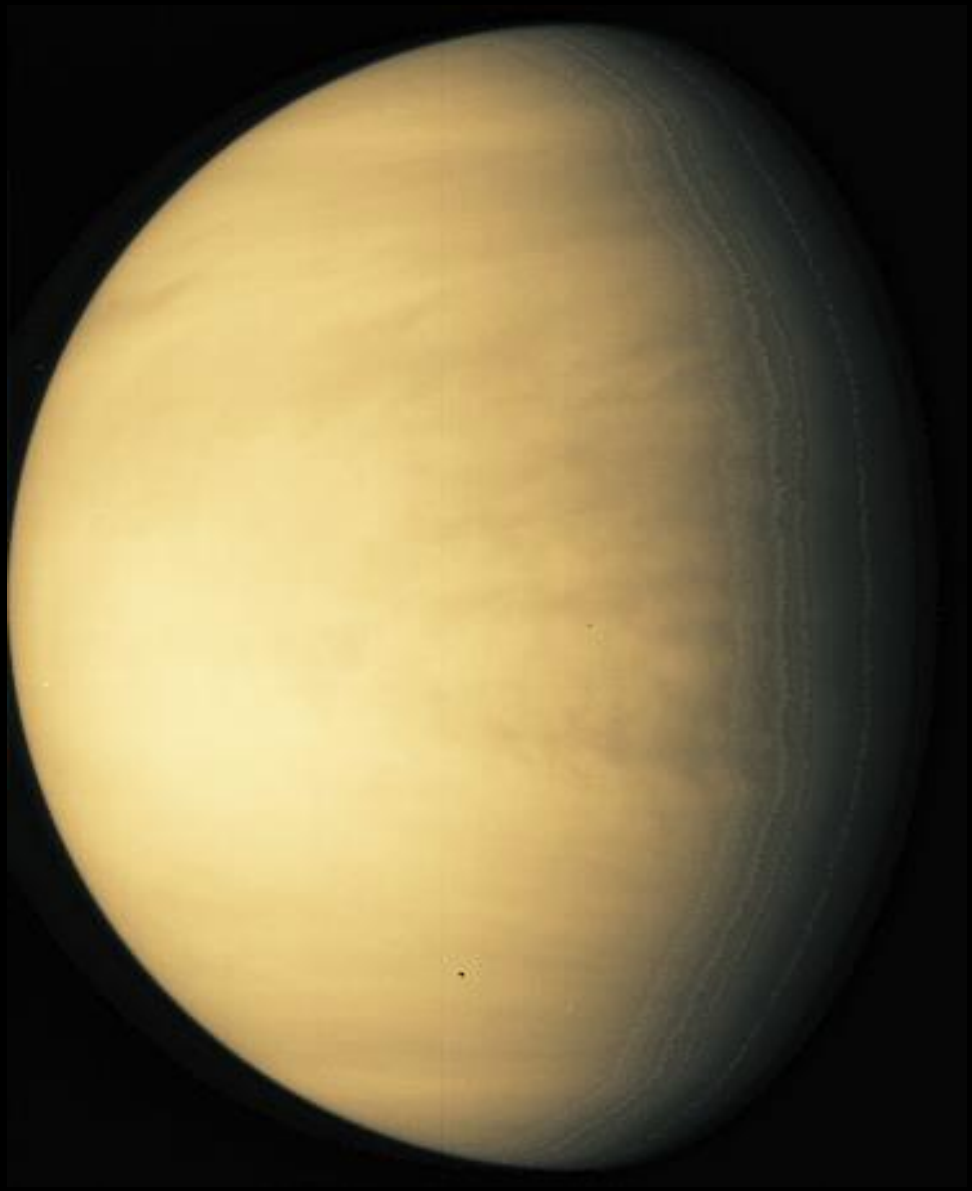


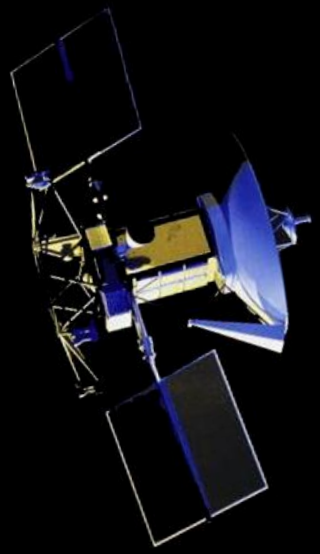
Image credit: NASA/JPL-Caltech

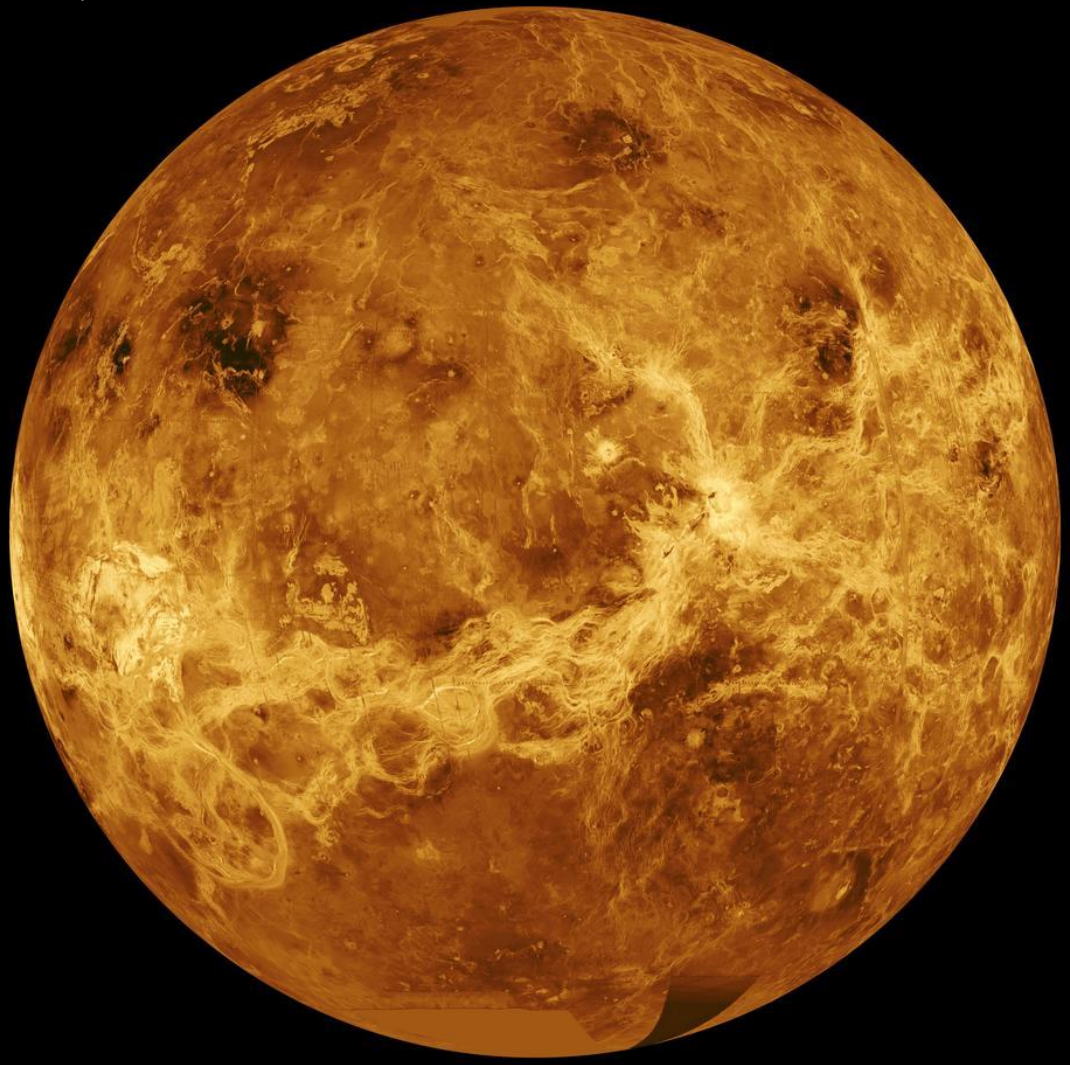
- Distance From Sun:
  67 Million Miles
- Average Temp: 867°F
- Diameter: 7,500 miles
- Orbital Period: 225 days
- Rotation Period: 243 days
  - backwards
- Atmosphere: very dense at 92 times denser than Earth's atmosphere
- Moons: 0

Under the clouds of Venus (Magellan images)

- Craters, volcanoes, mountain ranges, canyons, and more..
- 75% highlands / 25% lowlands, could not sustain an ocean.

Magellan
Radar Mapping Mission
1990-1994





earth

Image credit: NASA/JPL-Caltech

Earth data

Earth

3rd Rock from the Sun

- Distance From Sun: 93 Million Miles
- Average Temp: 59°F
- Diameter: 8,000 miles

Image credit: NASA/JPL-Caltech

Earth/Moon next to each other

Earth and Moon (to scale)

Image credit: NASA/JPL-Caltech

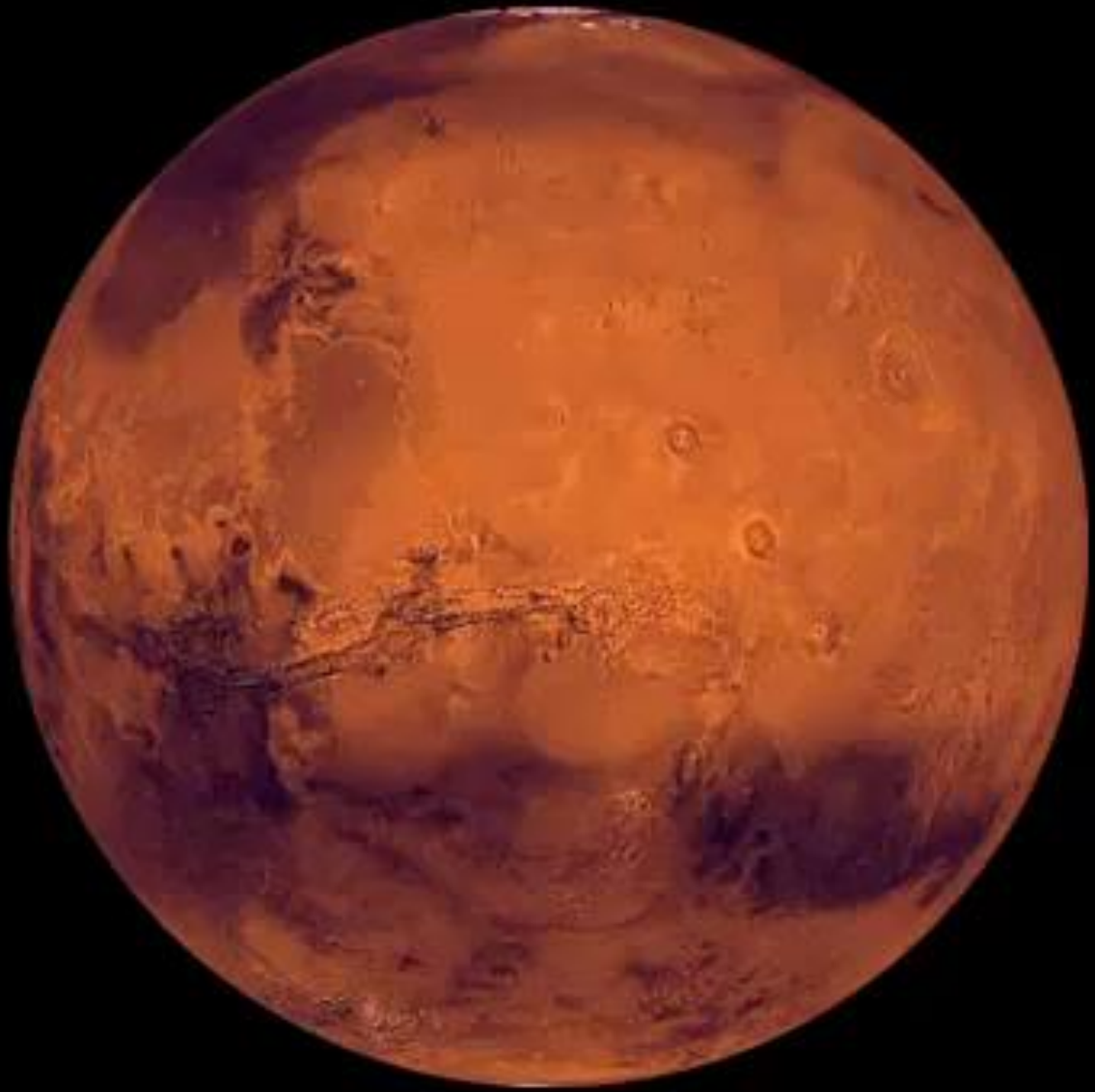
From Galileo

Image credit: NASA/JPL-Caltech

From moon

Earth (as seen from our moon)

Image credit: NASA/JPL-Caltech



Mars data

Mars

Average Distance From Sun:
142 Million Miles

- Average Temp: -85°F
- Surface Temp: -220°F to +80°F
- Atmosphere: 1% of Earth
- Diameter: 4,200 miles
- Orbital Period: 1.9 years
- Rotation: 24.7 hours
- Moons: 2

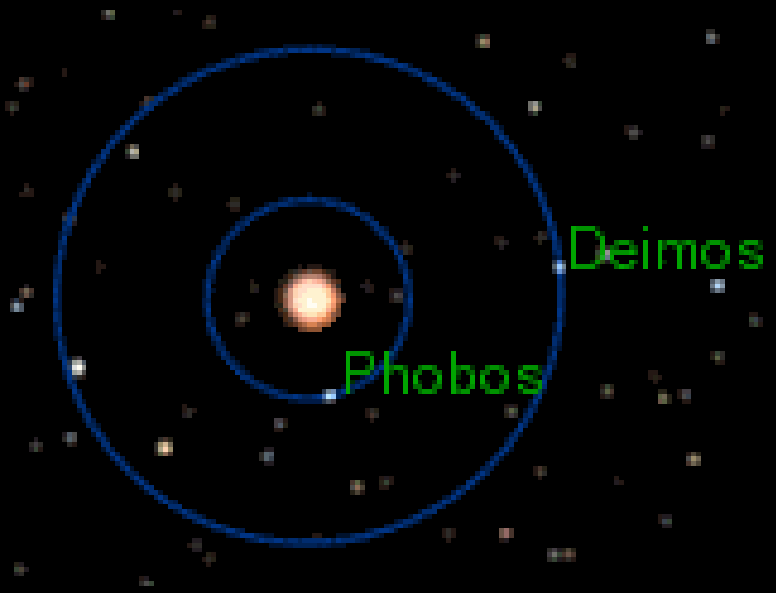


Image credit: NASA/JPL-Caltech

Deimos

Deimos –Mars smallest moon (8 miles diameter)

Image credit: NASA/JPL-Caltech

Phobos

Phobos – Mars biggest moon (14 miles diameter)

Escape Velocity: 24 mph

Image credit: NASA/JPL-Caltech

March 3, 2010:

Previous flybys of Phobos have shown that it is not dense enough to be solid all the way through.

It must be 25-35% porous.

This has led planetary scientists to believe it is a dust covered ‘rubble pile’ circling Mars, or is hollow, or has caverns.

Mars from Phobos

Mars, as seen from Phobos

Image credit: NASA/JPL-Caltech

Odyssey

Mars Odyssey

Launched: April 7, 2001
MOI: October 24, 2001
Controlled from Denver, CO

Major Instruments:

- **Thermal Emission Imaging System (THEMIS)**
- **Gamma Ray Spectrometer (GRS)**
- **Mars Radiation Environment Experiment (MARIE)**

Image credit: NASA/JPL-Caltech

Melas - The Grand Canyon of Mars

credit: NASA/JPL-Caltech

Olympus Mons

Largest Volcano in our Solar System: 100,000 feet tall

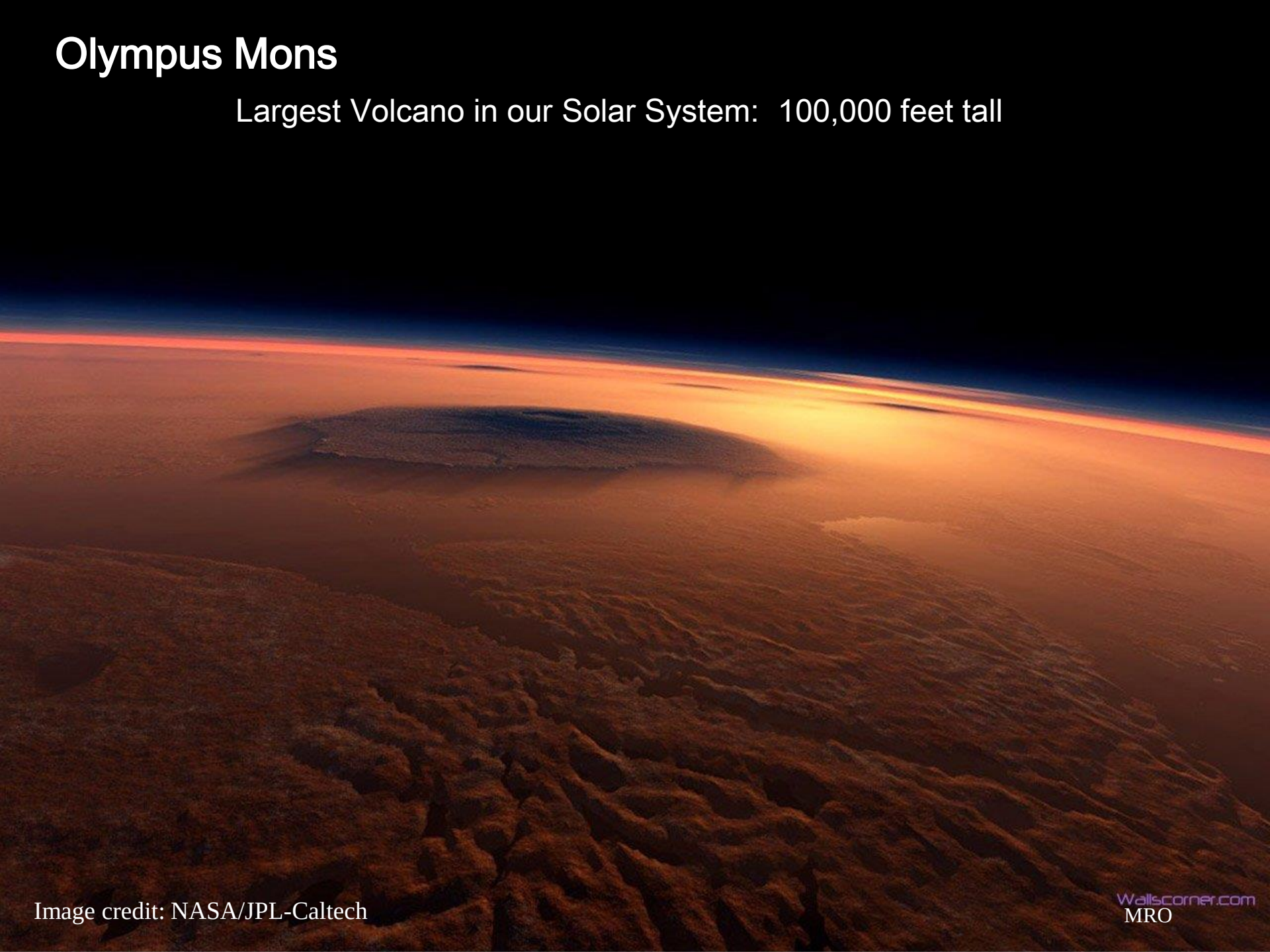
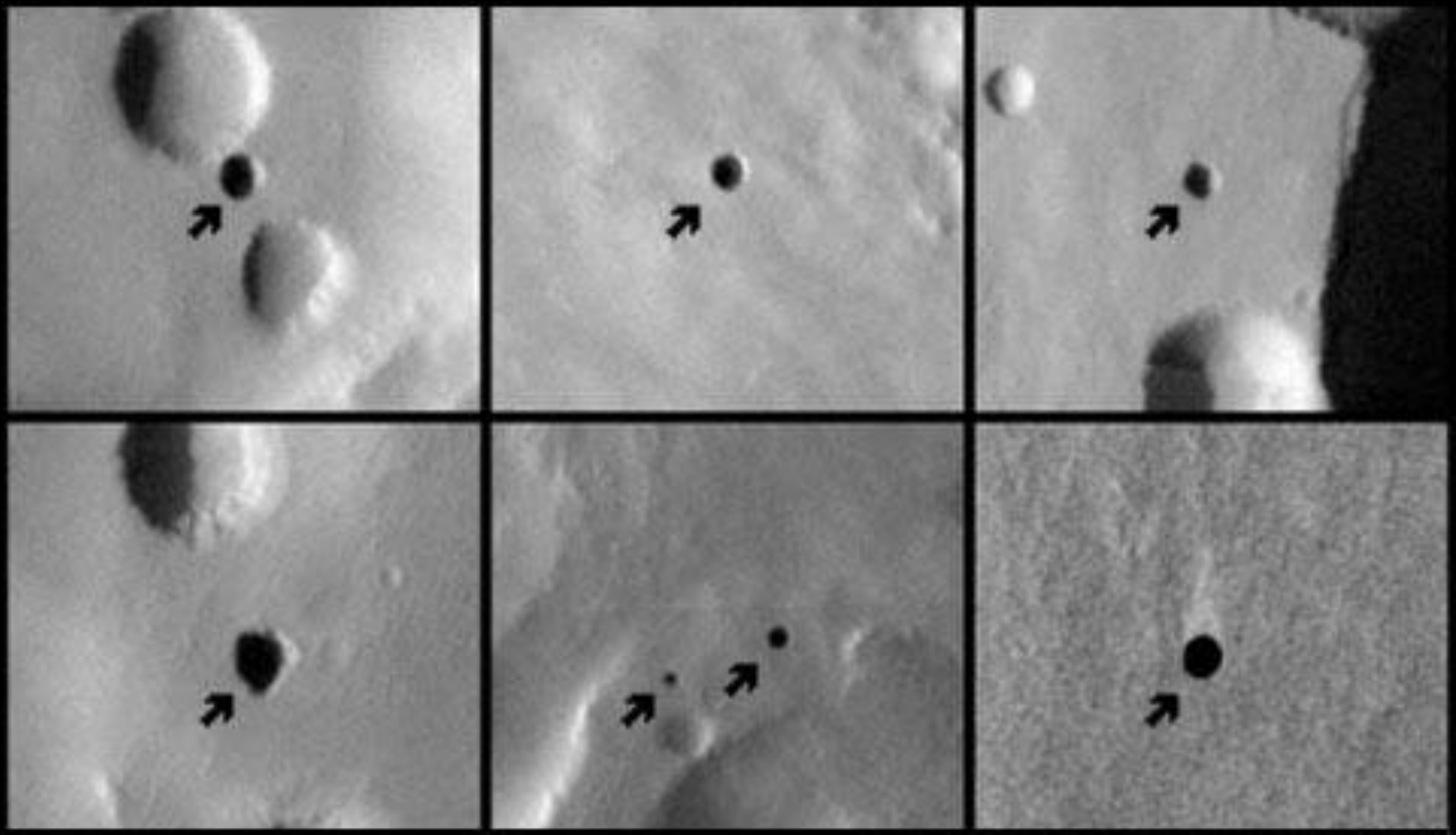


Image credit: NASA/JPL-Caltech

MRO

2007 - Very Dark Craters ?????



The very dark, nearly circular features range in diameter from 328 to 820 feet.

Image credit: NASA/JPL-Caltech

MRO

Mars Reconnaissance Orbiter (MRO)

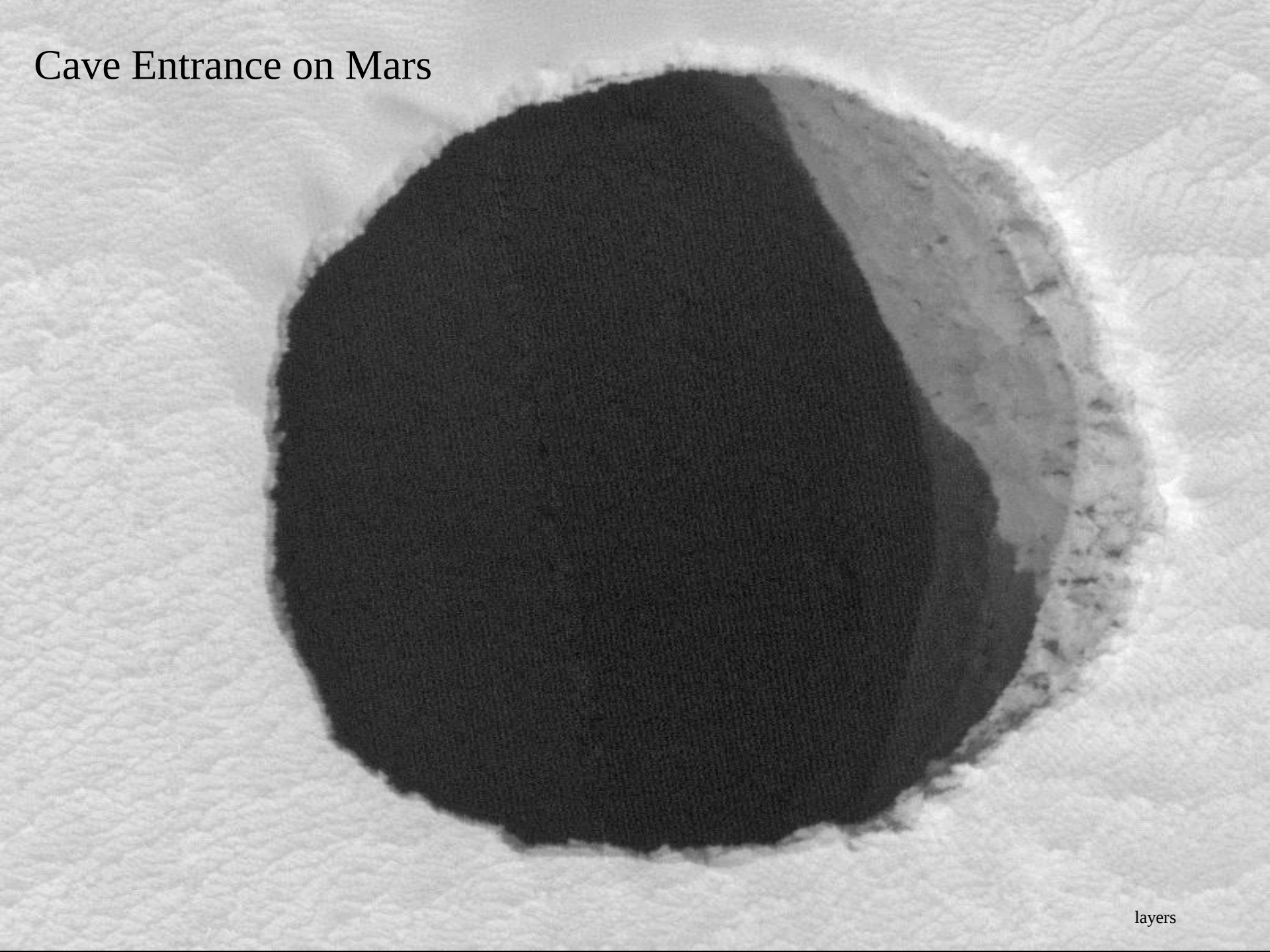
Launched: August 12, 2005
Arrived: March 10, 2006
10x resolution over Odyssey
Controlled from Denver, CO

Image credit: NASA/JPL-Caltech

Major Instruments:

- **Context Camera (CTX)**
- **Mars Color Imager (MARCI)**
- **High Resolution Imaging Science Experiment (HiRISE)**
- **Compact Reconnaissance Imaging Spectrometer for Mars (CRISM)**
- **Shallow Radar (SHARAD) (can see up to 1 km into ground)**

Cave Entrance on Mars

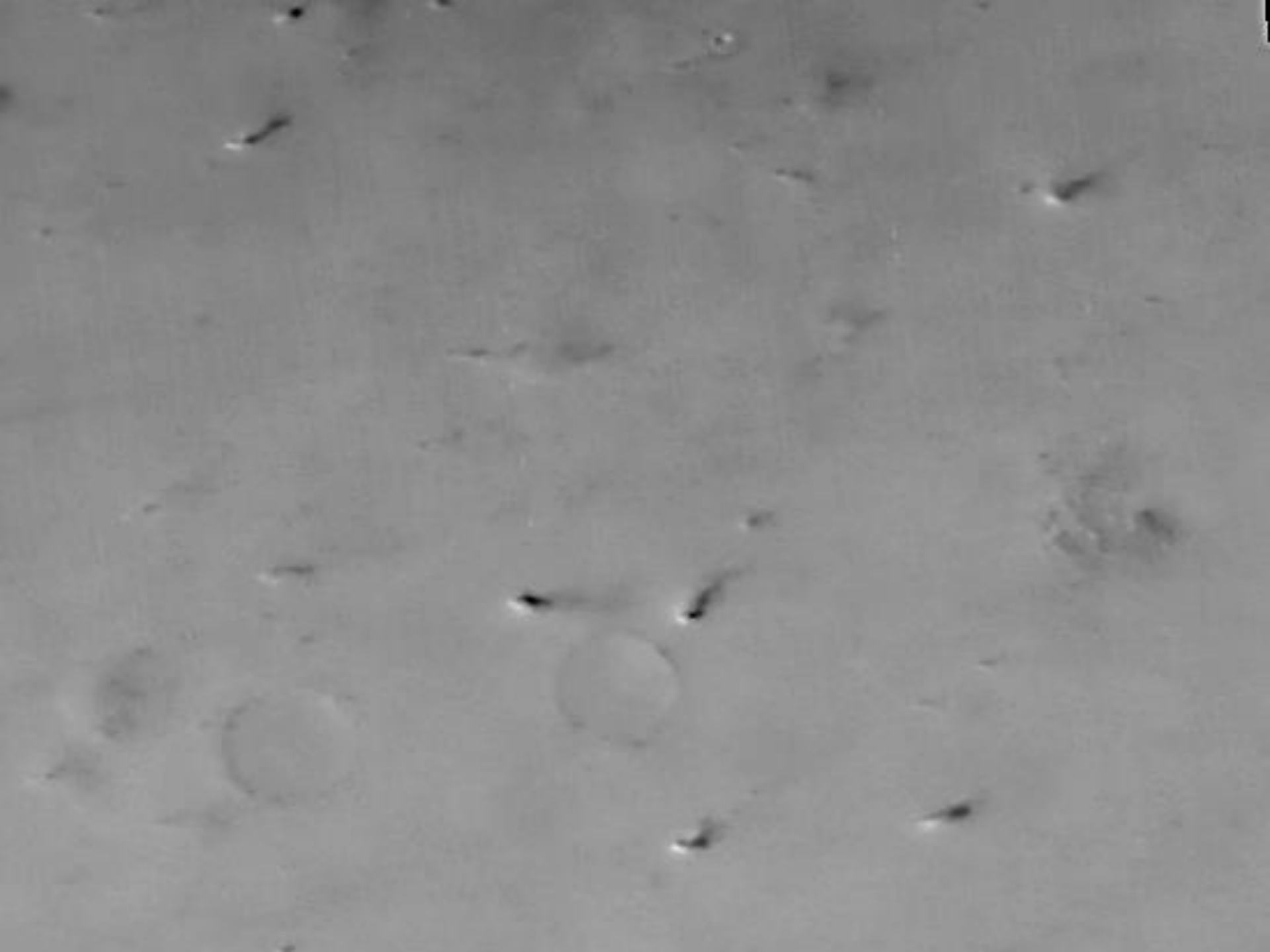


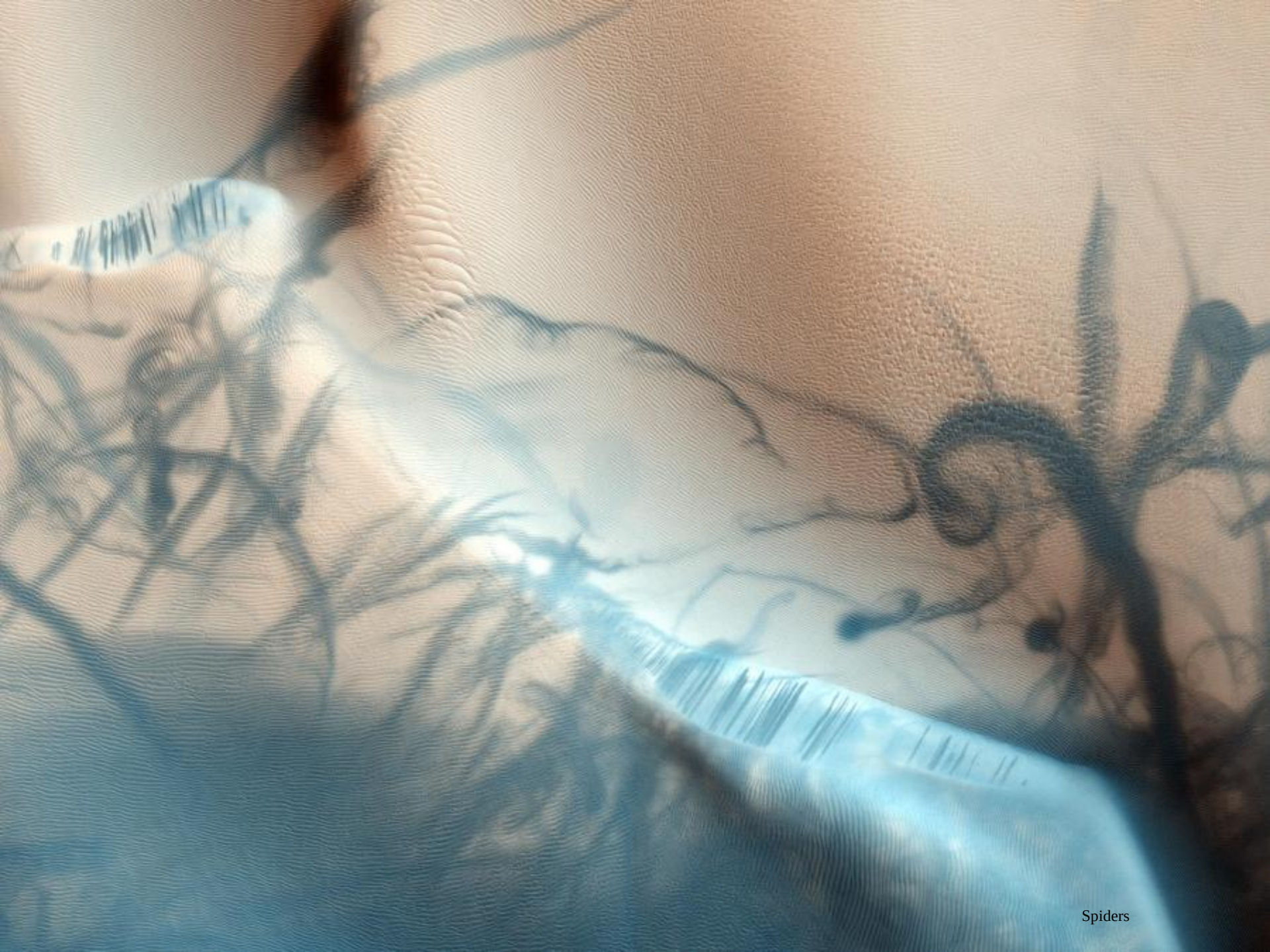
layers

Sand Dunes / Ripples

Dust devils

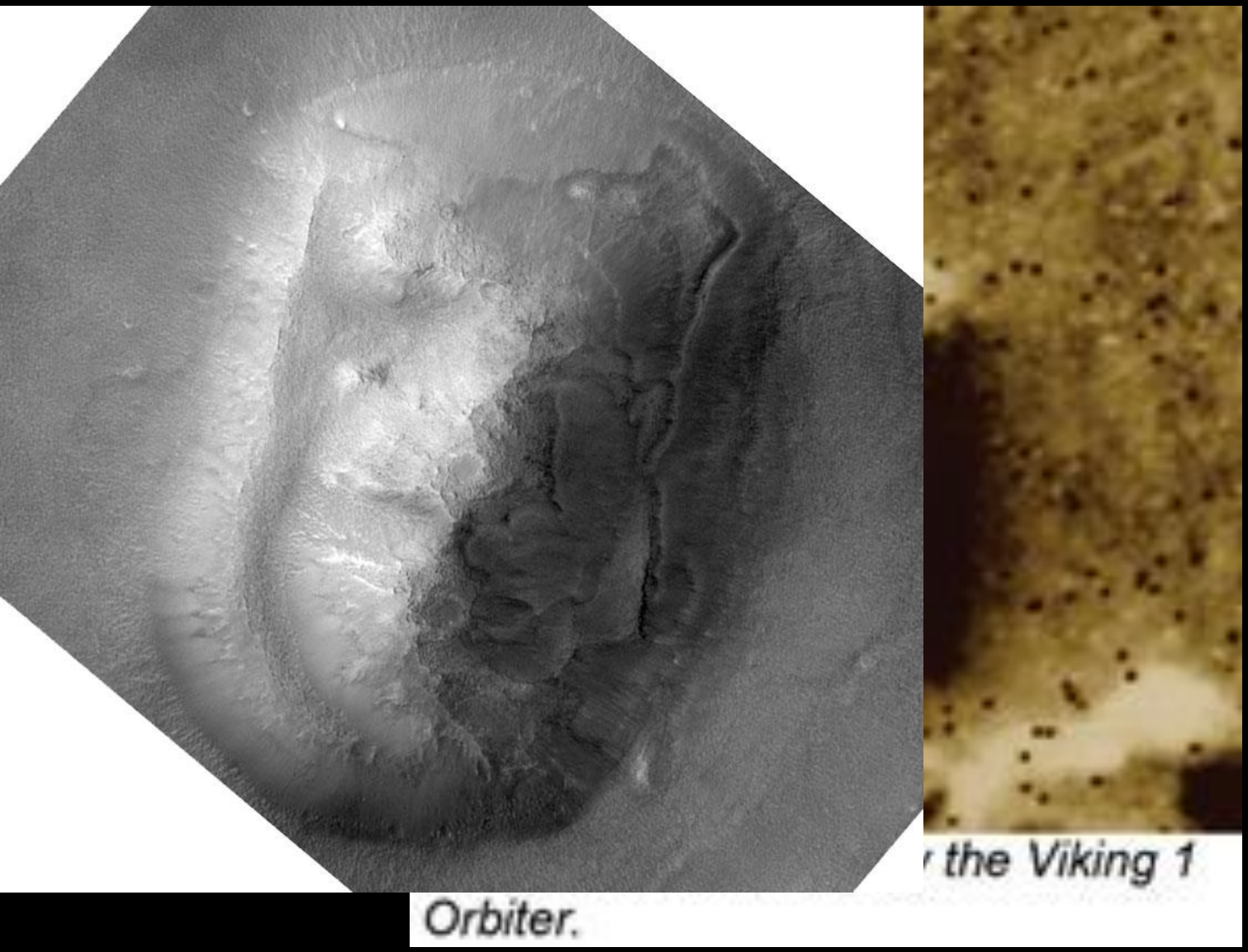

Sediments

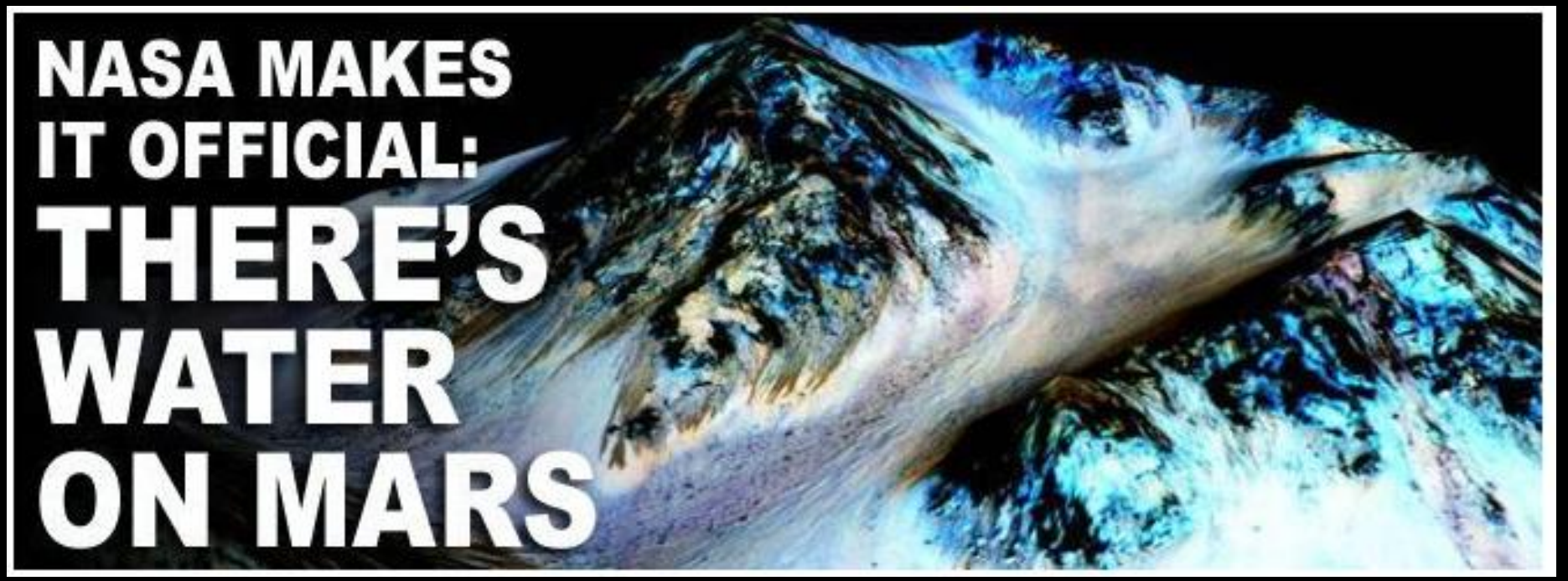




Spiders

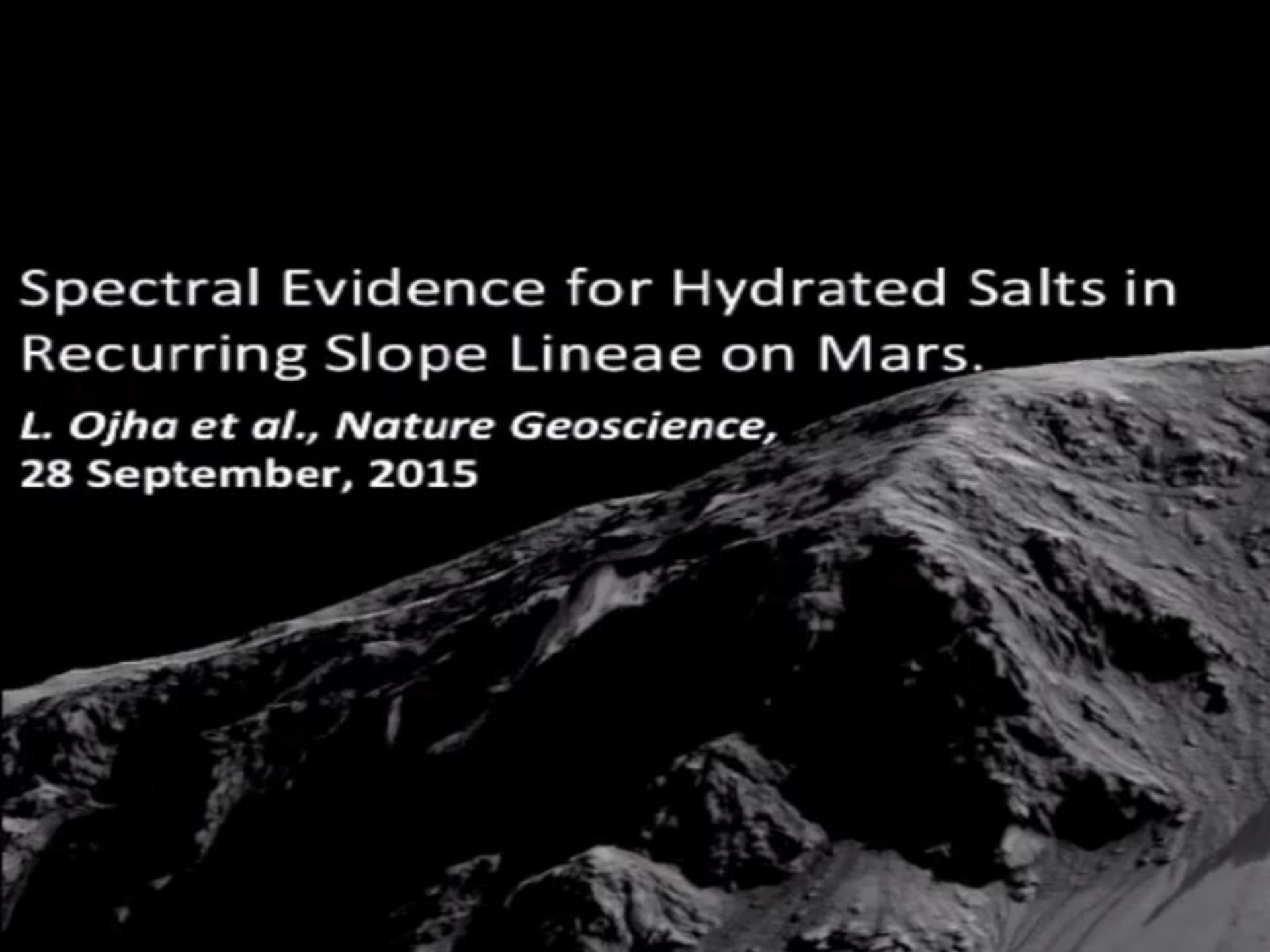
Face on Mars

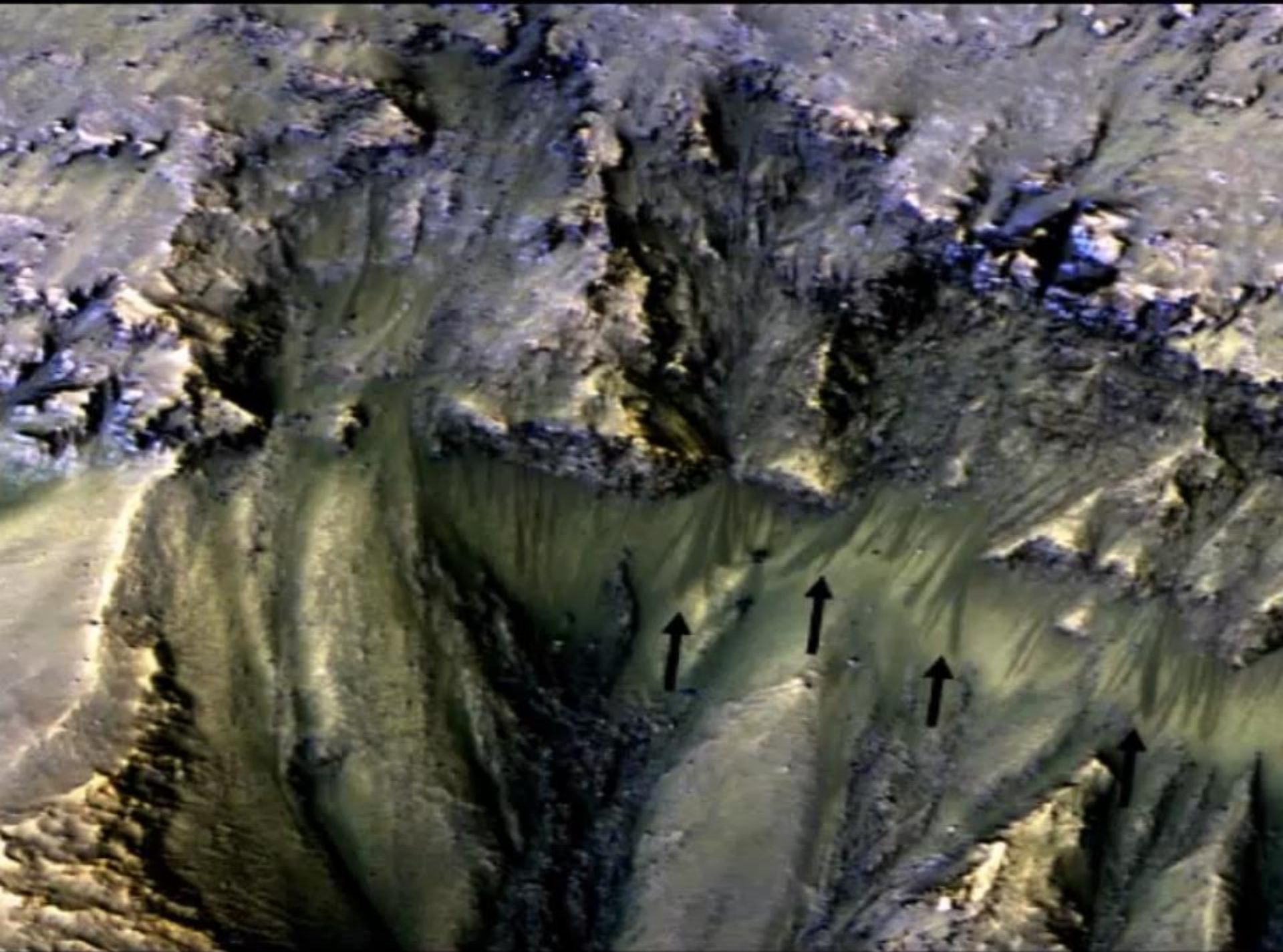


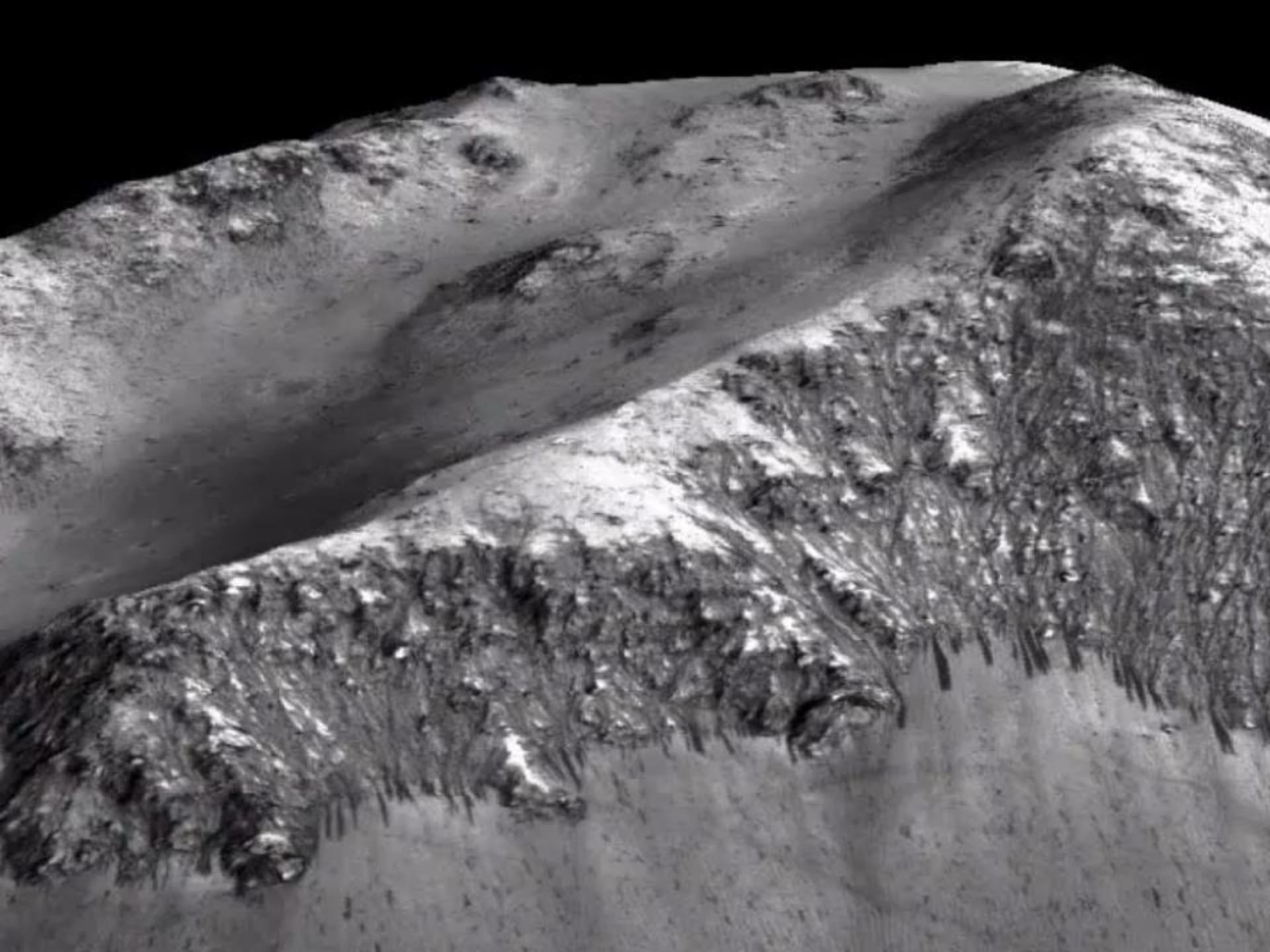

NASA MAKES
IT OFFICIAL:
THERE'S
WATER
ON MARS

Spectral Evidence for Hydrated Salts in Recurring Slope Lineae on Mars.

L. Ojha et al., Nature Geoscience,
28 September, 2015

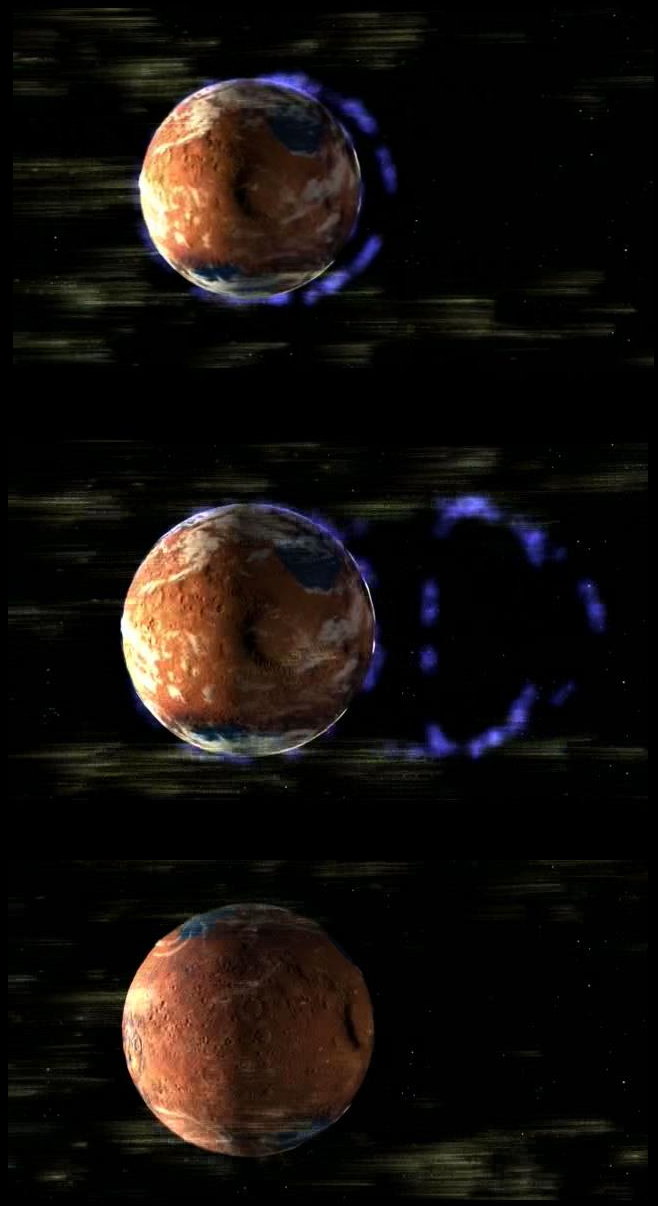






MAVEN

Launched: Nov 18, 2013
Mars Orbit: Sept 21, 2014
Controlled from Denver, CO



Mars' loss of its protective magnetic field may have triggered the loss of its atmosphere.

Mars Atmosphere and Volatile Evolution Mission (MAVEN) will explore Mars' upper atmosphere, ionosphere and how it interacts with the Sun. The spacecraft will determine why Mars lost the denser surface atmosphere that once allowed it support the presence of liquid water on its surface.

Mars 1997

Launched: Dec 4, 1996

Landed: July 4, 1998

Lasted: 92 days

Size
- **Small**
- **Length: 20 inches**
- **Height: 10 inches**

Sojourner

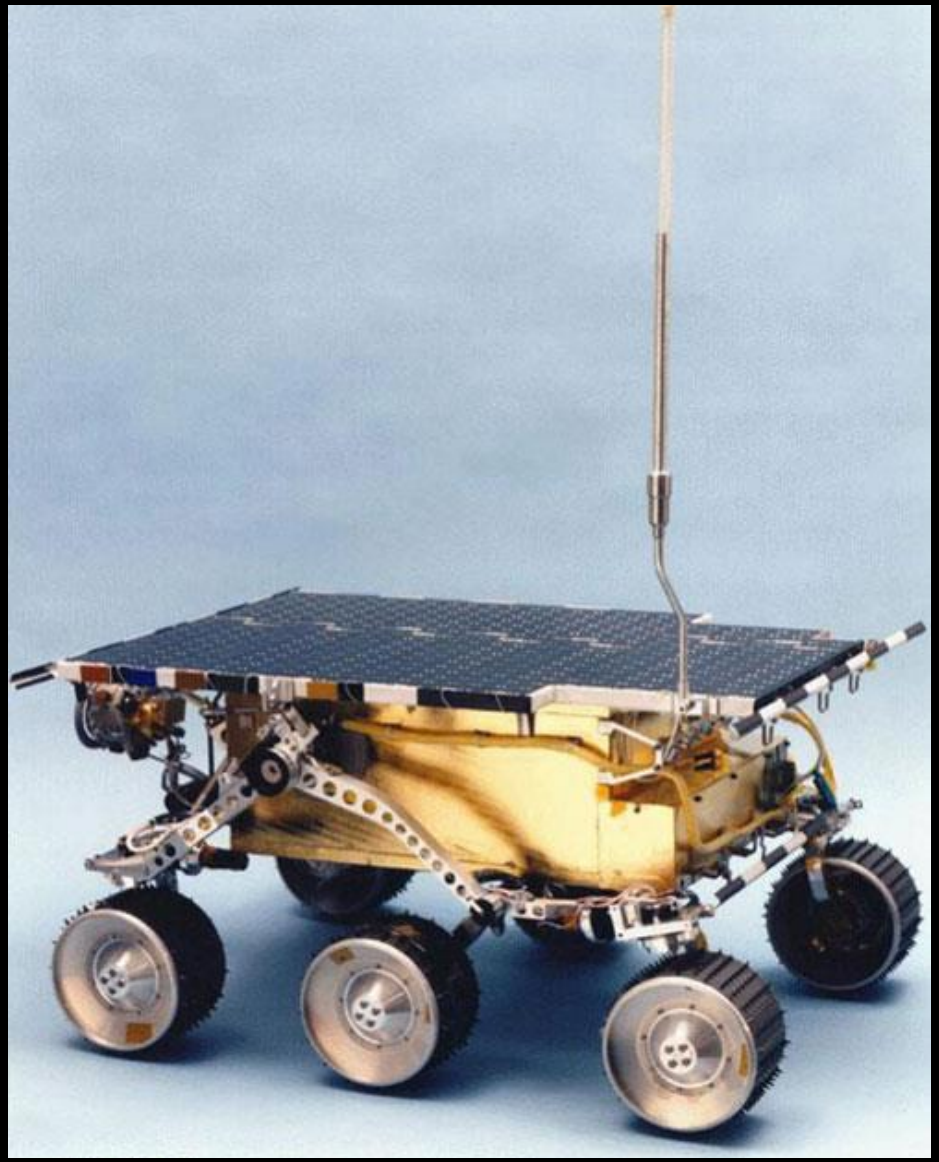


Image credit: NASA/JPL-Caltech

Mars Pathfinder Landing Site

July 4, 1997

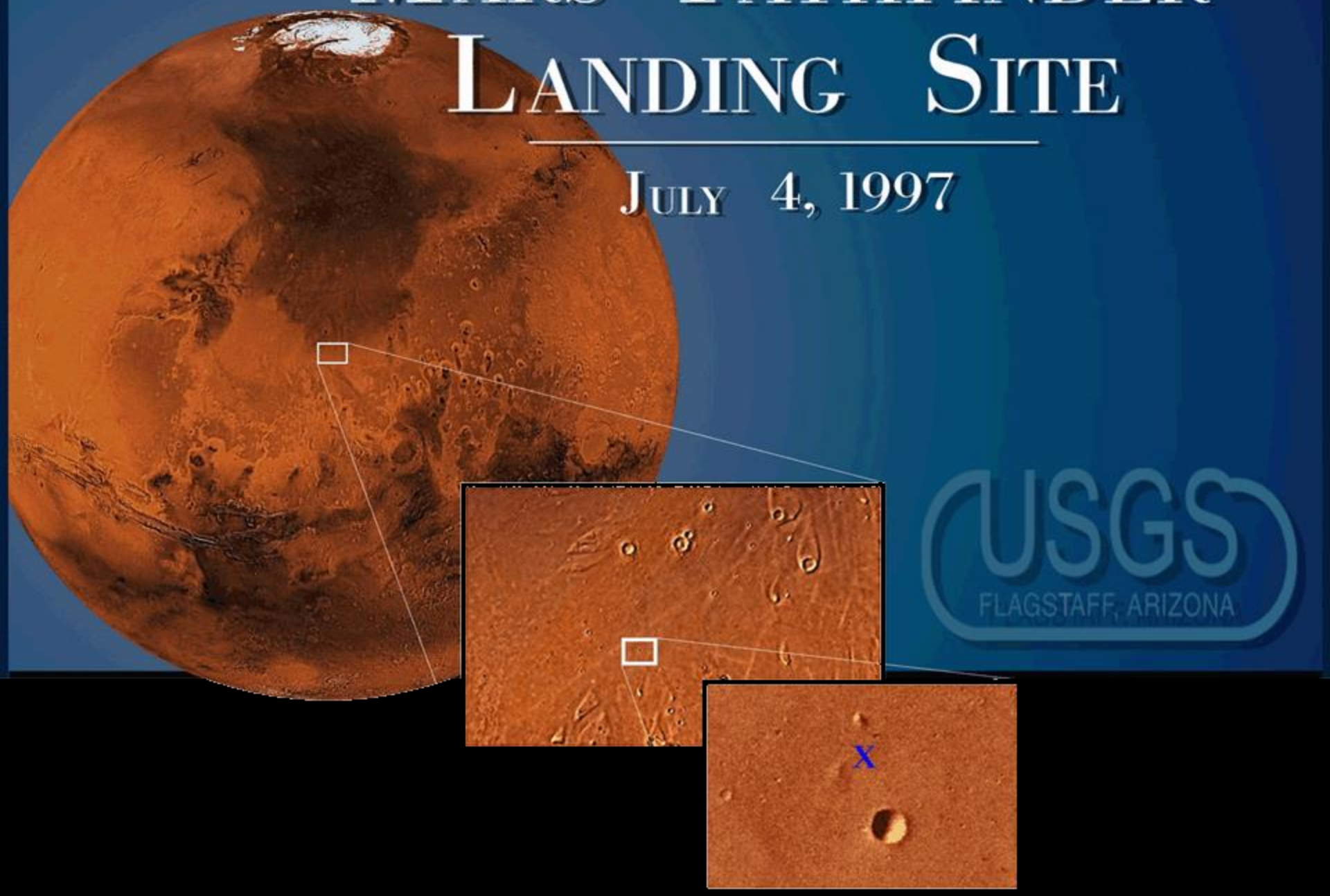


Image credit: NASA/JPL-Caltech

Sojourner on Mars

Mars 2003 Mars Exploration Rovers (MER)

Spirit:

Launched: June 10, 2003
Landed: January 4, 2004 at Gusev Crater
Got stuck at Troy 8/5/2009
Traveled 4.8 miles total
Last communication: 3/22/2010

Opportunity:

Launched: July 7, 2003
Landed: January 24, 2004 at Meridian Planum
Still rolling after more than 9.5 years
Traveled 14.3 miles so far
Next Destination: Solander Point

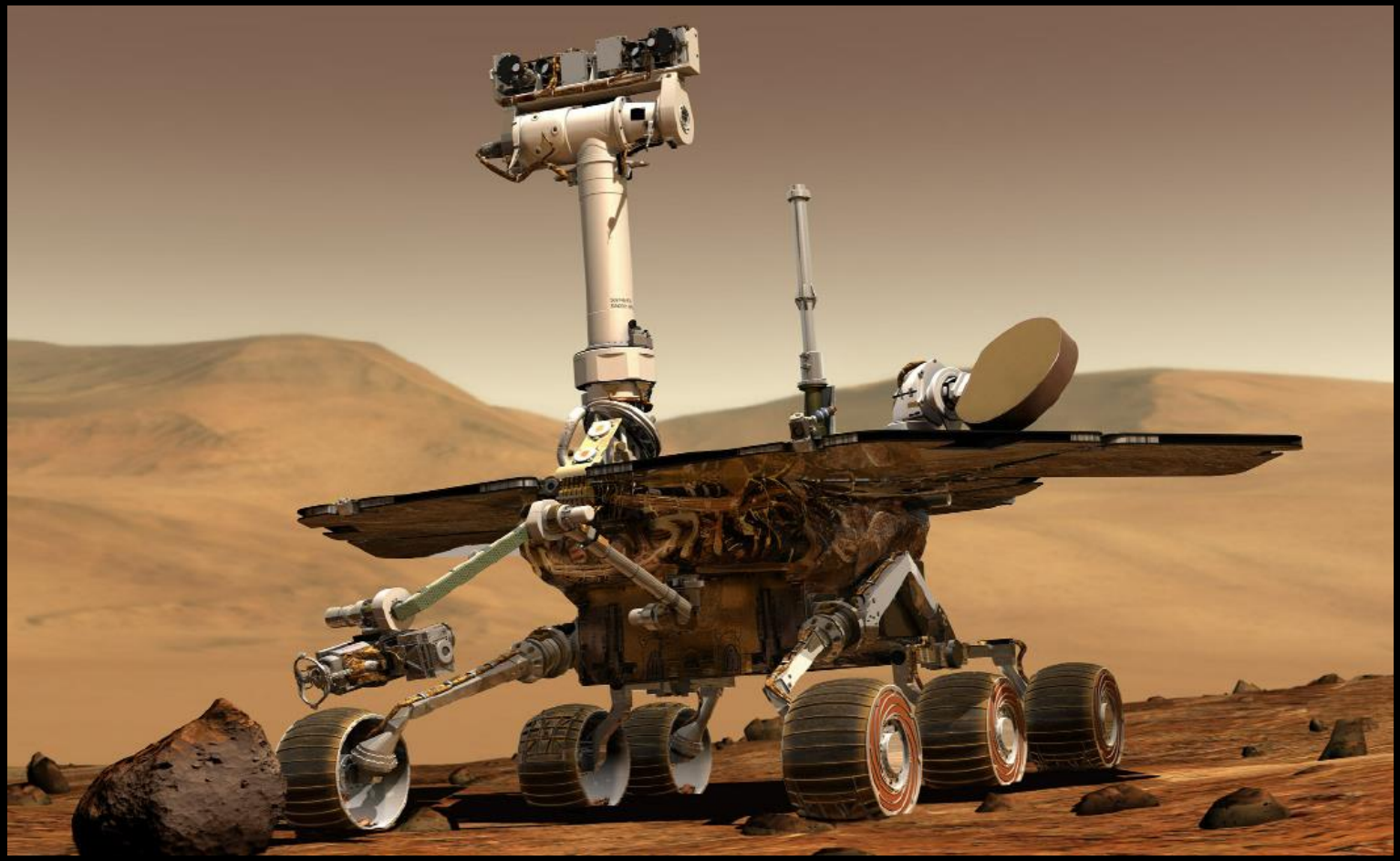


Image credit: NASA/JPL-Caltech

video

How Spirit and Opportunity got to Mars

Mars 1/25/2004
Opportunity on Mars

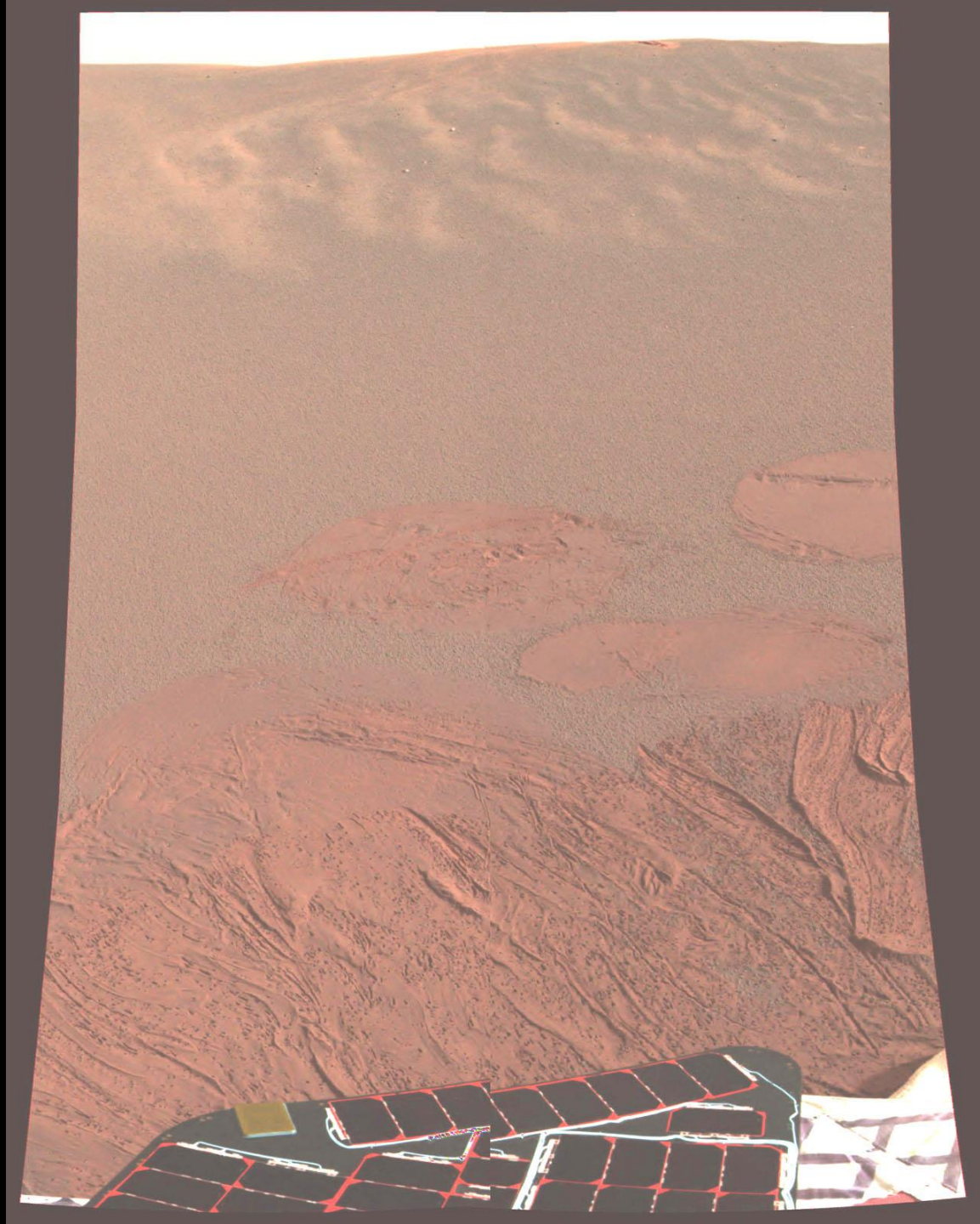


Image credit: NASA/JPL-Caltech

Opportunity checking out it's landing airbag…

Image credit: NASA/JPL-Caltech

Opportunity finds a Meteorite

Image credit: NASA/JPL-Caltech

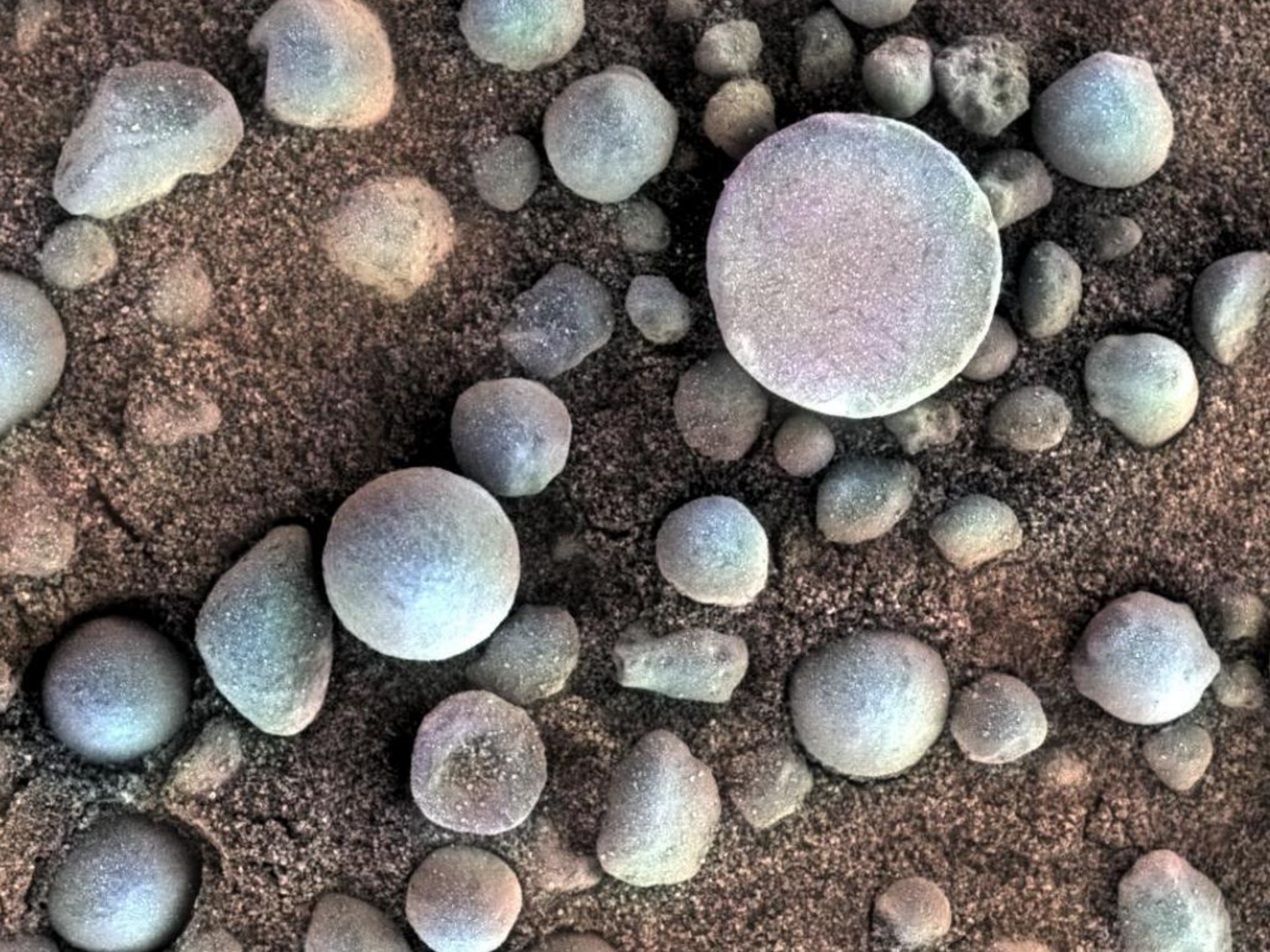
Opportunity finds Blueberries (Hematite Concretions)

In Southern Utah

On Mars

Image credit: NASA/JPL-Caltech

dunes

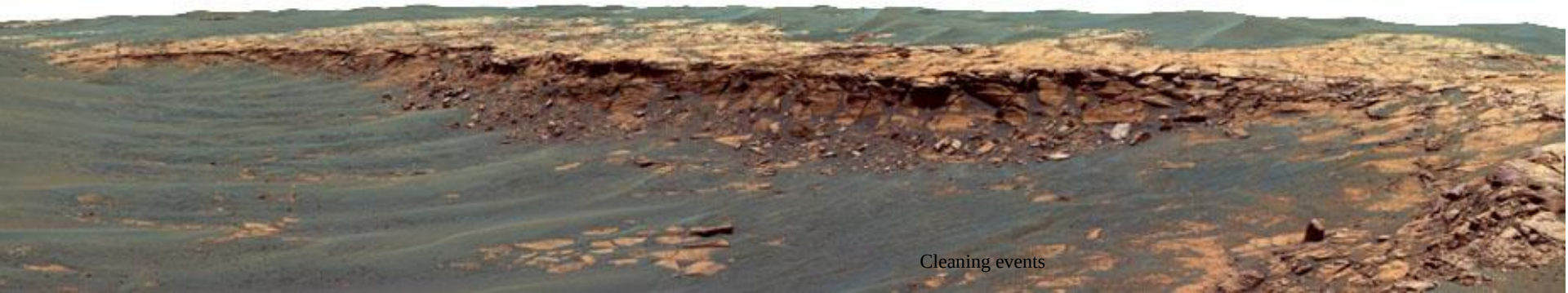


Sand Dunes

Image credit: NASA/JPL-Caltech

Image credit: NASA/JPL-Caltech

A rocky outcrop



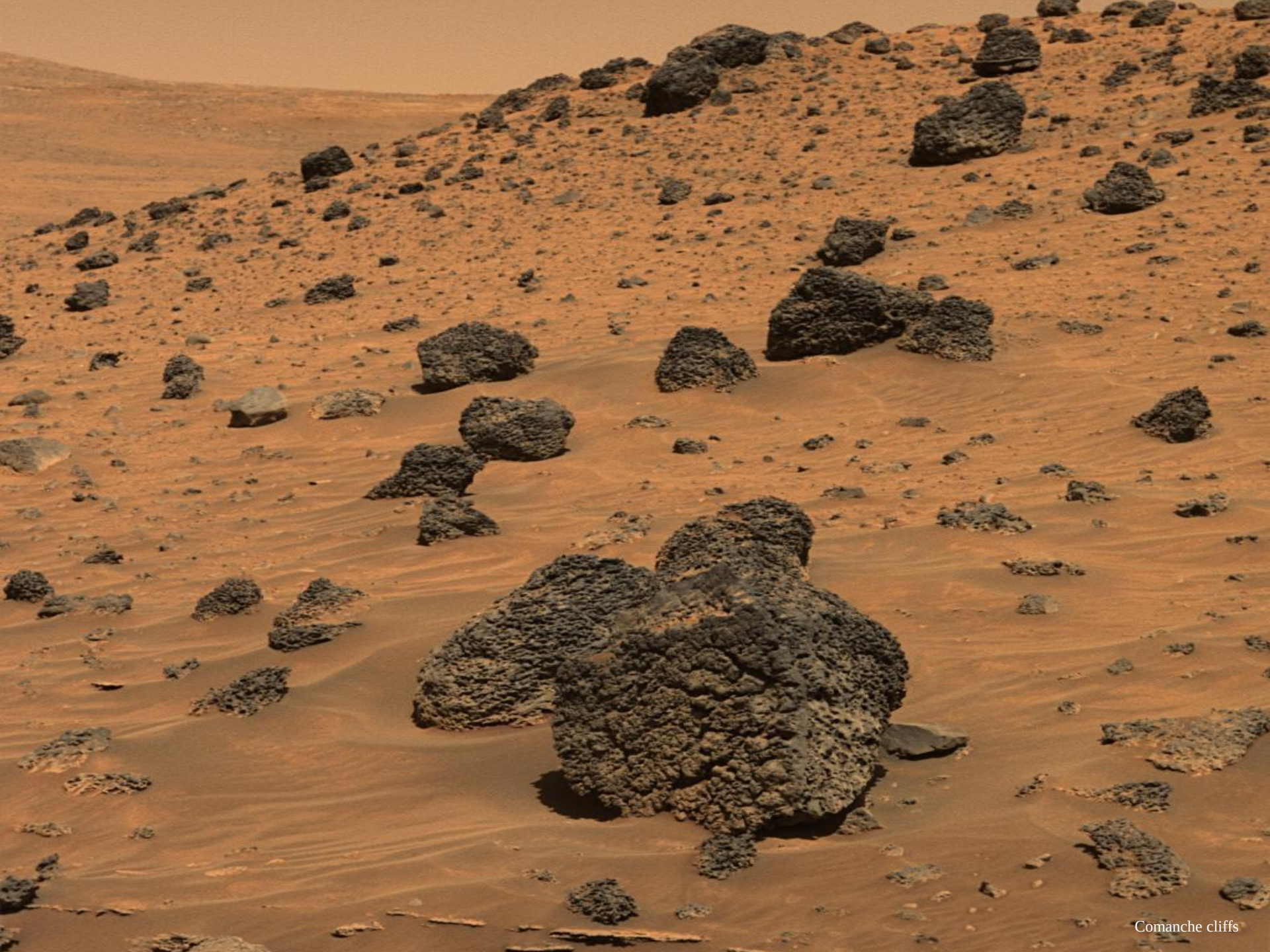
Opportunity finds Earth

Image credit: NASA/JPL-Caltech

Spirit's Landing Area on Mars

Image credit: NASA/JPL-Caltech

Volcanic hills



Comanche cliffs

Spirit at Comanche Cliffs

Image credit: NASA/JPL-Caltech

Spirit stuck in white dry powder at Troy (final resting place)

Image credit: NASA/JPL-Caltech

What would you do different?

Curiosity Rover (Launched: Nov 26, 2011)

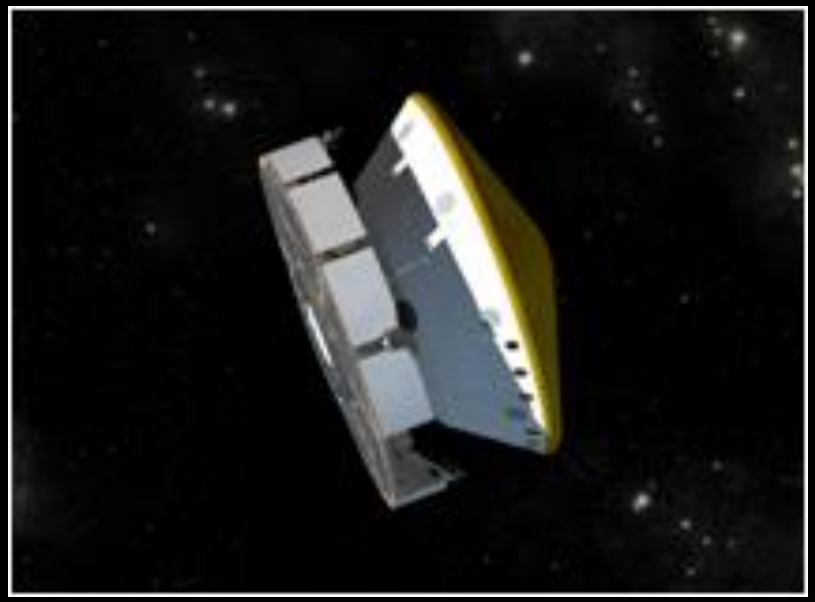
Image credit: NASA/JPL-Caltech

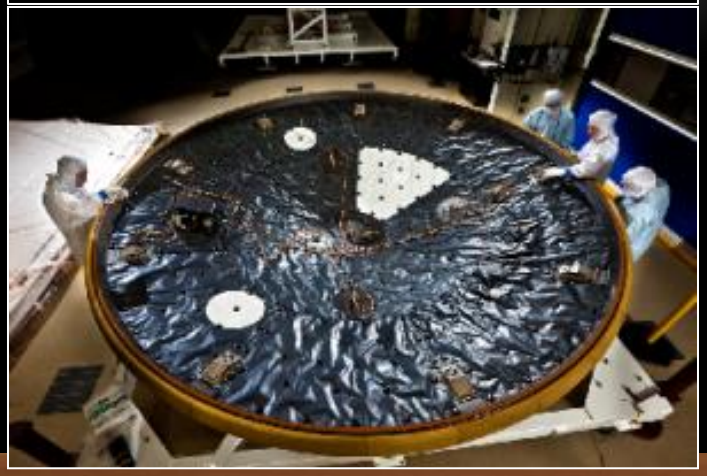
Curiosity compared to previous rovers

- 7 feet tall – 9 feet wide
- 8 foot long arm
- Weighs 2000 lbs
- Can roll over 30” tall rocks

Heat shield

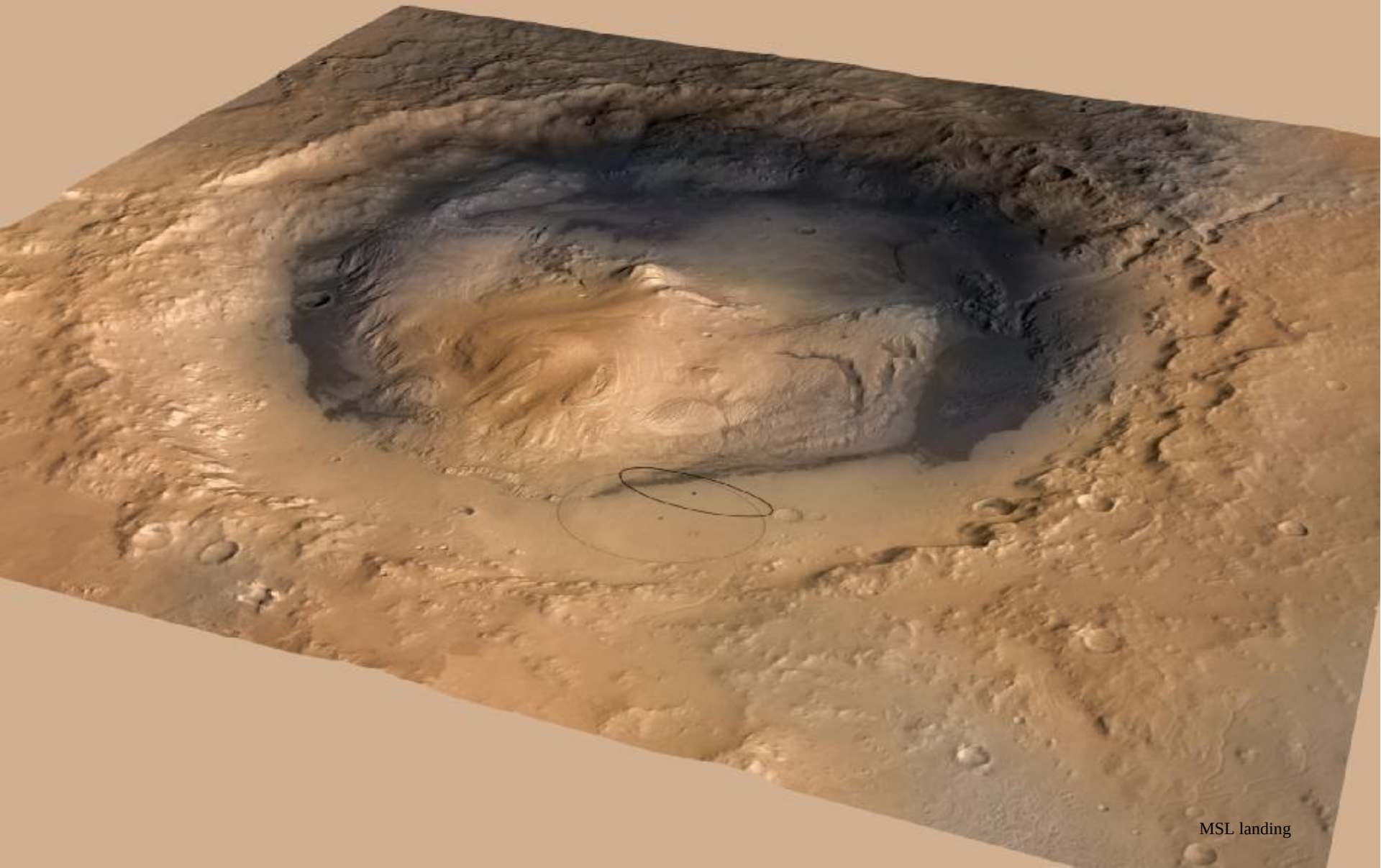
CURIOSITY (MSL) AEROSHELL





Gale Crater and Mount Sharp

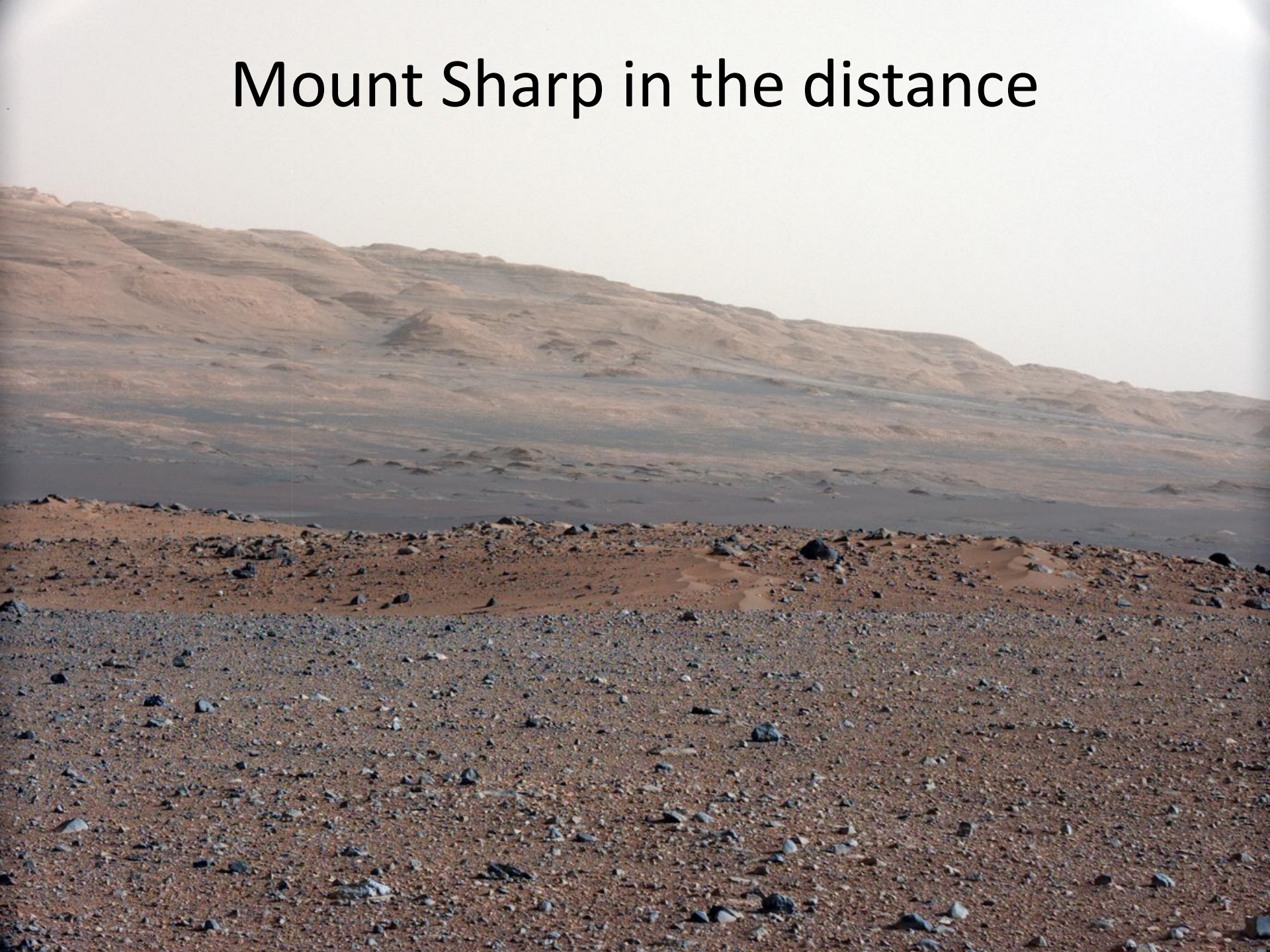
Landed in Gale Crater in August 5, 2012
Mount Sharp in the crater



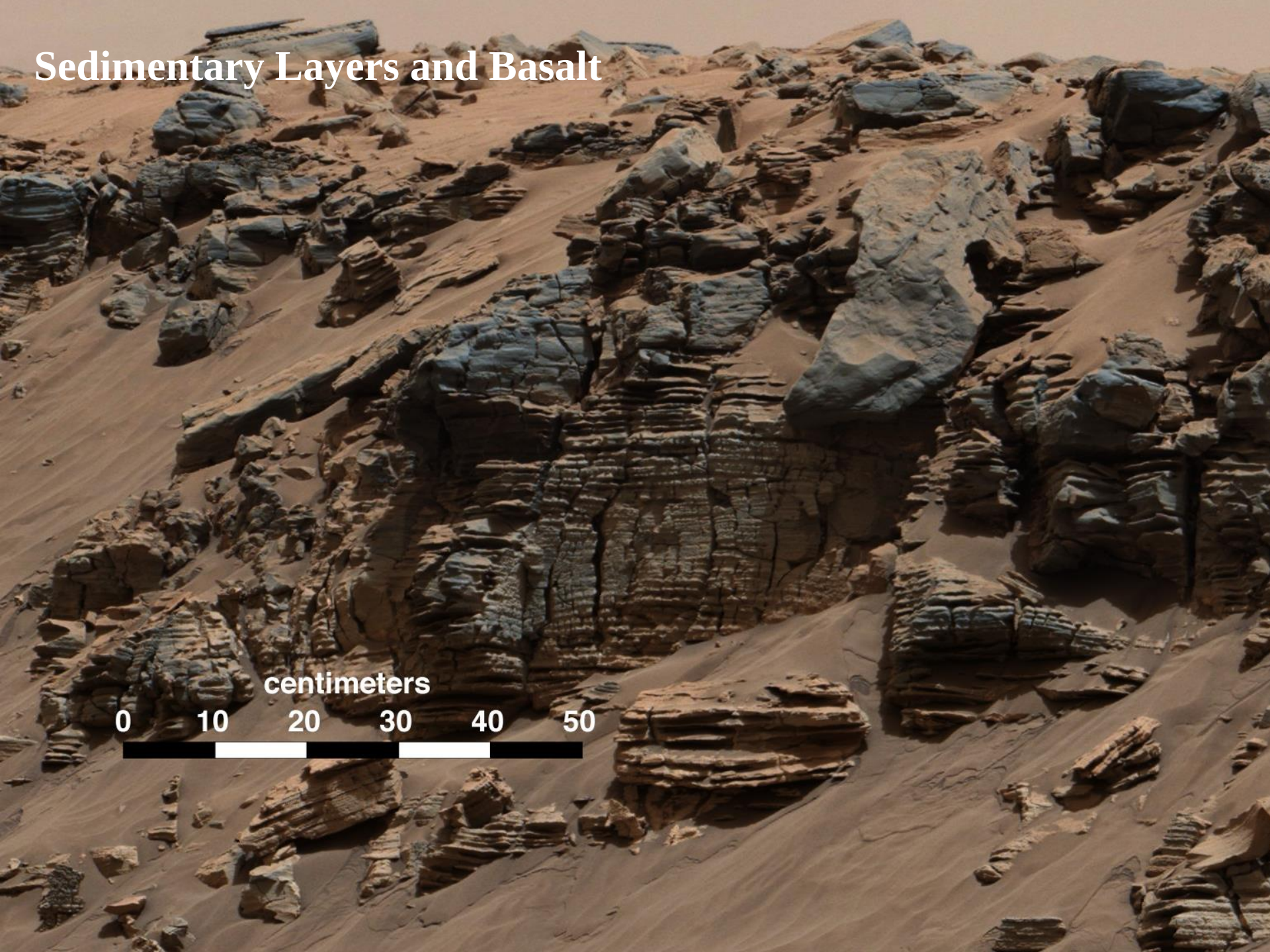
Curiosity Parachute by MRO (8/5/2012)

Actual fo

Mount Sharp in the distance



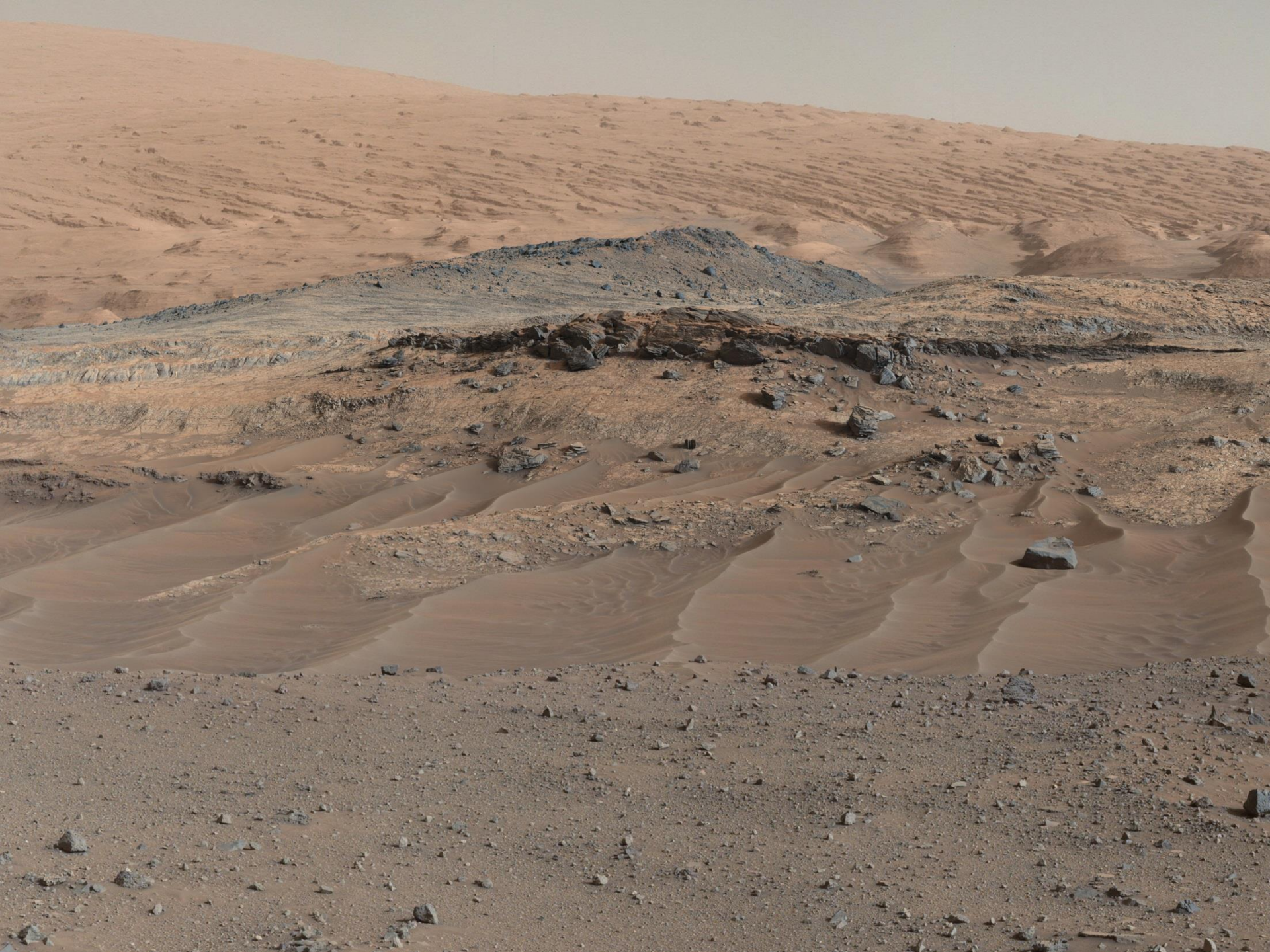
Sedimentary Layers and Basalt




**** OFF, GO HOME !!!
MARS FOR MARTIANS
SPIRIT

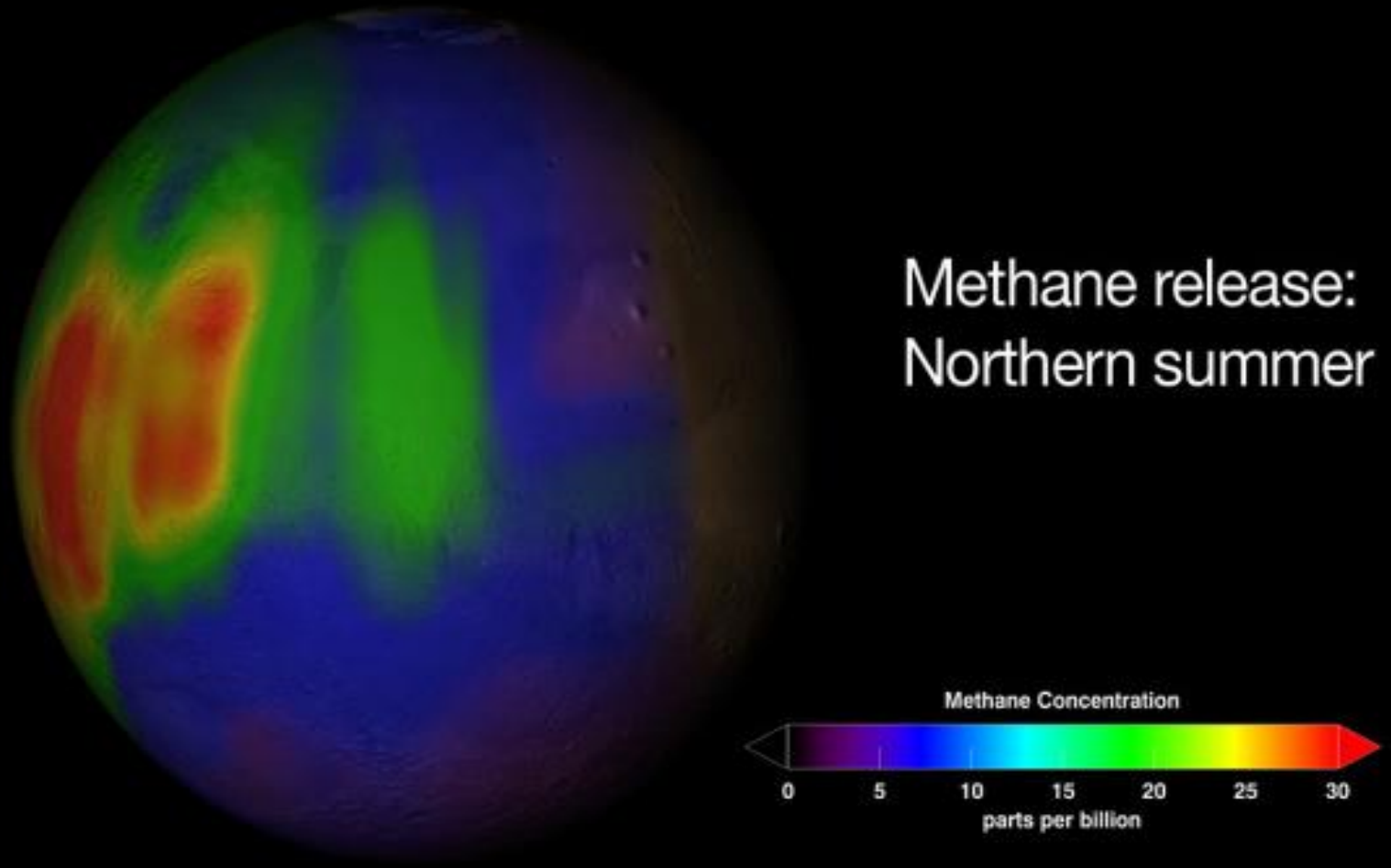
10.08.2015

NASA's Curiosity Rover Team Confirms Ancient Lakes on Mars



Oct 6, 2015

Methane Emissions / Plumes



Jan 19, 2009 - PASADENA, Calif. – A possible source of Methane Plumes is microbial life deep beneath the surface of Mars.

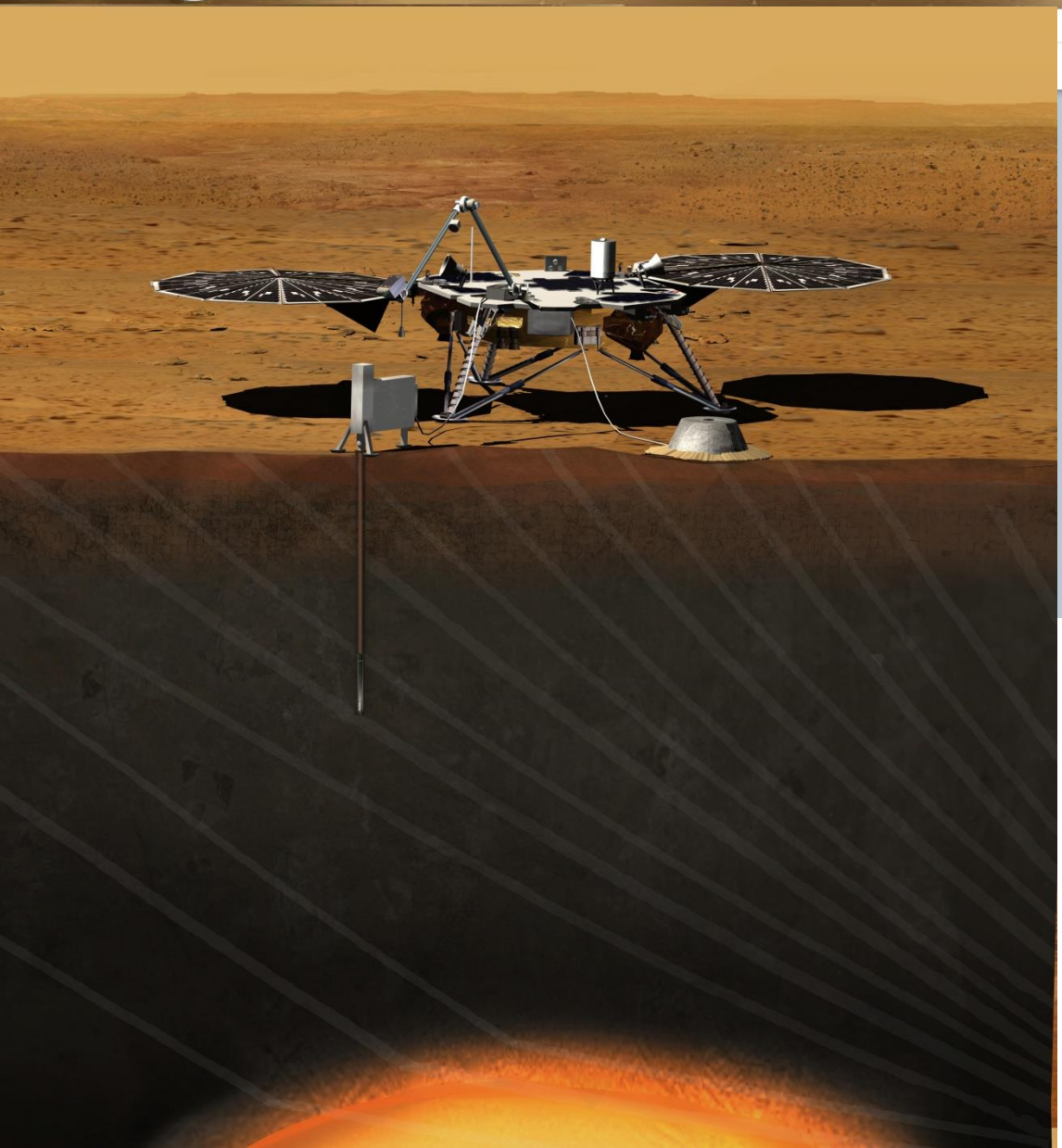
Are the methane concentrations observed evidence that life is currently present on the Red Planet? We do not yet know. But the regions where plumes of methane were detected on Mars now beckon to us, calling us to resolve their mystery. The next time we send out a spacecraft to the Red Planet to search for life, we will know exactly where to look.

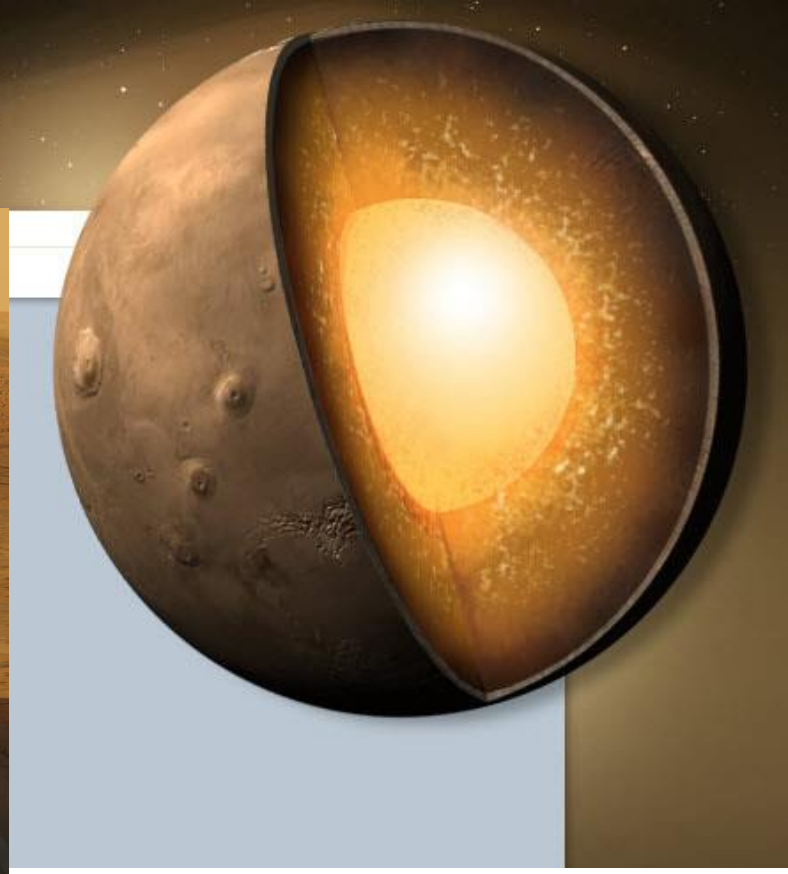
Image credit: NASA/JPL-Caltech

Maven

InSight

... into the early evolution of terrestrial planets.





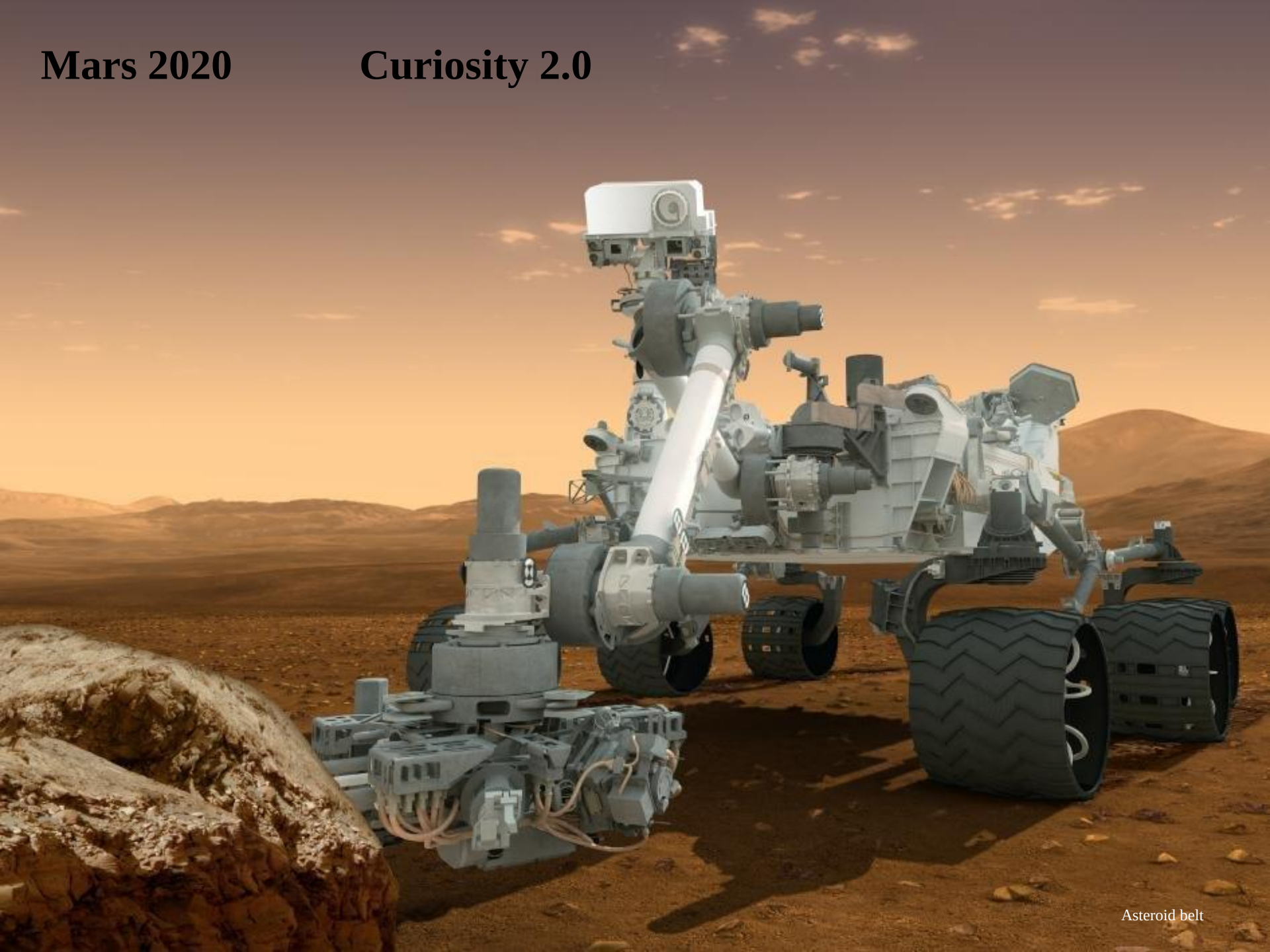
- Launch: ~~March 2016~~ 2018

- Seismic Exp. for Interior Structure
  - •SEIS Failed TVAC Testing
  - •Can't be ready for 3/16 window
- Heat Flow & Physical Properties

Mars Insight lander

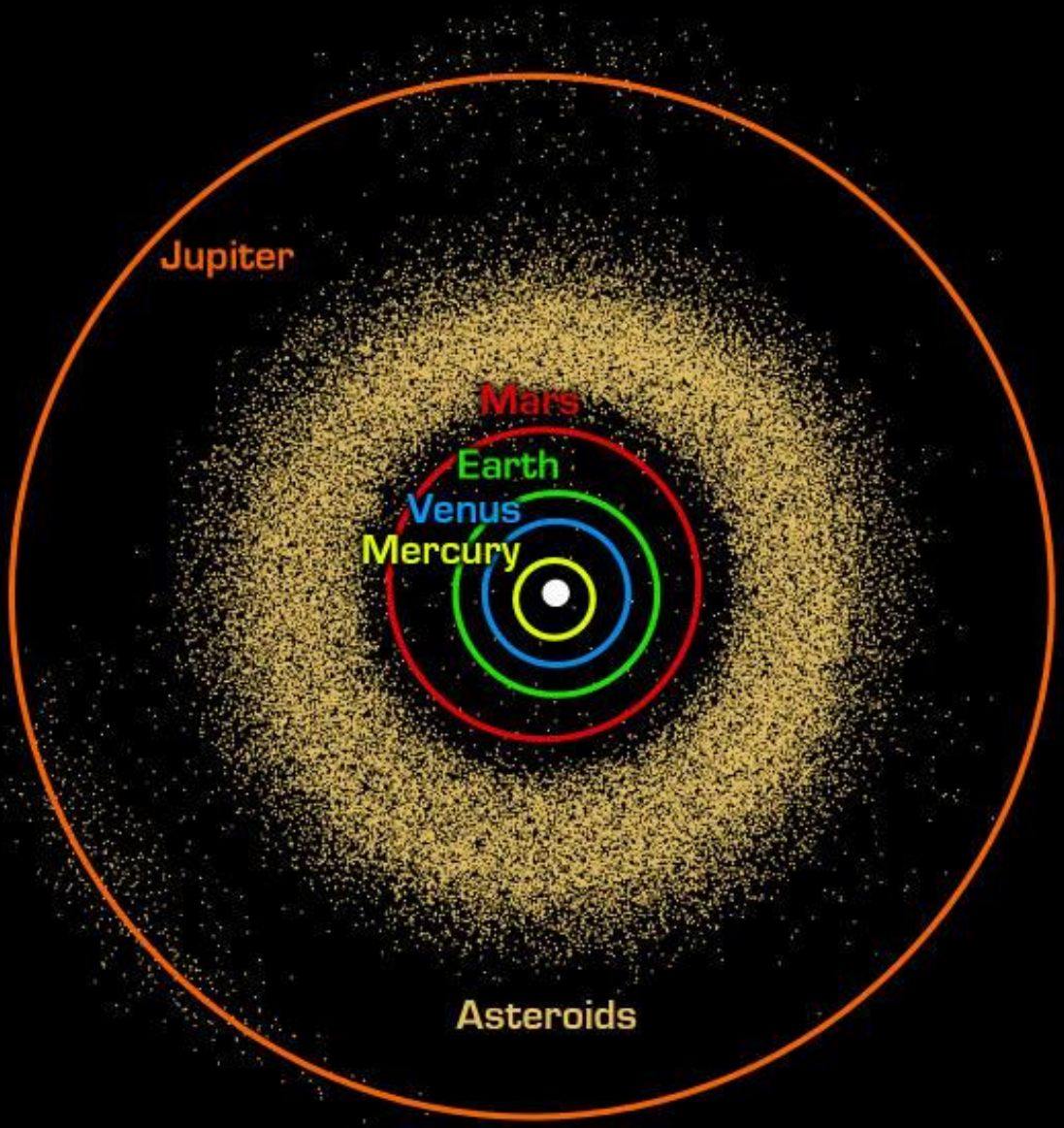
Image credit: NASA/JPL-Caltech

Mars 2020 Curiosity 2.0



Asteroid belt

Asteroid Belt (gold colored specs)



- Distance From Sun:
  260 Million Miles to center
- over 166,000 asteroids
- Largest:
  Ceres 1/3 of all mass
  600 miles in diameter

Image credit: NASA/JPL-Caltech

Asteroid: Gaspra

1st ever close-up photo of an asteroid

Gaspra (12x7 miles)

Image credit: NASA/JPL-Caltech

Ida

Ida (35 miles long)

Image credit: NASA/JPL-Caltech

Hubble images of the two biggest asteroids

Now a Dwarf Planet 600 mi dia

Largest Asteroid 330 mi dia

A "**dwarf planet**" is a celestial body that

a) is in orbit around the Sun,
b) has sufficient mass for its self-gravity to overcome rigid body forces (nearly round),
c) has not cleared the neighborhood around its orbit, and
d) is not a satellite.

Image credit: NASA/JPL-Caltech

dawn

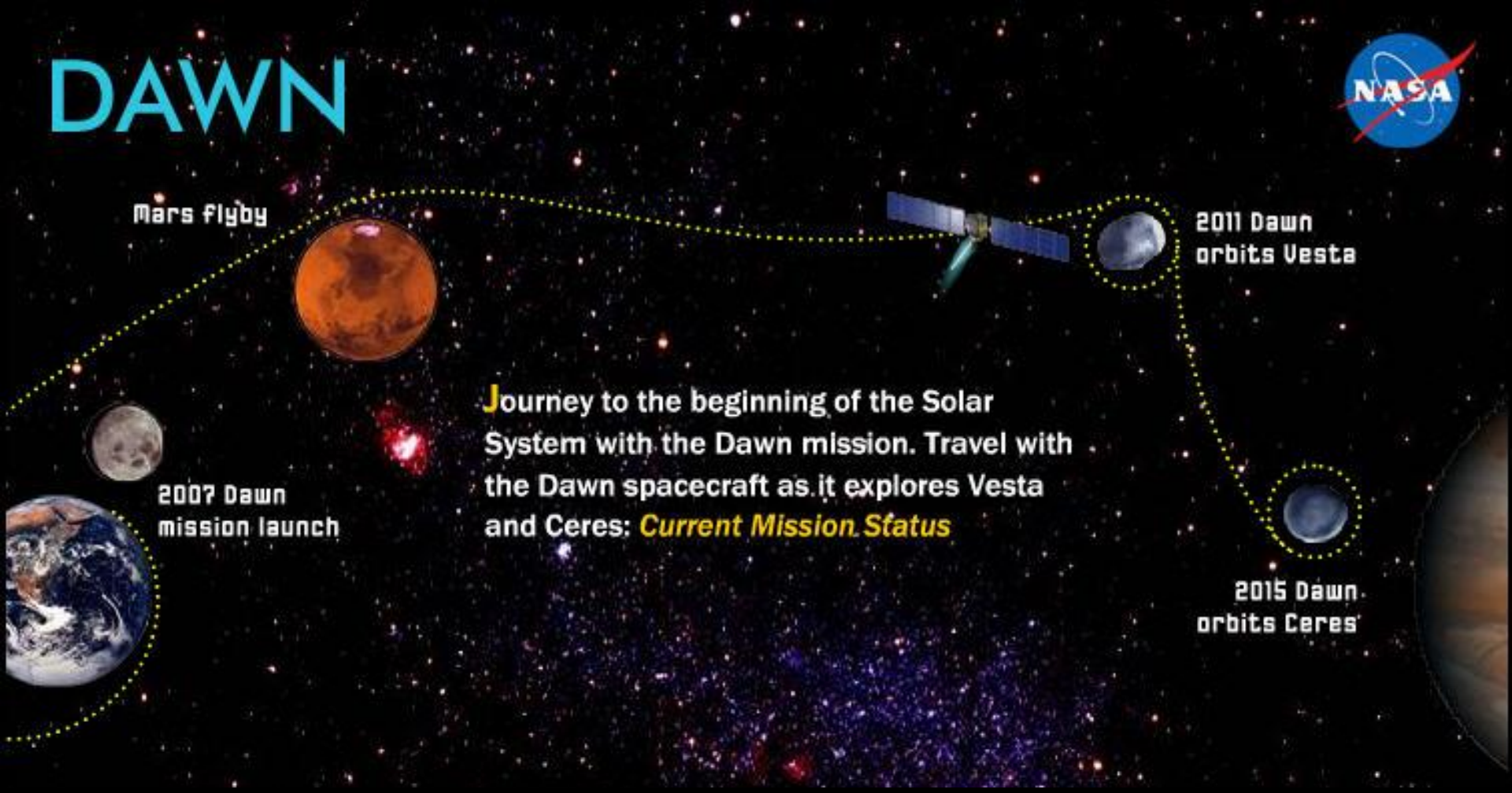


Image credit: NASA/JPL-Caltech

Launch: 9/27/07
Mars Flyby: 2/17/2009
Orbit Vesta: 7/15/2011
Depart Vesta: 9/4/2012
Orbit Ceres: Spring 2015

Vesta – close-up

Asteroid: Vesta Close-up Images

Looking Behind: Asteroid: Vesta – 326 miles in diameter
This photo taken Sept 5, 2012 as Dawn left Vesta's orbit

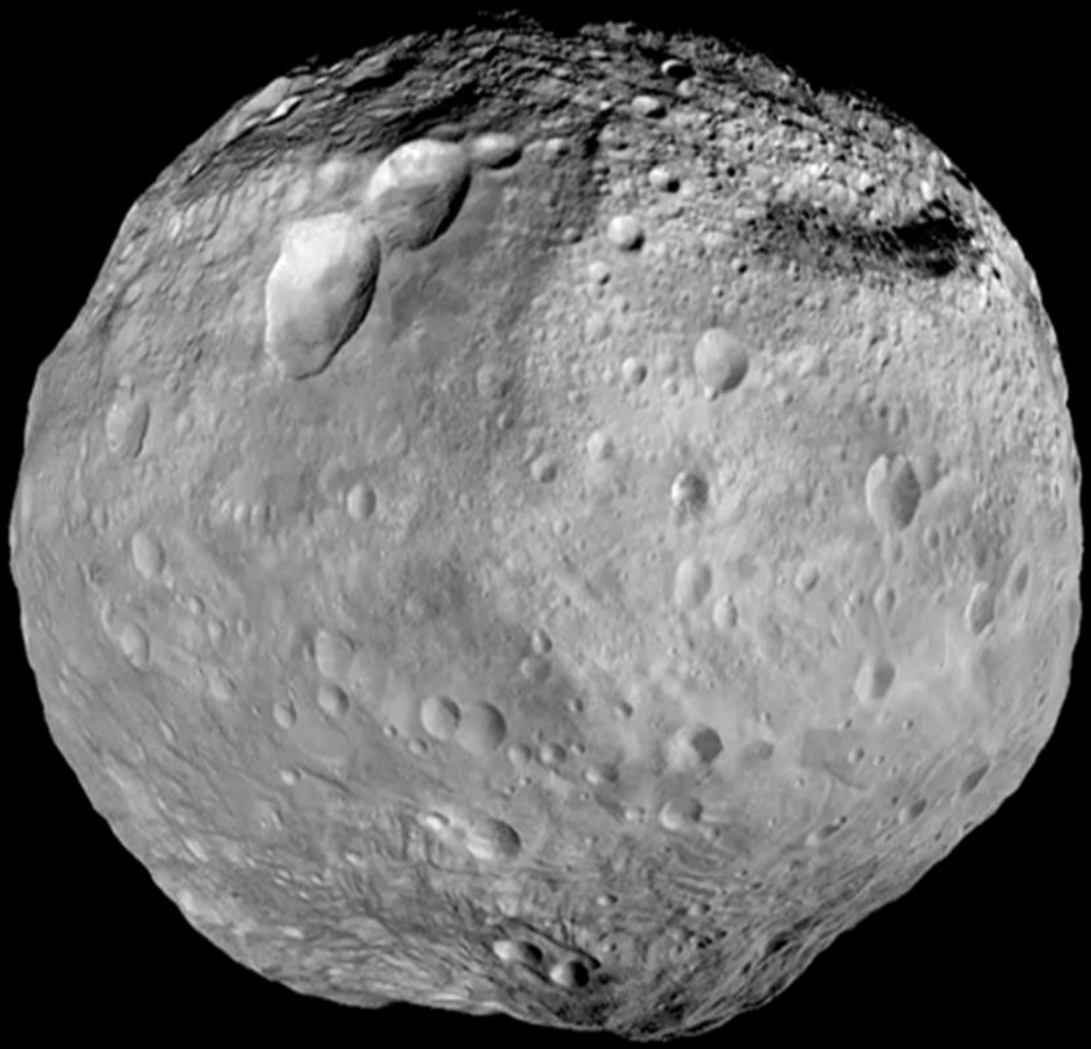
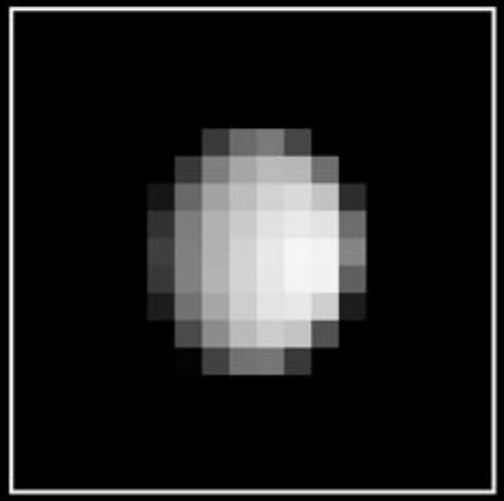


Image credit: NASA/JPL-Caltech

Looking Ahead: Asteroid: Ceres – 590 miles in diameter
This photo taken Dec 1, 2014 from 740,000 miles



Looking Ahead: Asteroid: Ceres – 590 miles in diameter
These photos taken Feb 12, 2015 from 52,000 miles

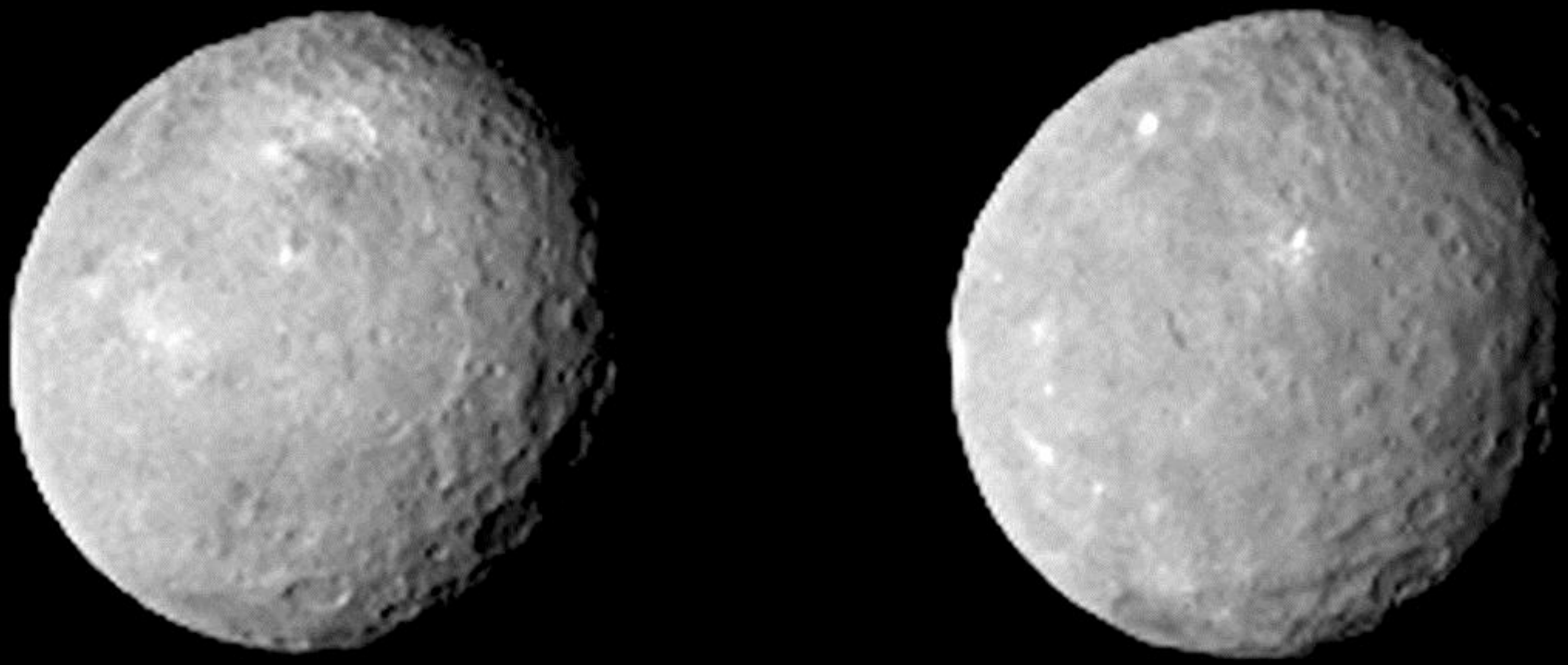


Image credit: NASA/JPL-Caltech

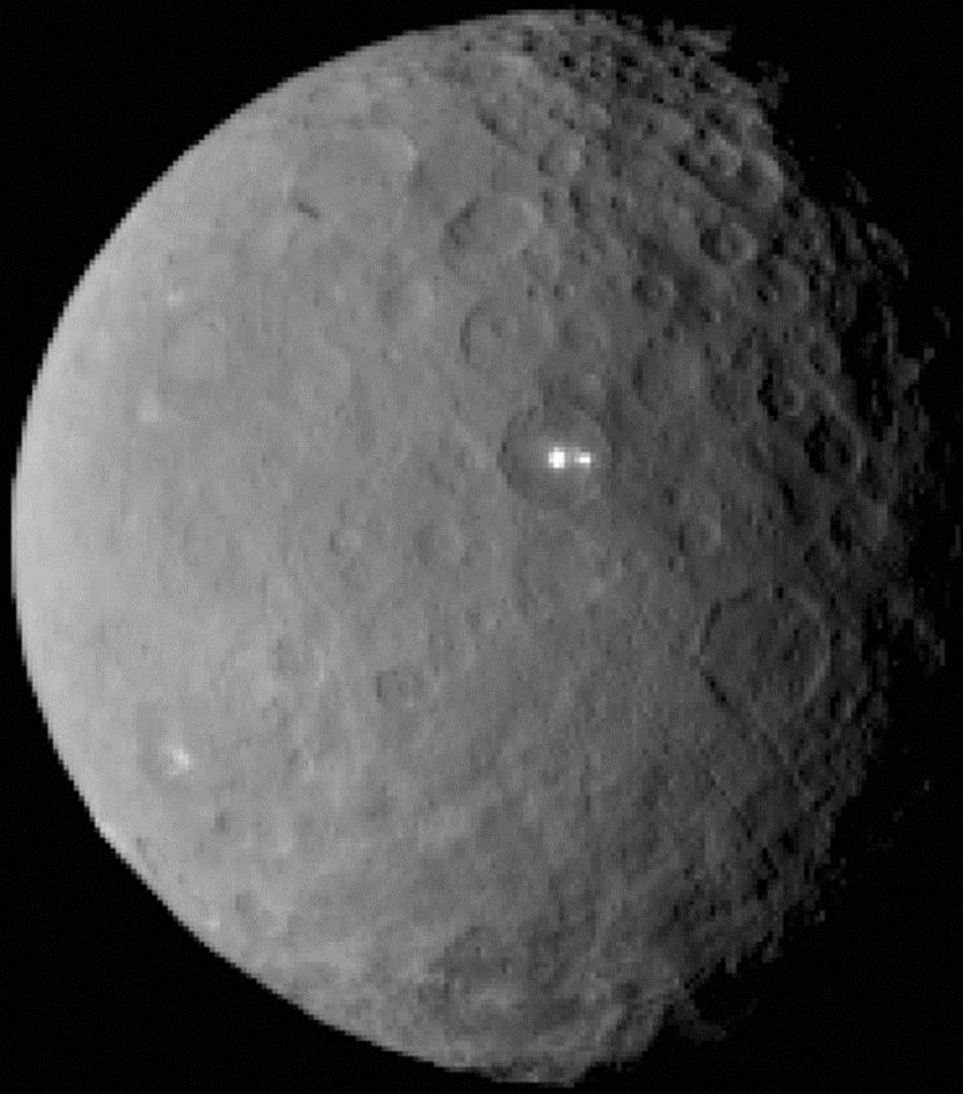
Asteroid: Ceres – 590 miles in diameter

Dawn arrived March 6, 2015

Image credit: NASA/JPL-Caltech

Ceres – Two mysterious bright spots?

Ceres – Feb 25, 2015



Arriving


Ceres – June, 2015

Near-Earth Asteroid 101955 Bennu

1,900 ft diameter

Image credit: NASA/JPL-Caltech

Jupiter

OSIRIS-Rex (mission to Bennu)

Origins Spectral Interpretation Resource Identification Security Regolith Explorer

Asteroid Sample/Return Mission

Launch: Sept, 2016
Asteroid Orbit: 2019
Asteroid Sample: 2020
Earth Return: 2023

Image credit: NASA/JPL-Caltech

Jupiter

- Distance From Sun:
  483 Million Miles
- Average Temp: -166°F
- Diameter: 88,000 miles
- Orbital Period: 12 years
- Moons: 67

galileo

Image credit: NASA/JPL-Caltech

Galileo

Launch: 1989
Orbit Jupiter: 1995
Mission End: 2003

First two years focused on Jupiter.

Extended mission (6 years) focused on Jupiter's moons, with emphasis on Europa, Callisto, Ganymede, and Io.

Image credit: NASA/JPL-Caltech

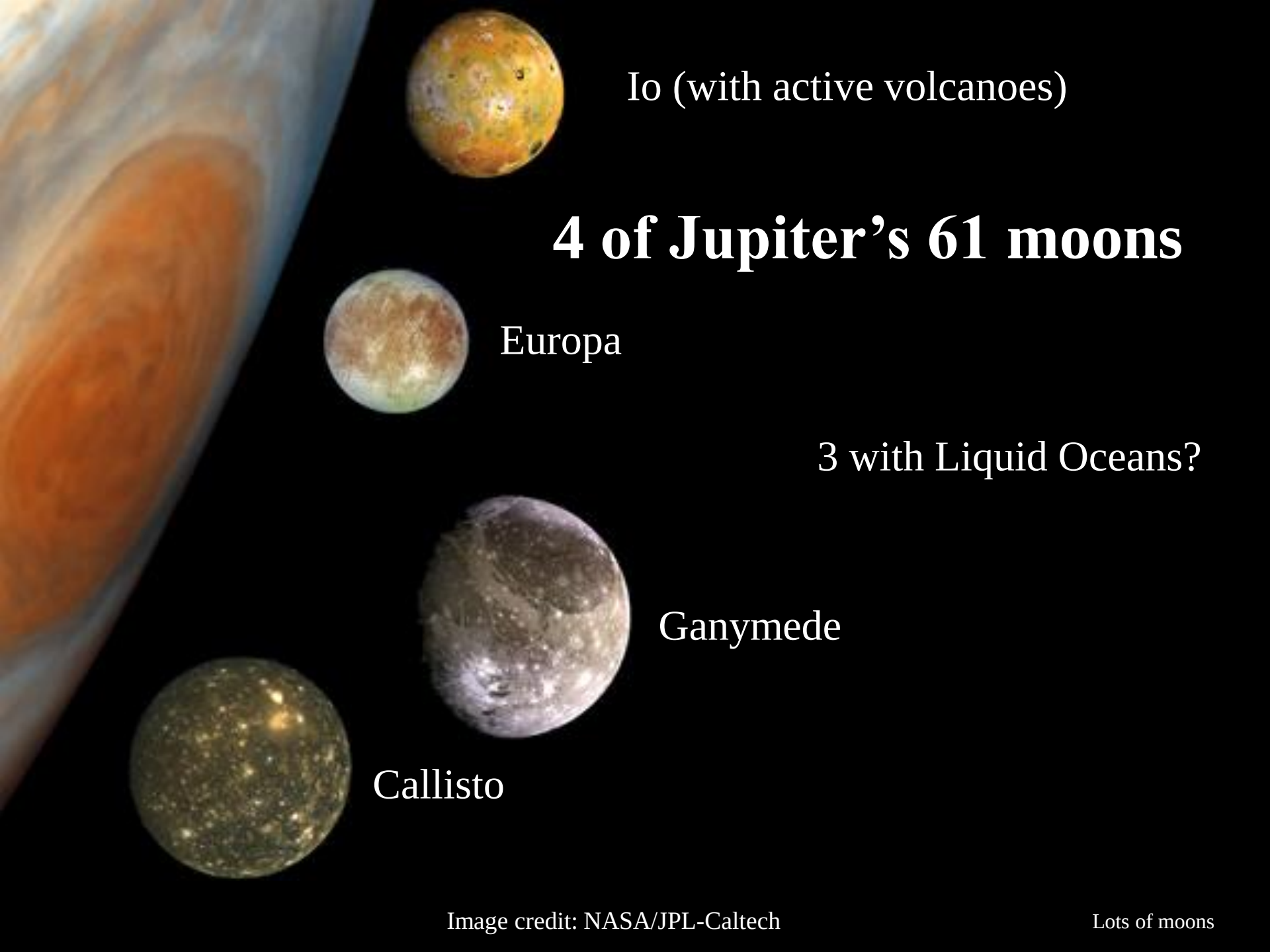


Image credit: NASA/JPL-Caltech

Imagine if Earth had 61 moons

Io

Volcanic Eruption on IO

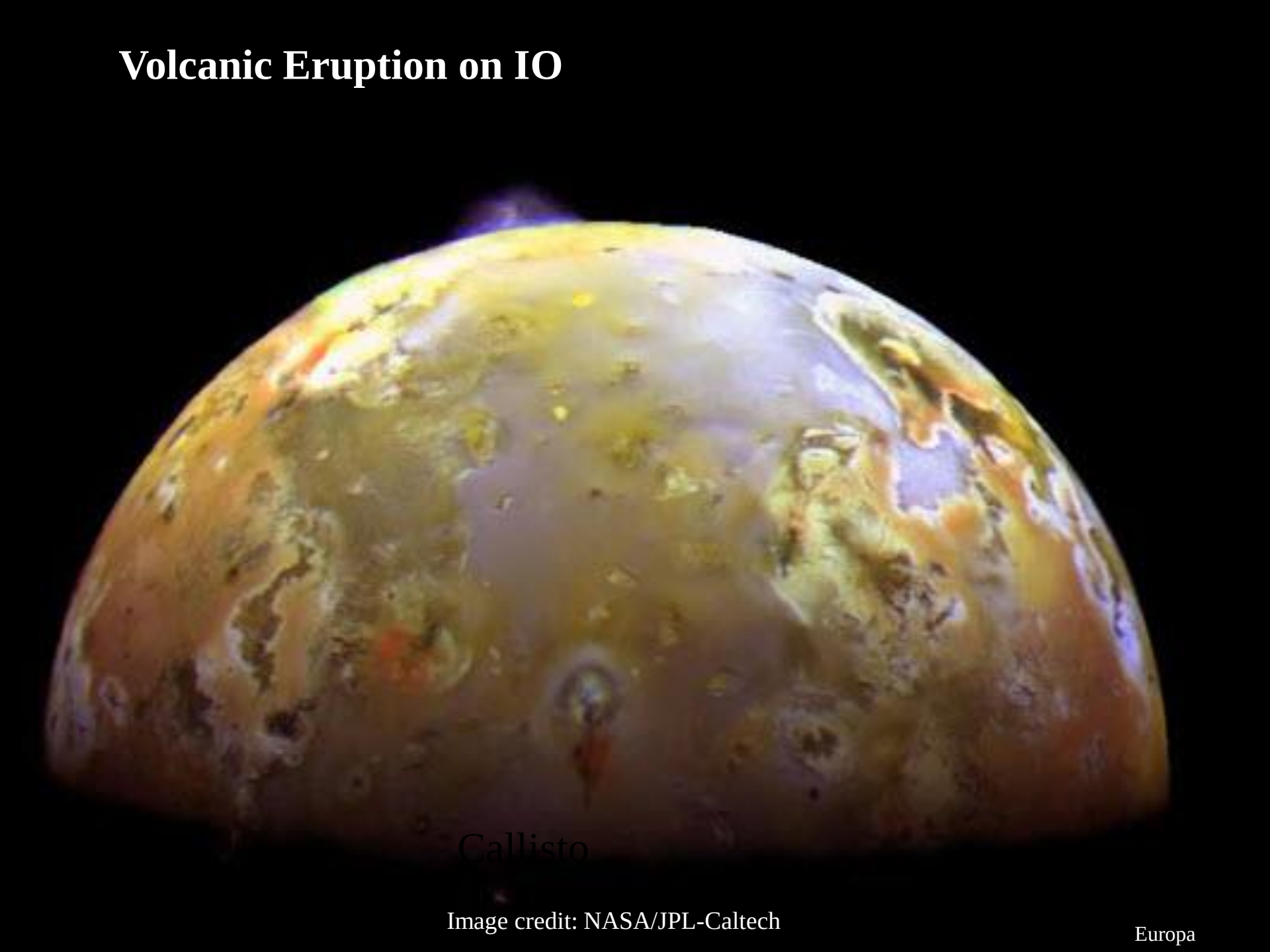


Image credit: NASA/JPL-Caltech

Callisto

Europa

Europa
Ice – 3 miles thick with liquid salt water ocean beneath

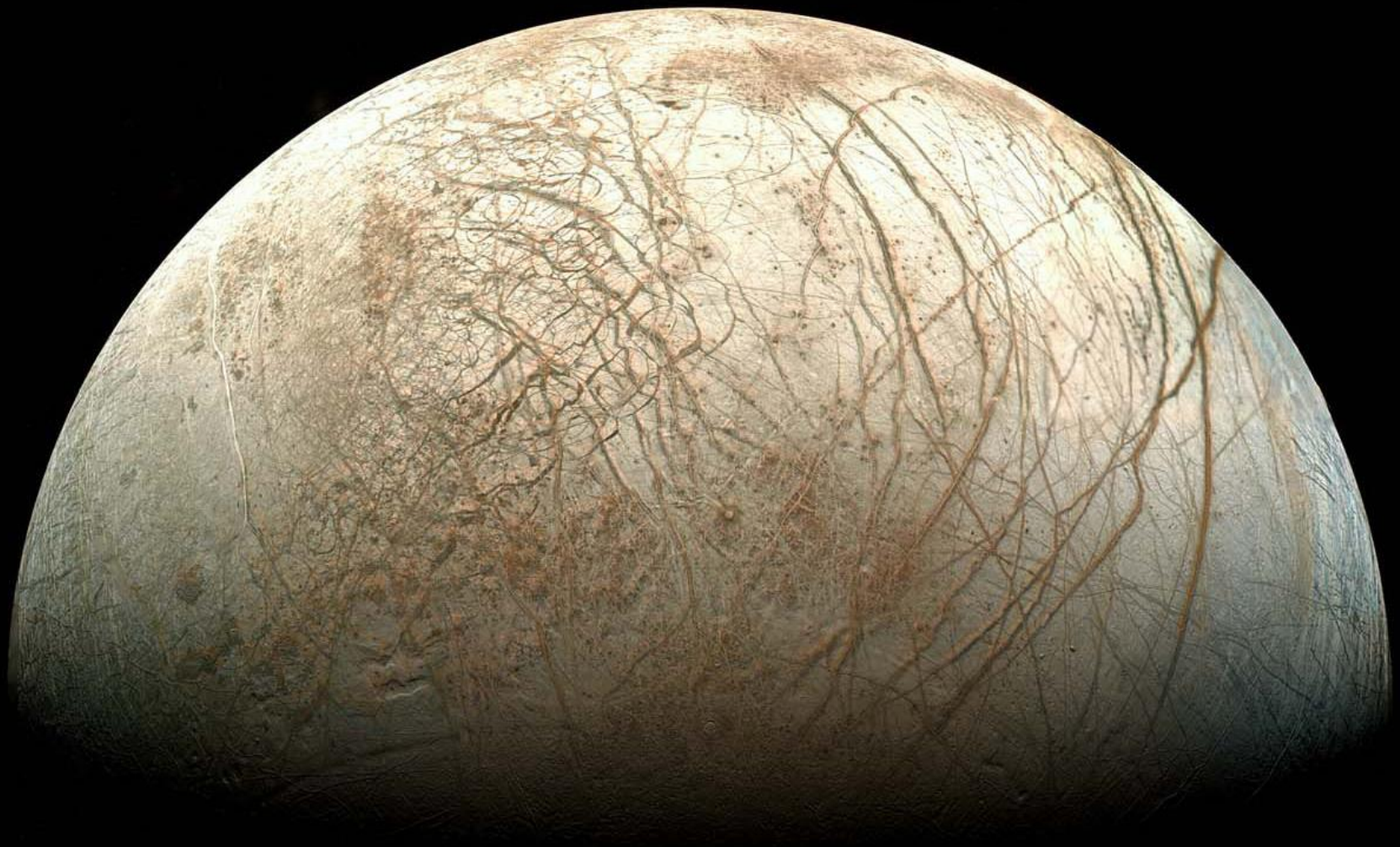
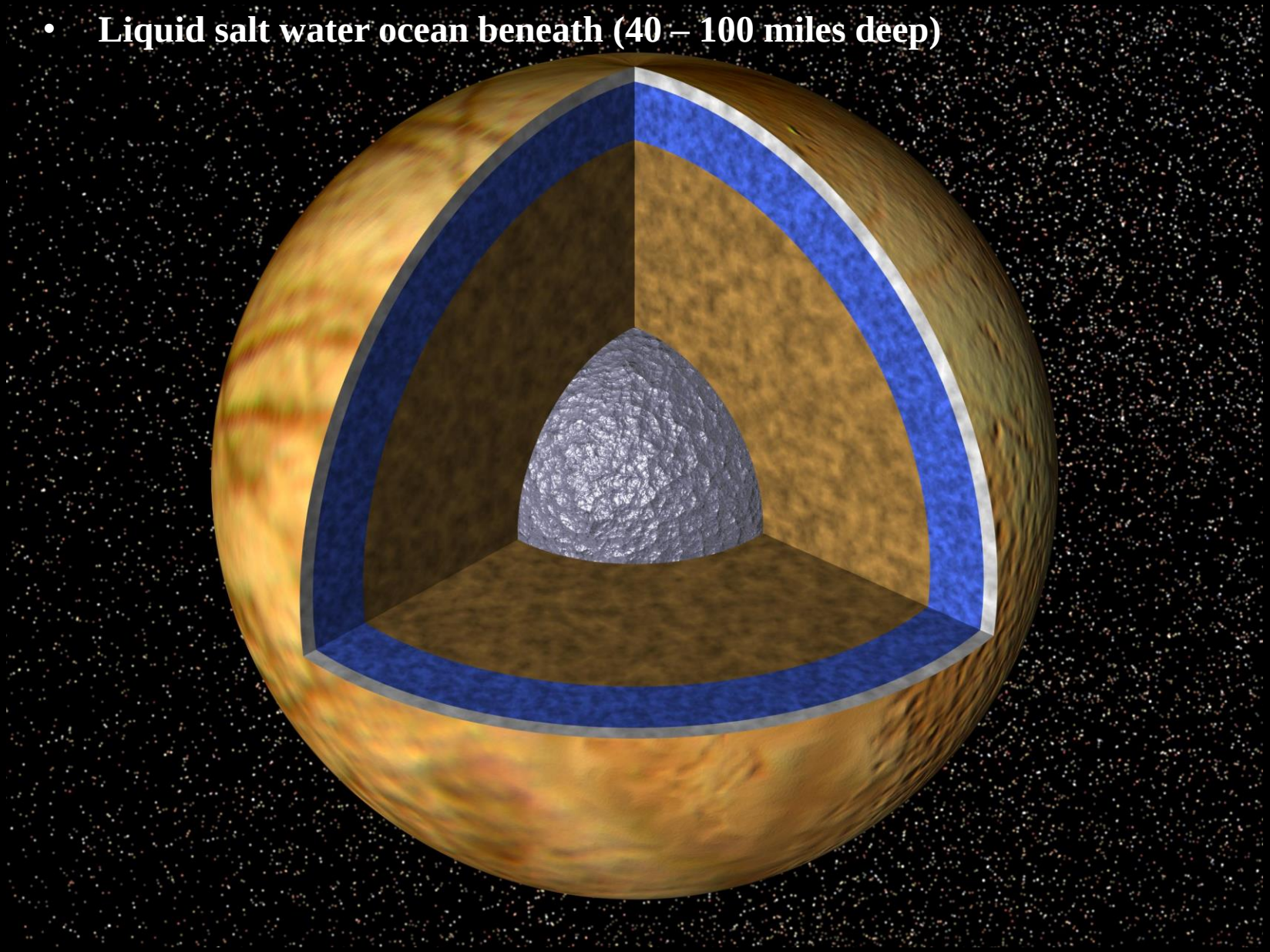


Image credit: NASA/JPL-Caltech

Deep Ocean

Europa

- Ice – 3 miles thick with
- Liquid salt water ocean beneath (40 – 100 miles deep)




JUNO - Launched August 5, 2011
Polar Orbit of Jupiter
Solar Powered
Arrives at Jupiter: July 4, 2016
Image credit: NASA/JPL-Caltech
Earth and Moon

Cassini

Saturn

- Distance From Sun: 888 Million Miles
- Average Temp: -220^{o}F
- Diameter: 75,000 miles
- Orbital Period: 29 years
- Moons: 62

Image credit: NASA/JPL-Caltech

Cassini

Cassini and Huygens

Mission to Saturn and its largest moon Titan.

Launch: 10/15/1997

Orbit Saturn: 7/1/2004

Huygens Release: 12/2004

Landed on Titan: 1/12/2005

Image credit: NASA/JPL-Caltech

Rings in true color

Image credit: NASA/JPL-Caltech

Earth from Saturn

Cassini snaps a photo of Earth

On 7/19/2013, earthlings were told to go outside and wave at the sky. Cassini took the photo. Shall we zoom in?

Zoom in

What causes the gaps in the Saturn rings?

A moon in the rings (where are the ripples?)

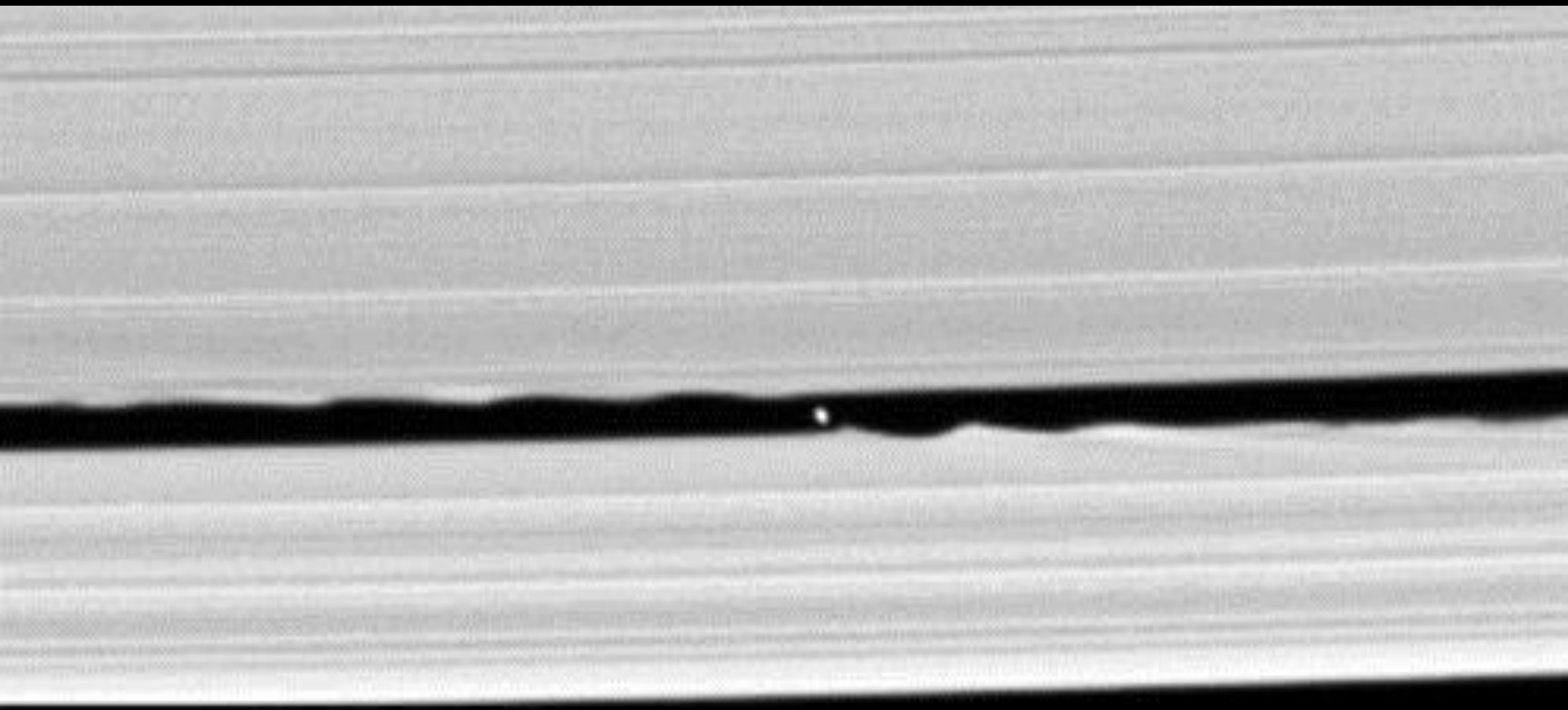
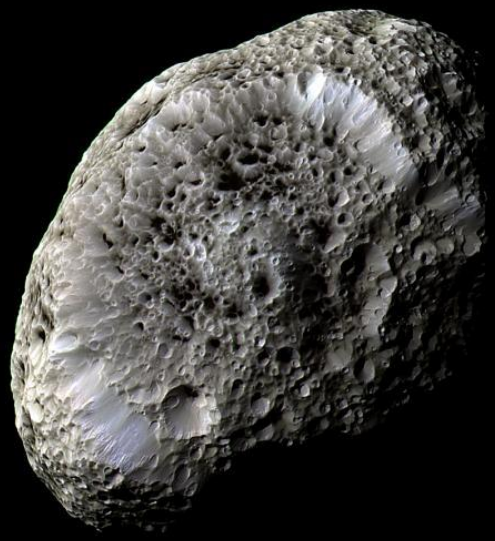


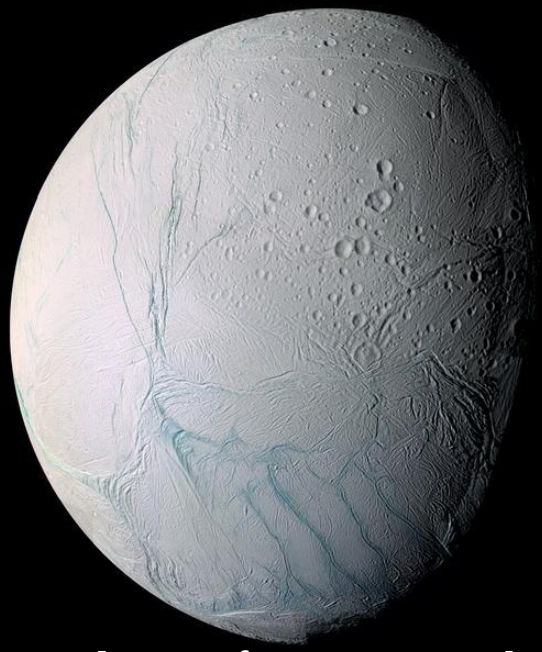
Image credit: NASA/JPL-Caltech

Cassini Images of Saturn Moons

Hyperion

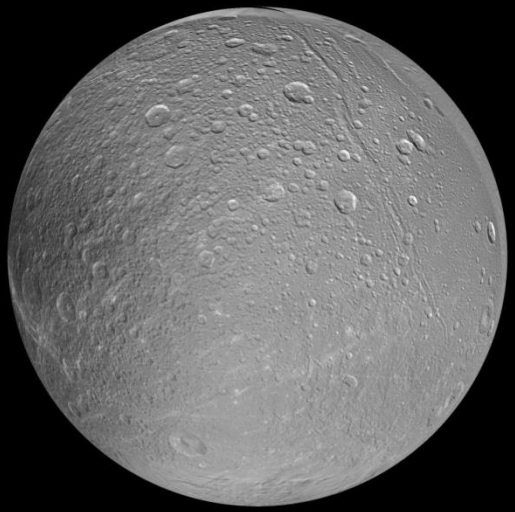


Enceladus



Evidence of trace atmosphere
and liquid ocean under ice.

Dione



Evidence of liquid ocean under ice

Image credit: NASA/JPL-Caltech

Plume

Water plumes shooting from Enceladus south pole

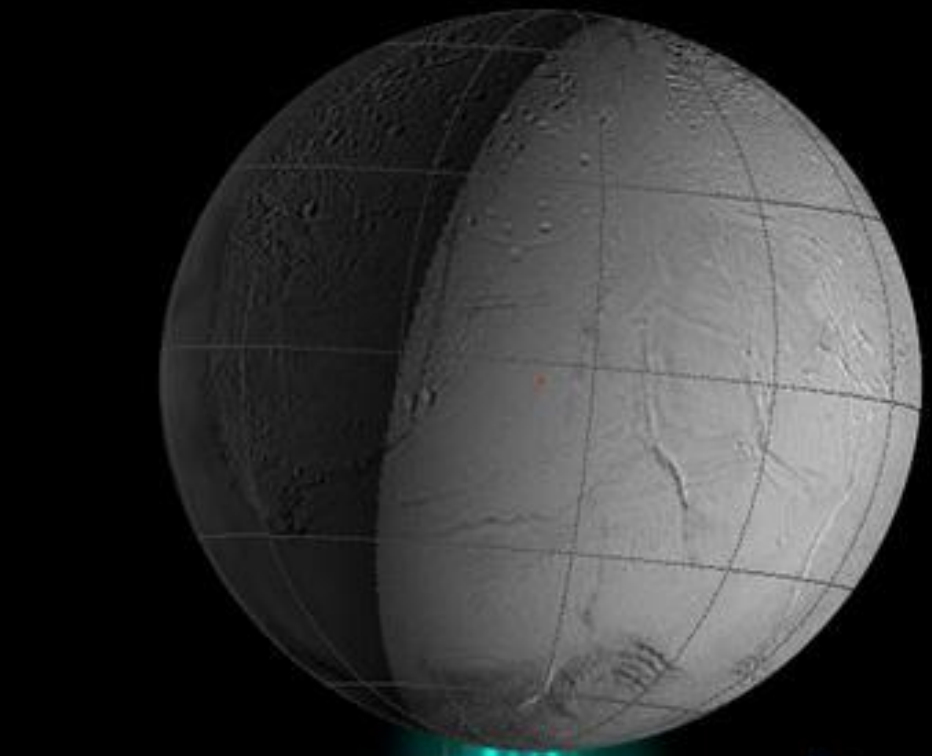


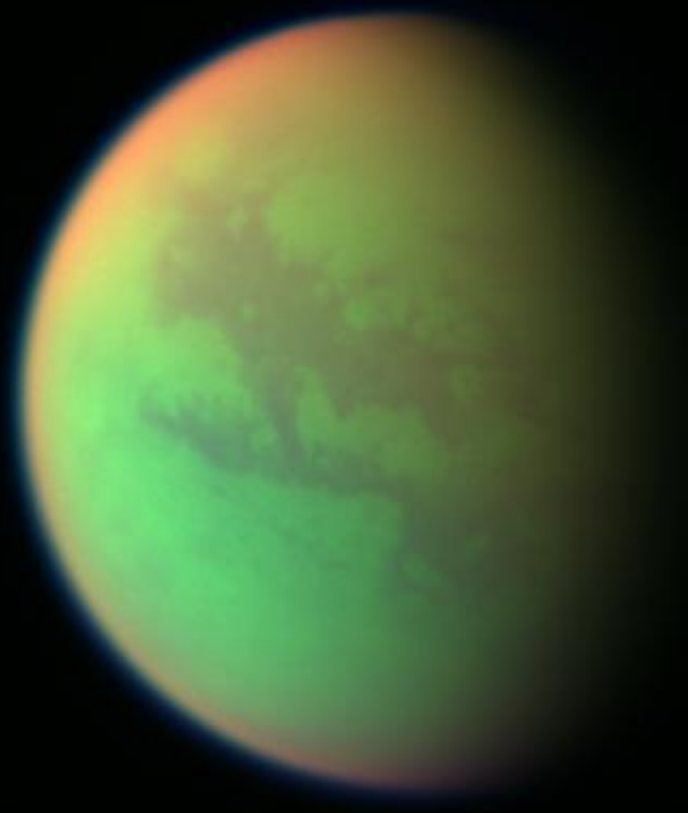
Image credit: NASA/JPL-Caltech

Images of Saturn's moon Titan

Dense atmosphere

Hubble Image

Continents/Oceans visible?



Cassini Image

Image credit: NASA/JPL-Caltech

Huygens' Descent

1270 km
above surface

Mach 20
300-250 km

Mach 1.5
150-180 km
T_0

T_0 + 2.5s

T_0 + 32.5s
145-170 km
95 m/s

T_0 + 42s

T_0 + 15 min
105-125 km
35 m/s

5-6 m/s
T_6-T_0 + 150 min
(maximum)

Actual Descent:
2.5 Hours

Entry

Pilot-chute deployment

Front-shield separation

Main-parachute jettison
Stabiliser-parachute deployment

Surface impact

Peak deceleration
Heat-flux peak

Back-cover release
Main-parachute deployment

Instrument configuration for descent

Stabiliser-parachute inflated

Surface mission phase duration >3 min

Actual Surface Mission:90 Min

Image credit: NASA/JPL-Caltech

Lake Shore?

Image credit: NASA/JPL-Caltech

Liquid flow erosion on Titan

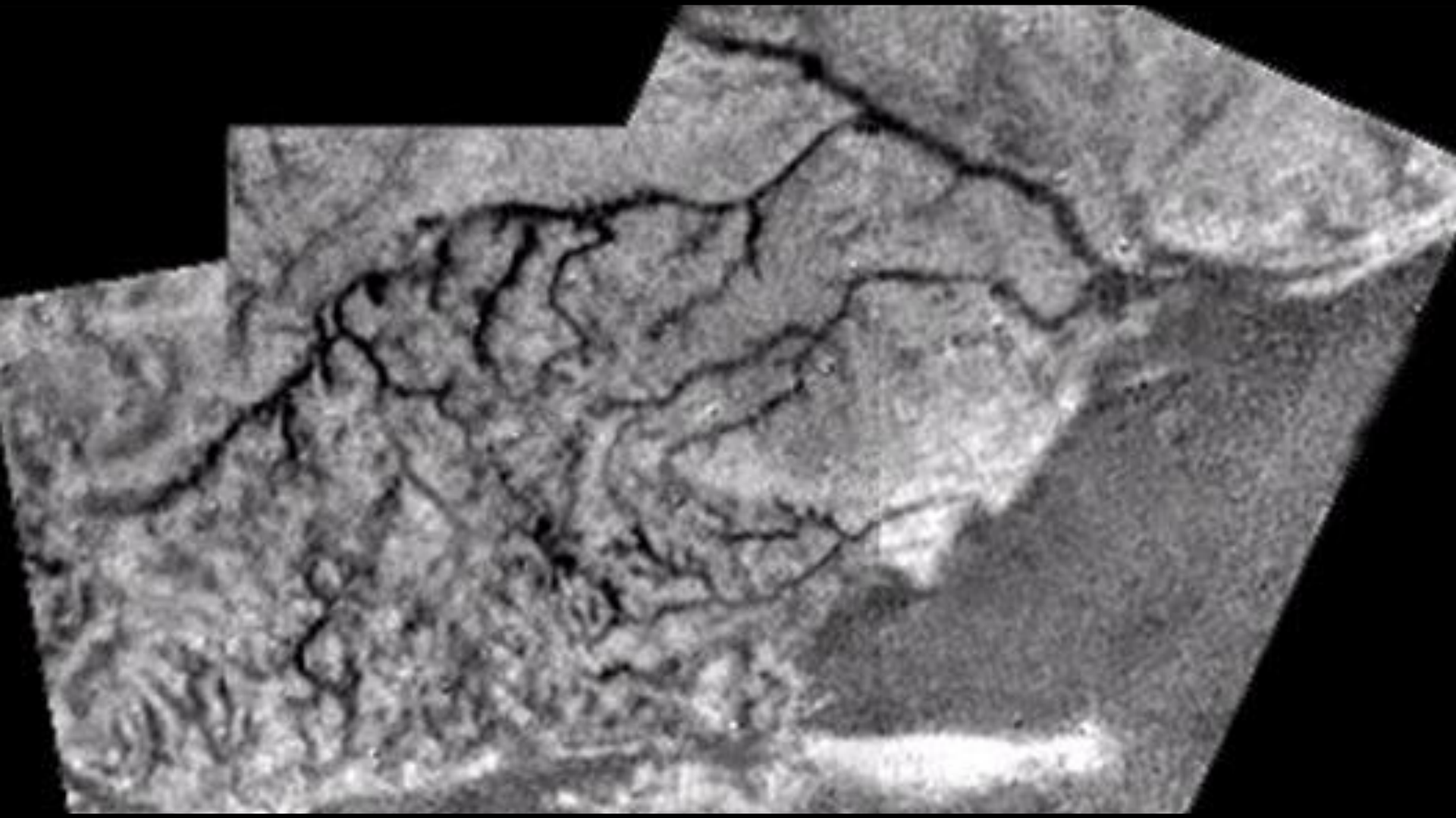
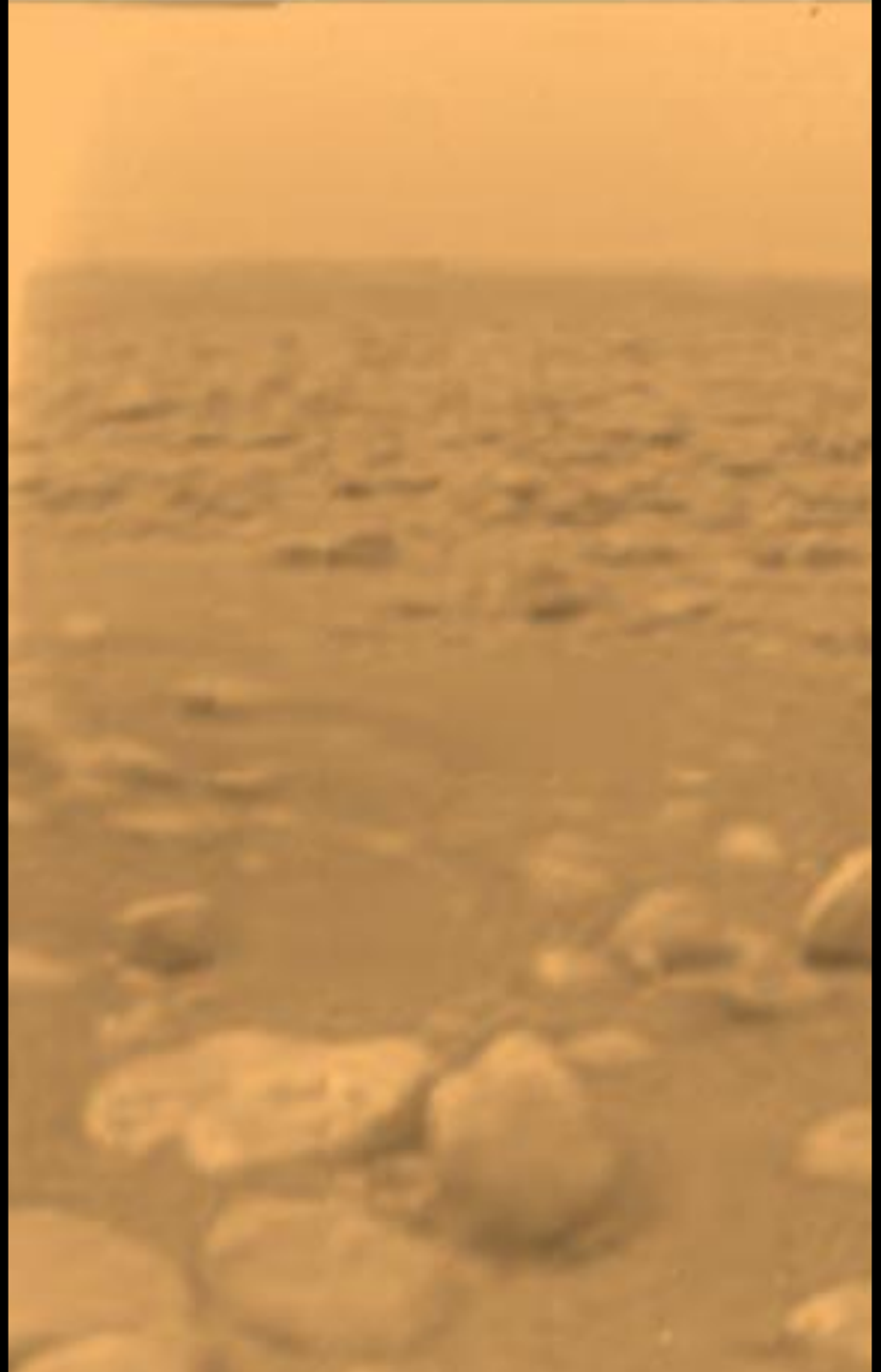


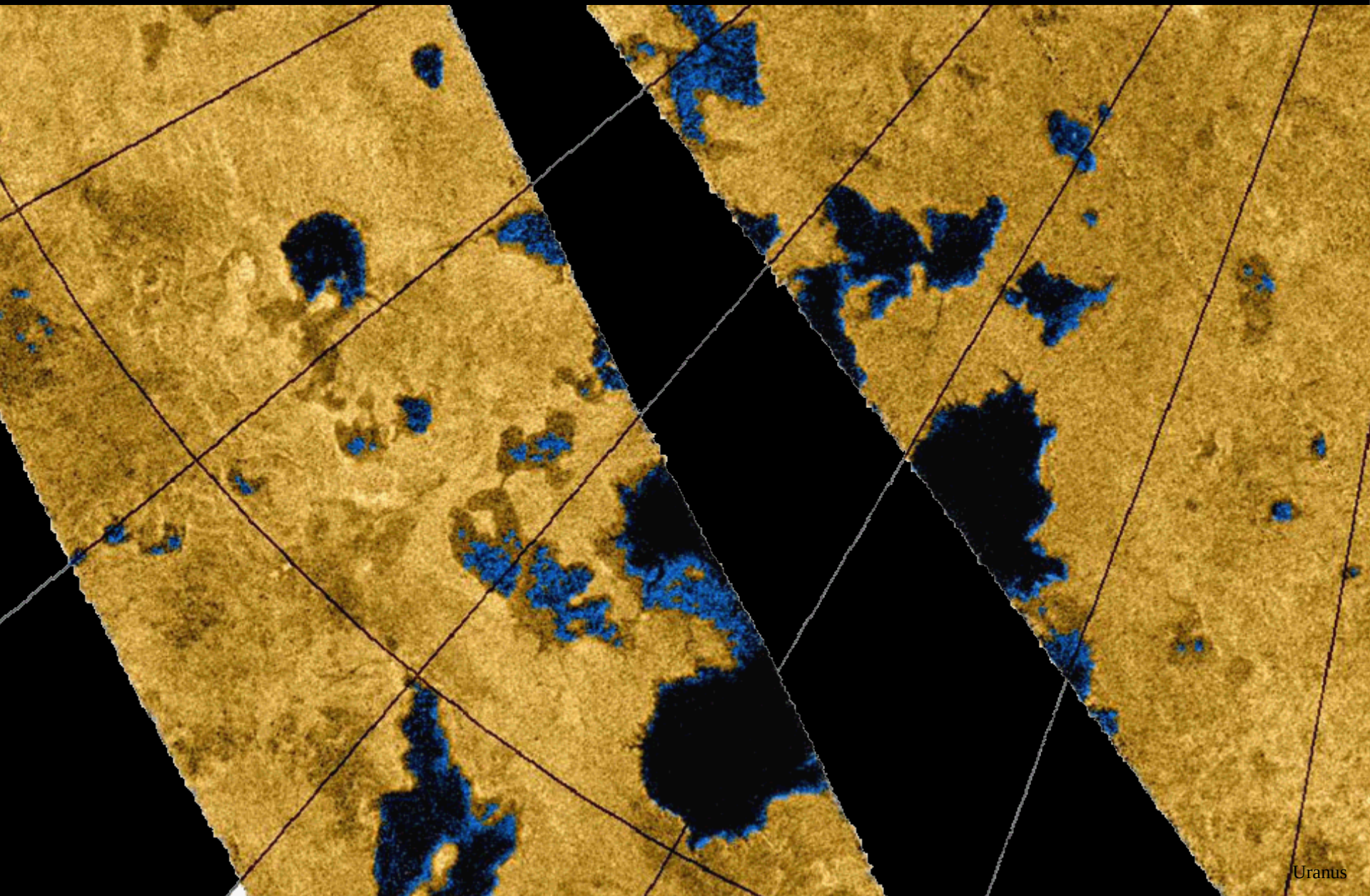
Image credit: NASA/JPL-Caltech

Huygens Probe image
from
the Surface of Titan



Liquid Hydrocarbon Lakes on Titan

Image credit: NASA/JPL-Caltech



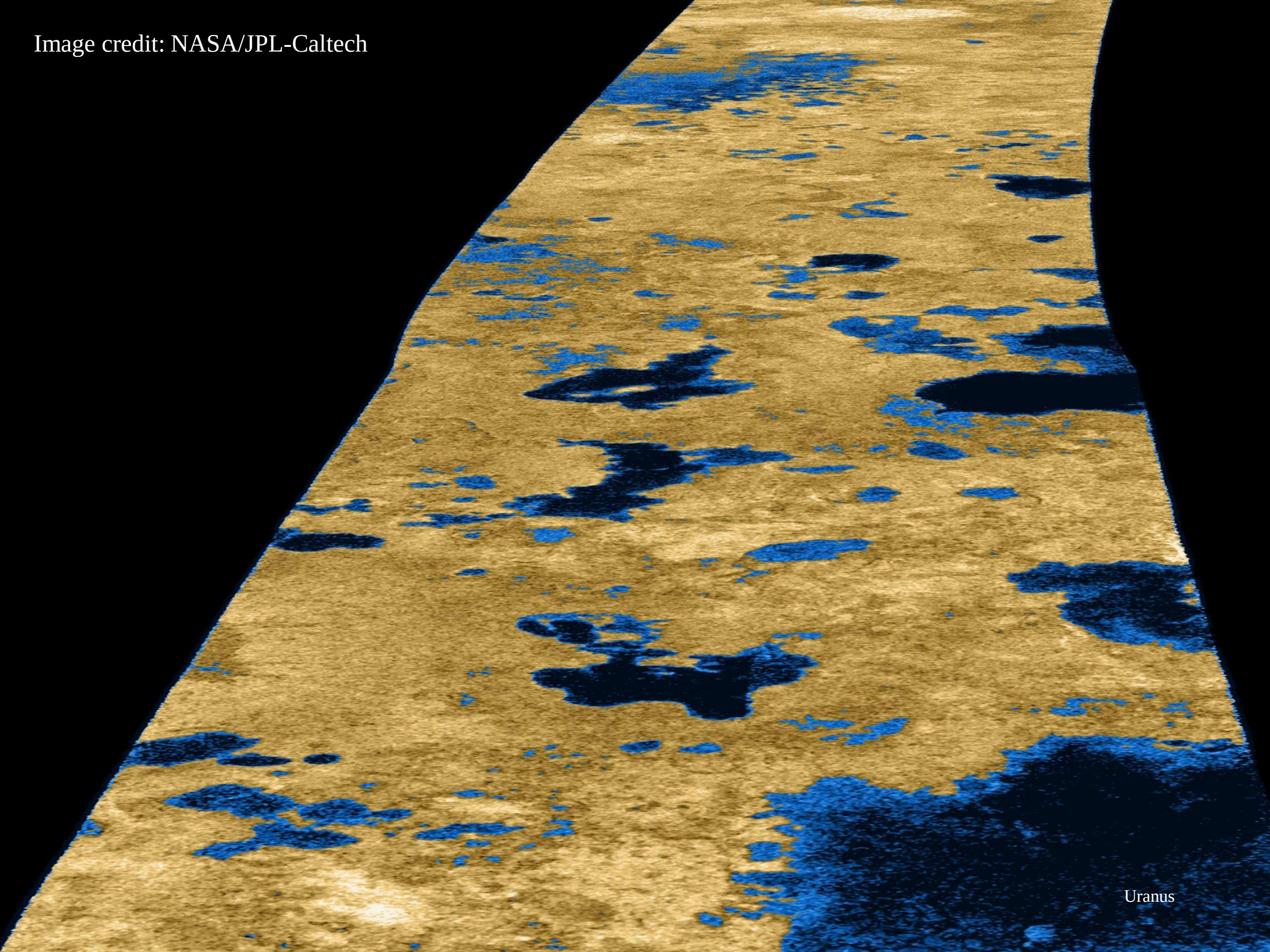


Image credit: NASA/JPL-Caltech
Uranus

Size: Titan Sea vs. Earth's Lake Superior

Image credit: NASA/JPL-Caltech

Titan Mare Lander

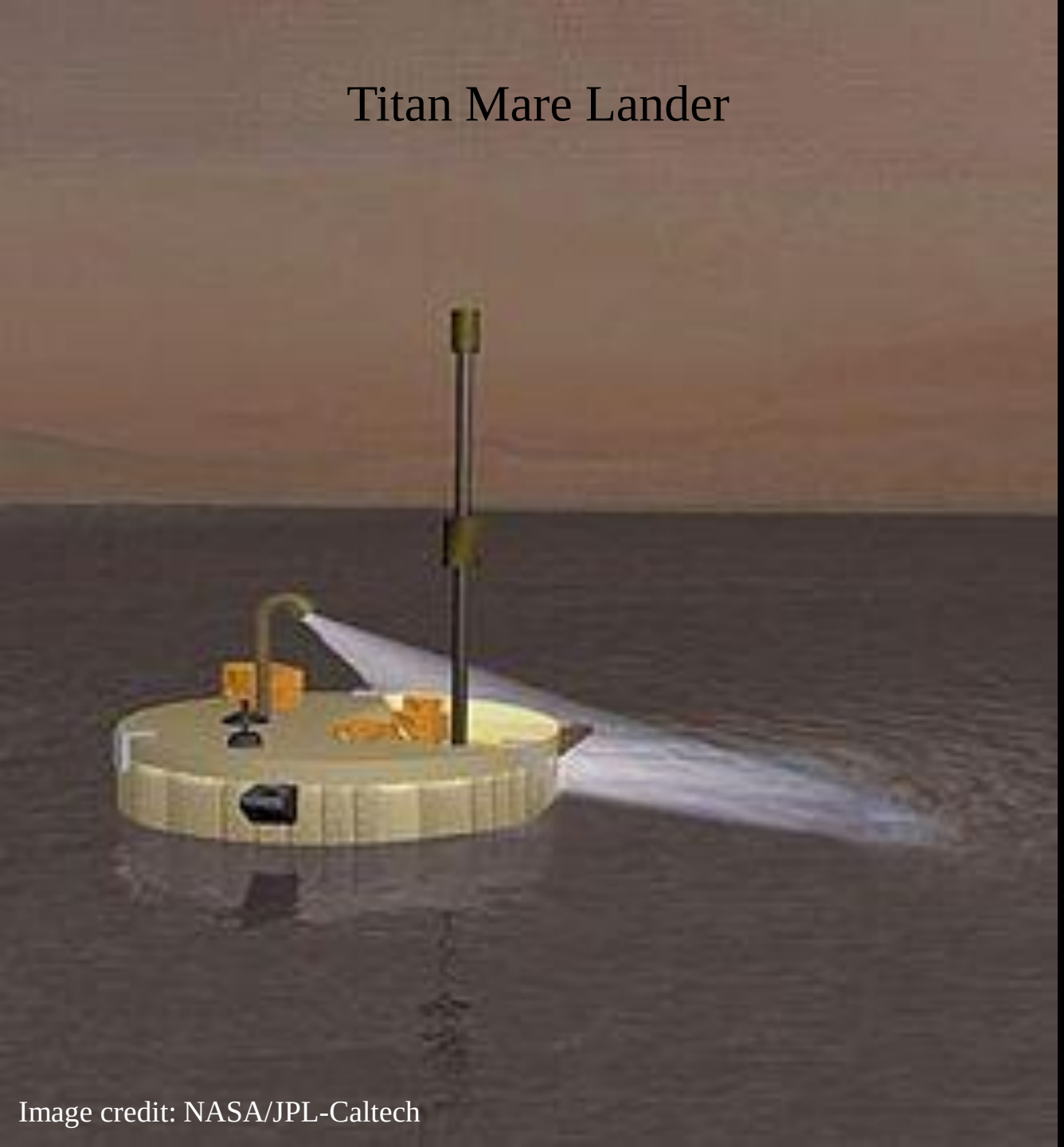
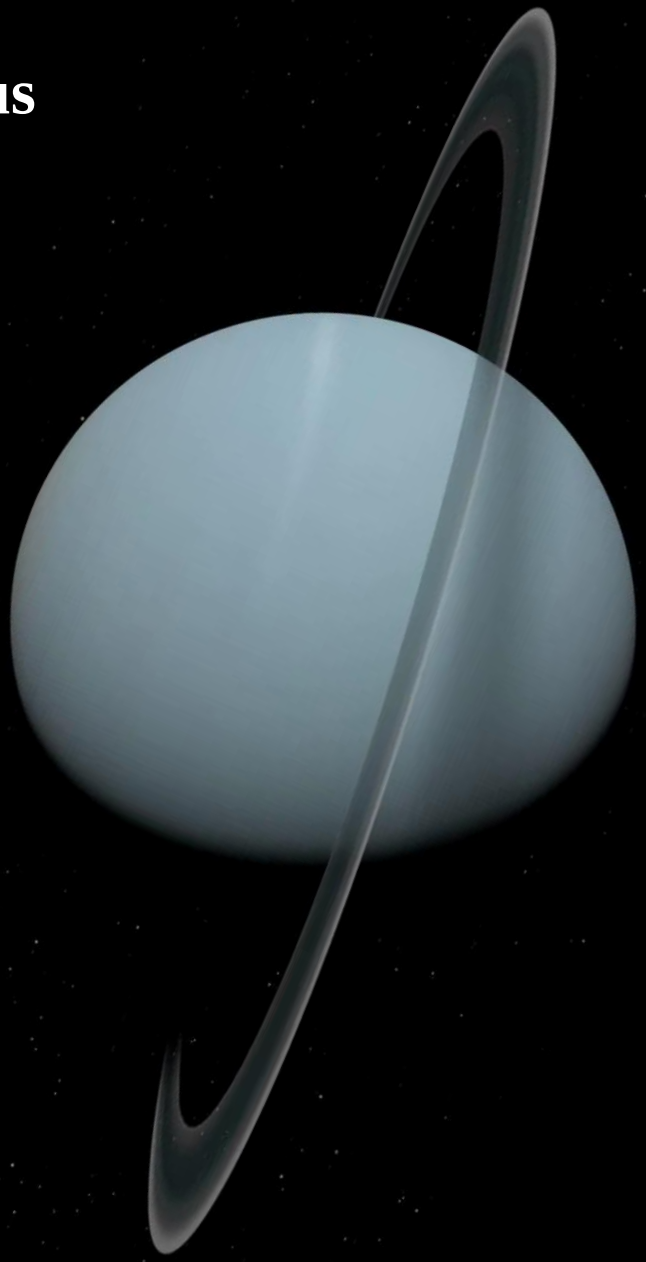


Image credit: NASA/JPL-Caltech

Mission to land a boat on the seas of Titan

Uranus



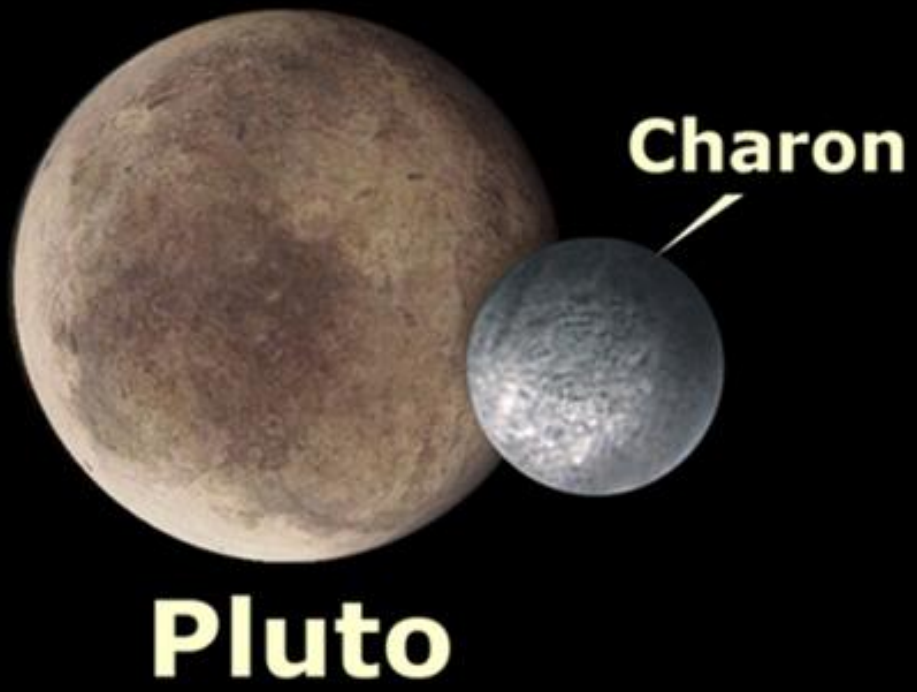
- Distance From Sun: 1.8 Billion Miles
- Average Temp: -319°F
- Diameter: 32,000 miles
- Orbital Period: 84 years
- Rotation Period: 17 hrs (560 mph winds)
- Moons: 27

Neptune

- Distance From Sun: 2.8 Billion Miles
- Average Temp: -328°F
- Diameter: 31,000 miles
- Orbital Period (year): 165 years (slow)
- Rotation Period:19 hrs (1,300 mph winds)
- Moons: ~~13~~ 14 (7/2013)

Pluto (1978)

- Distance From Sun: 3.7 Billion Miles
- Average Temp: -400^{o}F
- Pluto diameter: 1,500 miles, Charon diameter: 750 miles
- Orbital Period: 248 years
- Moons: 1 (known in 1978)
    - Charon found in 1978



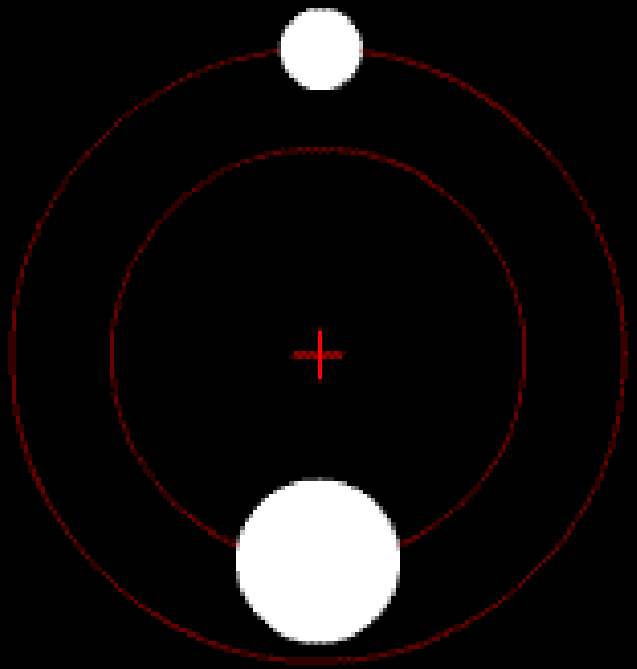
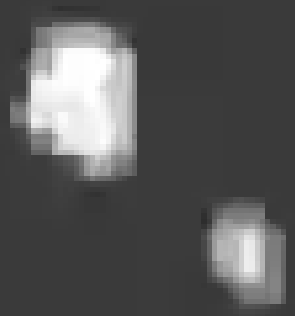


Image credit: NASA/JPL-Caltech

Hubble Best View

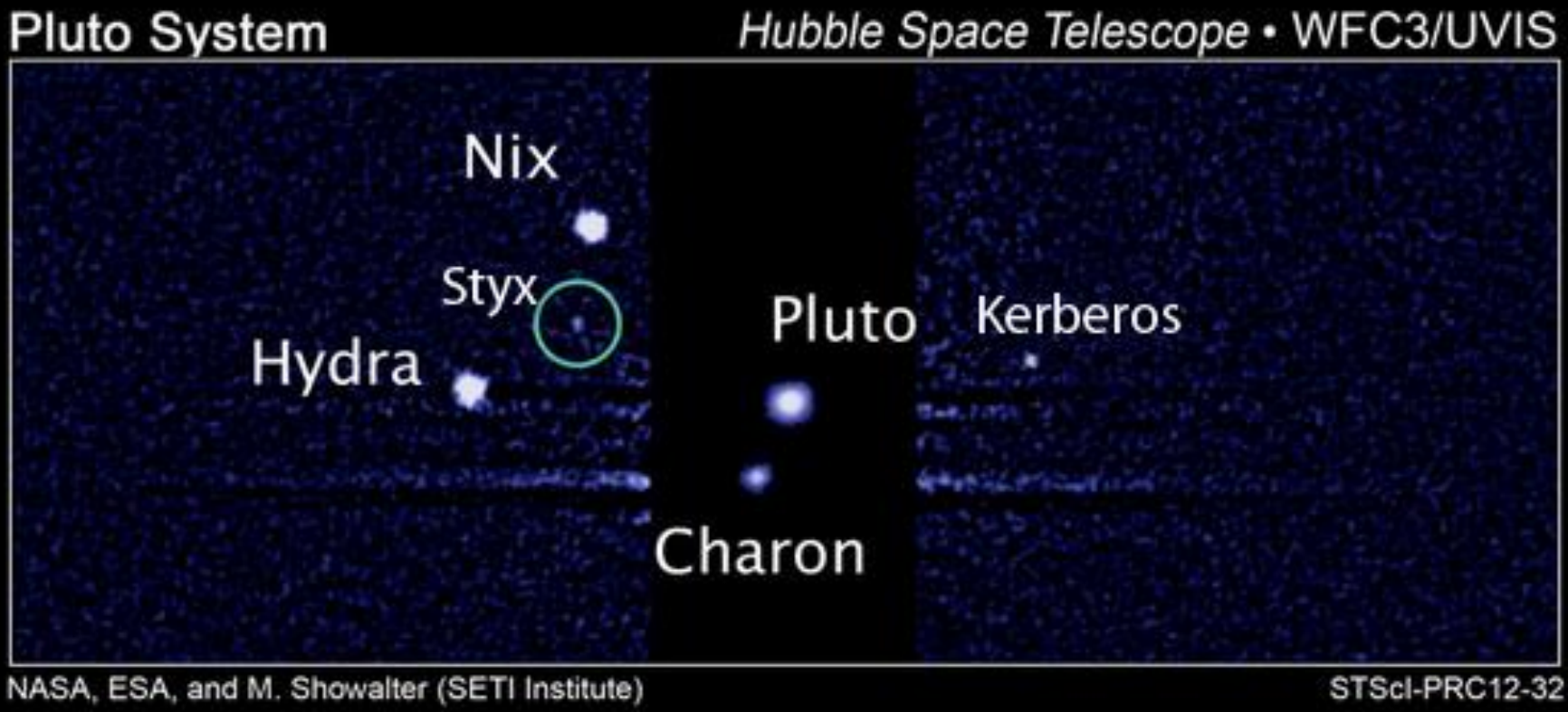


Pluto (7/1/2013)

Introducing: Styx and Kerberos

Pluto Moons: Now at **5**

- Charon found in 1978
- Nix and Hydra found in 2005
- Kerberos found in 2011
- Styx found in 2012



New Horizons (Pluto - Kuiper Belt Mission)

Launched: Jan 17, 2006

Pluto Flyby: July 14, 2015

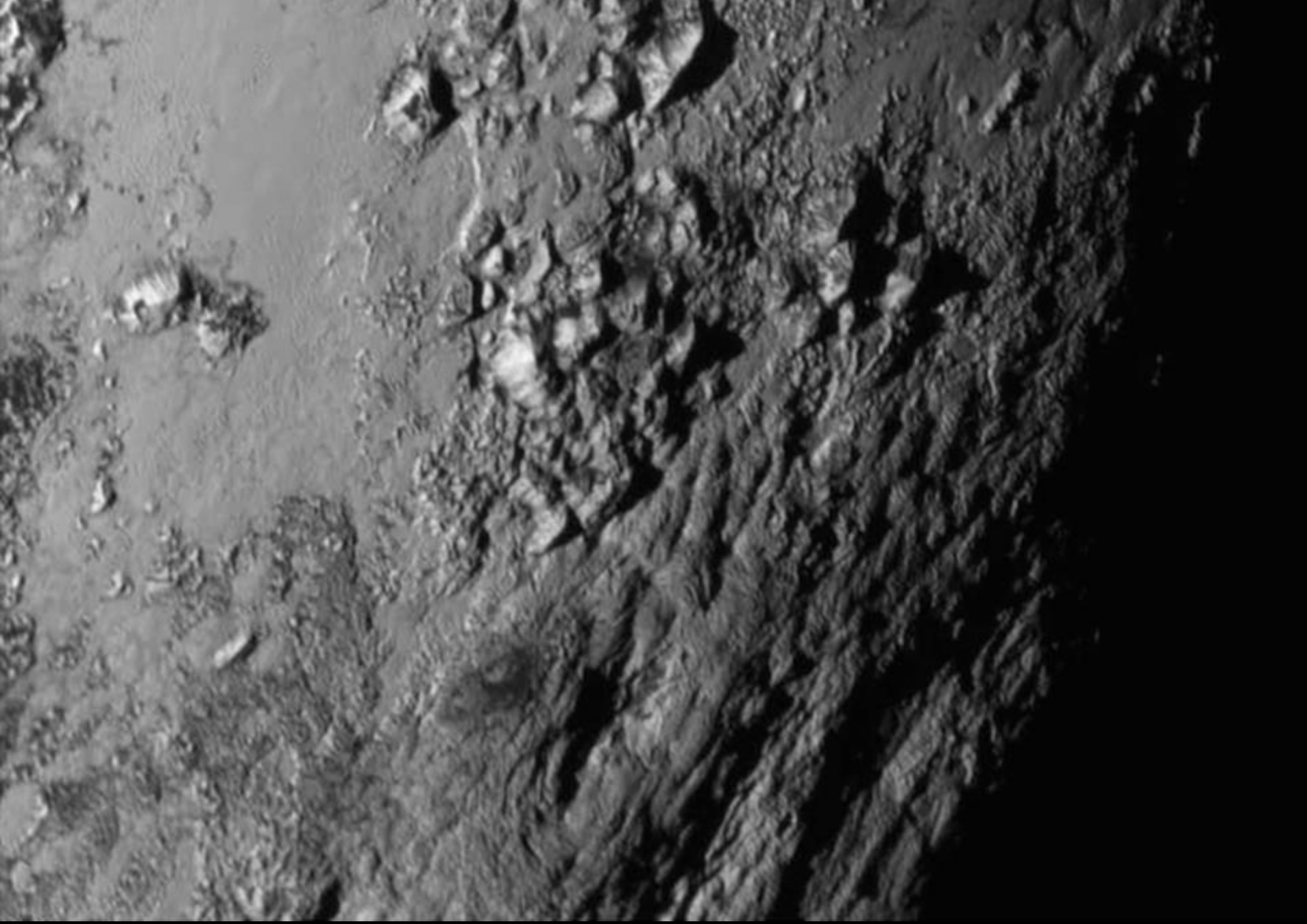
Image credit: NASA/JPL-Caltech

Pluto – July 6, 2015

Image credit: NASA/JPL-Caltech

Pluto – July 13, 2015

Image credit: NASA/JPL-Caltech



Pluto – July 14, 2015

Image credit: NASA/JPL-Caltech

Charon – July 14, 2015

Image credit: NASA/JPL-Caltech

Nix and Hydra – July 14, 2015

New Horizons KBO Flyby – 2018/2019

Image credit: NASA/JPL-Caltech

Far beyond Pluto, a possible Planet Nine

Planet 9

- 56 billion miles from sun
- 5,000 times mass of Pluto
- 20,000 years per orbit
- meets planet definition

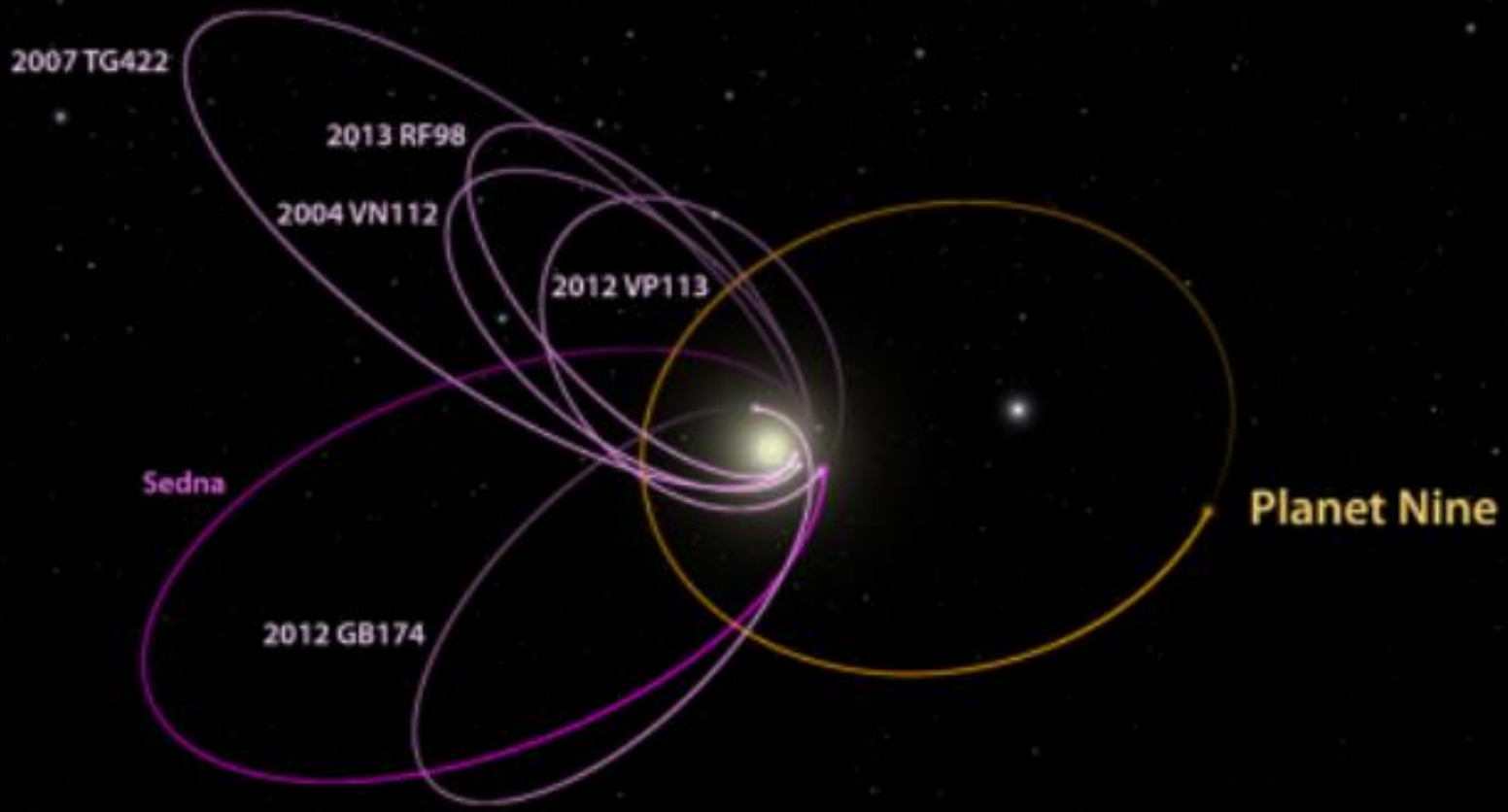
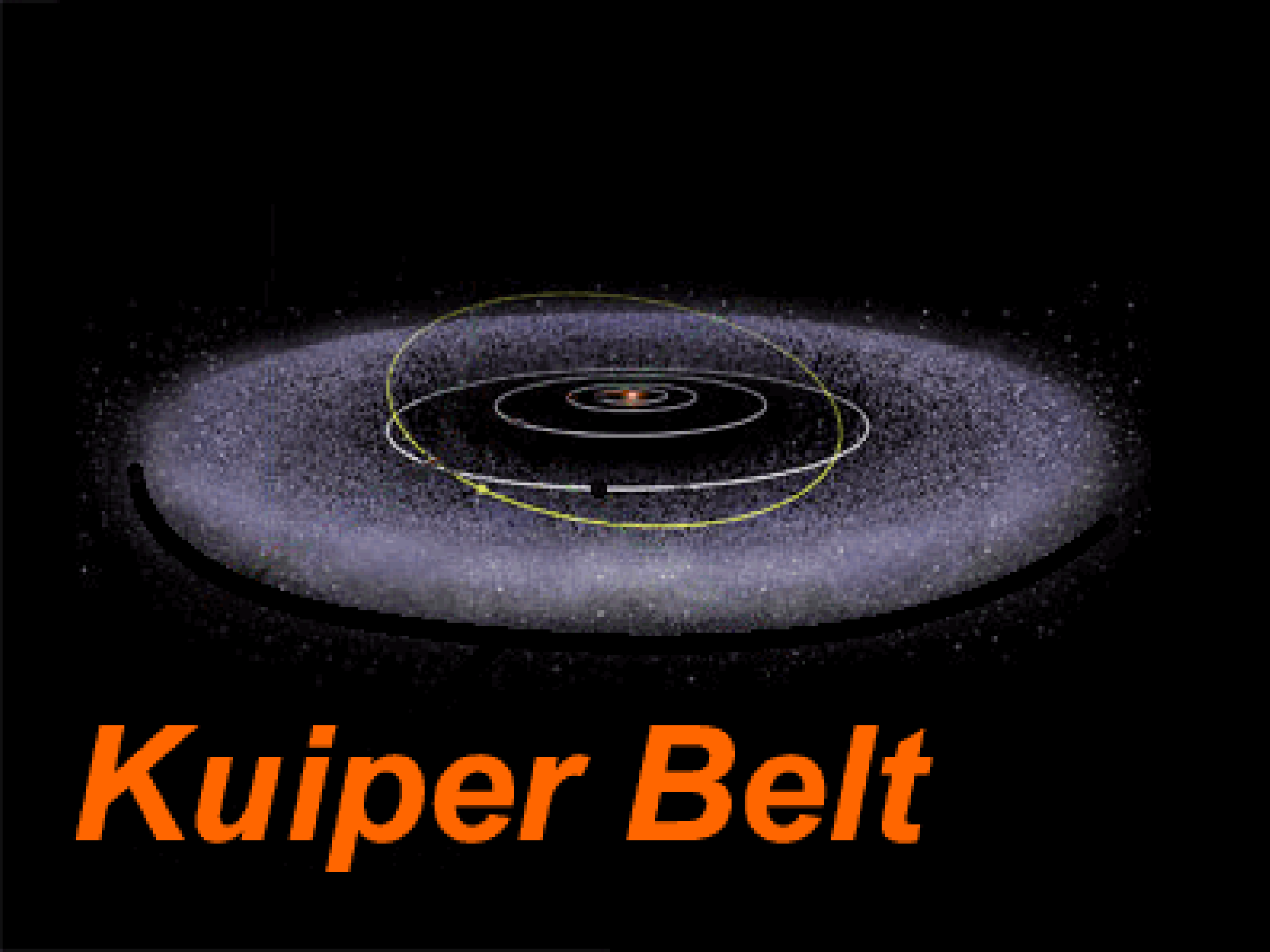
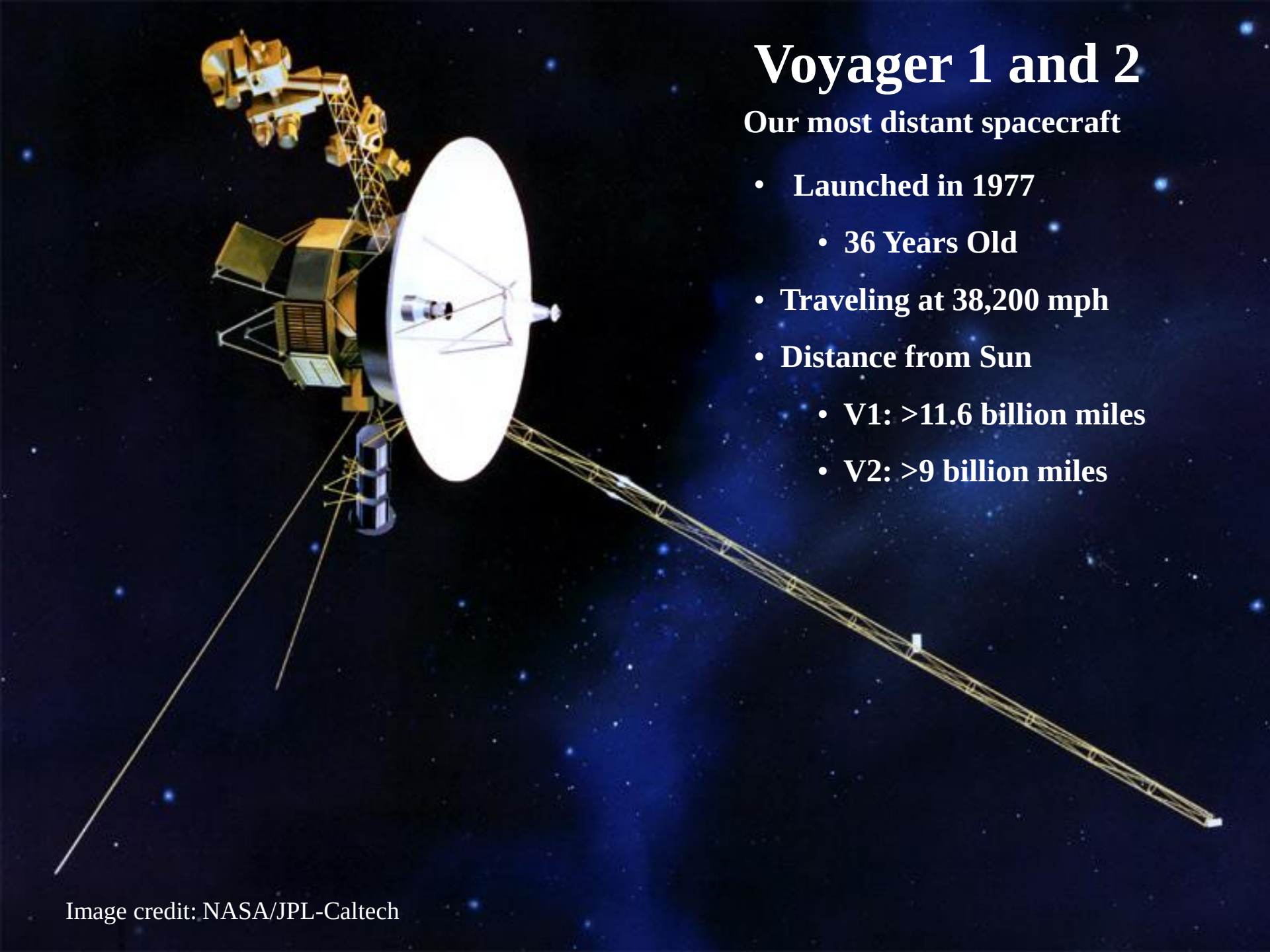


Image credit: Caltech/R. Hurt (IPAC)


Kuiper Belt



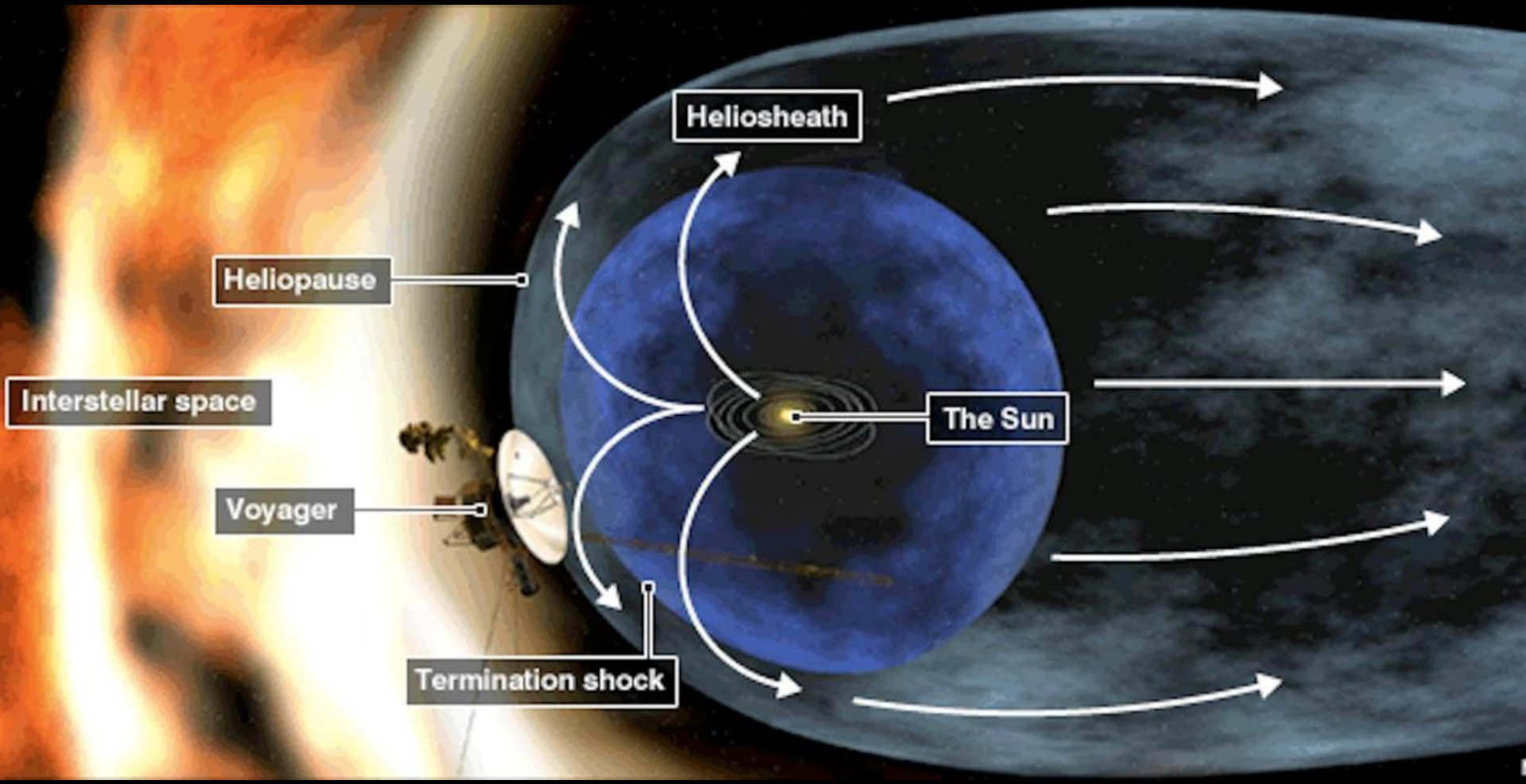
Voyager 1 and 2

Our most distant spacecraft

- **Launched in 1977**
  - **36 Years Old**
- **Traveling at 38,200 mph**
- **Distance from Sun**
  - **V1: >11.6 billion miles**
  - **V2: >9 billion miles**

Image credit: NASA/JPL-Caltech

Announced 9/12/2013:
Voyager 1 officially crossed Heliopause into interstellar space on, or about, 8/25/2012.
Voyager 2 appears to be about 3 years behind and is still in the Heliosheath.



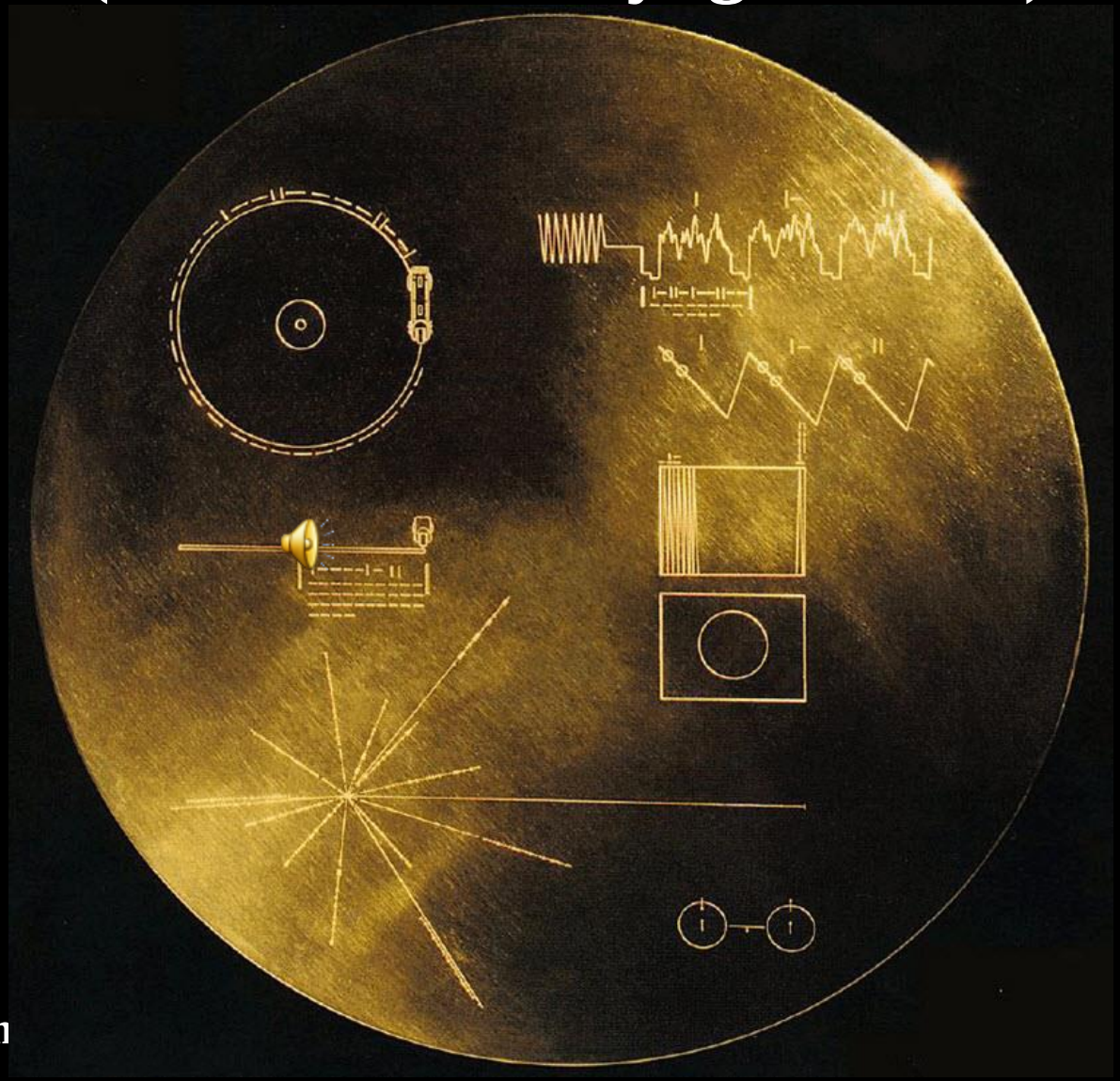
Oort cloud

If someone/something finds Voyager someday, what would you want them to know about us, and about life on earth?

The Gold Record (mounted on Voyager 1 & 2)

What's on the record?

- **Scenes from Earth**
  - **115 images**
- **Music from Earth**
  - **27 songs**
- **Sounds from Earth**
  - **21 collections**
- **Greetings From Earth**
  - **in 55 languages**
- **Printed Messages**
  - **President Carter**
  - **UN Sec Gen Waldheim**



Scenes from Earth

© FRANK DRAKE

NASA

© NATIONAL ASTRONOMY AND IONOSPHERE CENTER

UN/DPI PHOTO
NASA

Image credit: NASA/JPL-Caltech

Music from Earth

	Composer/Location, Artist/Performer, Time Length
1	Bach, Brandenburg Concerto No. 2 in F. First Movement, Munich Bach Orchestra, Karl Richter, conductor. 4:40
2	Java, court gamelan, "Kinds of Flowers," recorded by Robert Brown. 4:43
3	Senegal, percussion, recorded by Charles Duvelle. 2:08
4	Zaire, Pygmy girls' initiation song, recorded by Colin Turnbull. 0:56
5	Australia, Aborigine songs, "Morning Star" and "Devil Bird," recorded by Sandra LeBrun Holmes. 1:26
6	Mexico, "El Cascabel," performed by Lorenzo Barcelata and the Mariachi México. 3:14
7	"Johnny B. Goode," written and performed by Chuck Berry. 2:38
8	New Guinea, men's house song, recorded by Robert MacLennan. 1:20
9	Japan, shakuhachi, "Tsuru No Sugomori" ("Crane's Nest,") performed by Goro Yamaguchi. 4:51
10	Bach, "Gavotte en rondeaux" from the Partita No. 3 in E major for Violin, performed by Arthur Grumiaux. 2:55
11	Mozart, The Magic Flute, Queen of the Night aria, no. 14. Edda Moser, soprano. Bavarian State Opera, Munich, Wolfgan
12	Georgian S.S.R., chorus, "Tchakrulo," collected by Radio Moscow. 2:18
13	Peru, panpipes and drum, collected by Casa de la Cultura, Lima. 0:52
14	"Melancholy Blues," performed by Louis Armstrong and his Hot Seven. 3:05
15	Azerbaijan S.S.R., bagpipes, recorded by Radio Moscow. 2:30
16	Stravinsky, Rite of Spring, Sacrificial Dance, Columbia Symphony Orchestra, Igor Stravinsky, conductor. 4:35
17	Bach, The Well-Tempered Clavier, Book 2, Prelude and Fugue in C, No.1. Glenn Gould, piano. 4:48
18	Beethoven, Fifth Symphony, First Movement, the Philharmonia Orchestra, Otto Klemperer, conductor. 7:20
19	Bulgaria, "Izlel je Delyo Hagdutin," sung by Valya Balkanska. 4:59
20	Navajo Indians, Night Chant, recorded by Willard Rhodes. 0:57
21	Holborne, Paueans, Galliards, Almains and Other Short Aeirs, "The Fairie Round," performed by David Munrow and th
22	Solomon Islands, panpipes, collected by the Solomon Islands Broadcasting Service. 1:12

Sounds From Earth

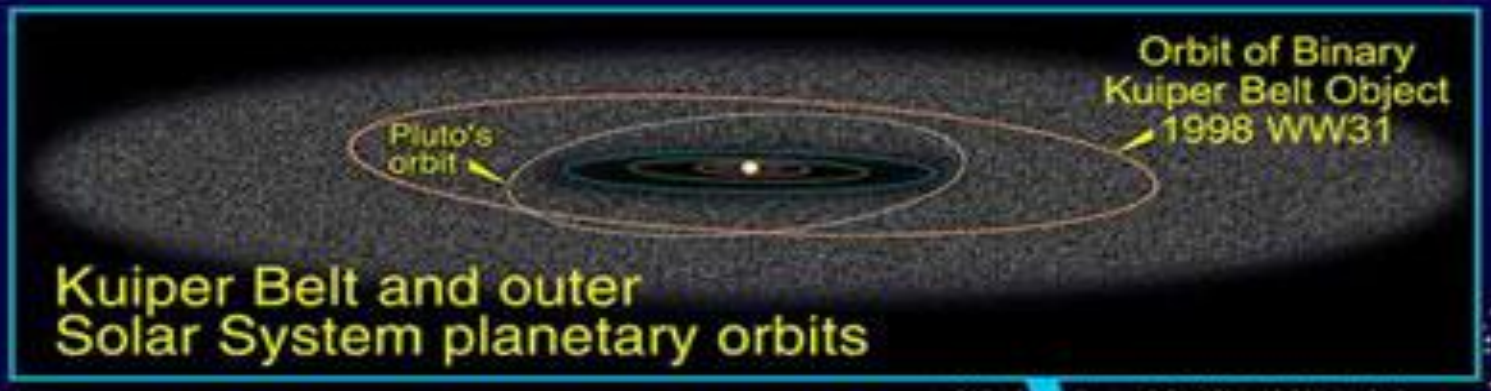
- Tame Dog
- Tractor, Riveter
- Chimpanzee
- Mud Pots
- Tractor, Bus, Auto

- Music of the Spheres
- Volcanoes, Earthquake, Thunder
- Wind, Rain, Surf
- Crickets, Frogs
- Birds, Hyena, Elephant
- Wild Dog
- Footsteps, Heartbeat, Laughter
- Fire, Speech
- The First Tools
- Herding Sheep, Blacksmith, Sawing
- Morse Code, Ships
- Horse and Cart
- Train
- F-111 Flyby, Saturn V Lift-off
- Kiss, Mother and Child
- Life Signs, Pulsar

Greetings From Earth

- Akkadian
- Amoy (Min dialect)
- Arabic
- Aramaic
- Armenian
- Bengali
- Burmese
- Cantonese
- Czech
- Dutch
- English
- French
- German
- Greek
- Gujarati
- Hebrew
- Hindi

- Hittite
- Hungarian
- Lla
- Indonesian
- Italian
- Japanese
- Kannada
- Kechua
- Korean
- Latin
- Luganda
- Mandarin
- Marathi
- Nepali
- Nguni
- Nyanja
- Oriya
- Persian
- Polish
- Portuguese
- Punjabi
- Rajasthani
- Romanian
- Russian
- Serbian
- Sinhalese
- Sotho
- Spanish
- Sumerian
- Swedish
- Thai
- Turkish
- Ukranian
- Vietnamese
- Welsh
- Wu



Oort Cloud (home of comets)

- Extends out more than 1 light year from the sun

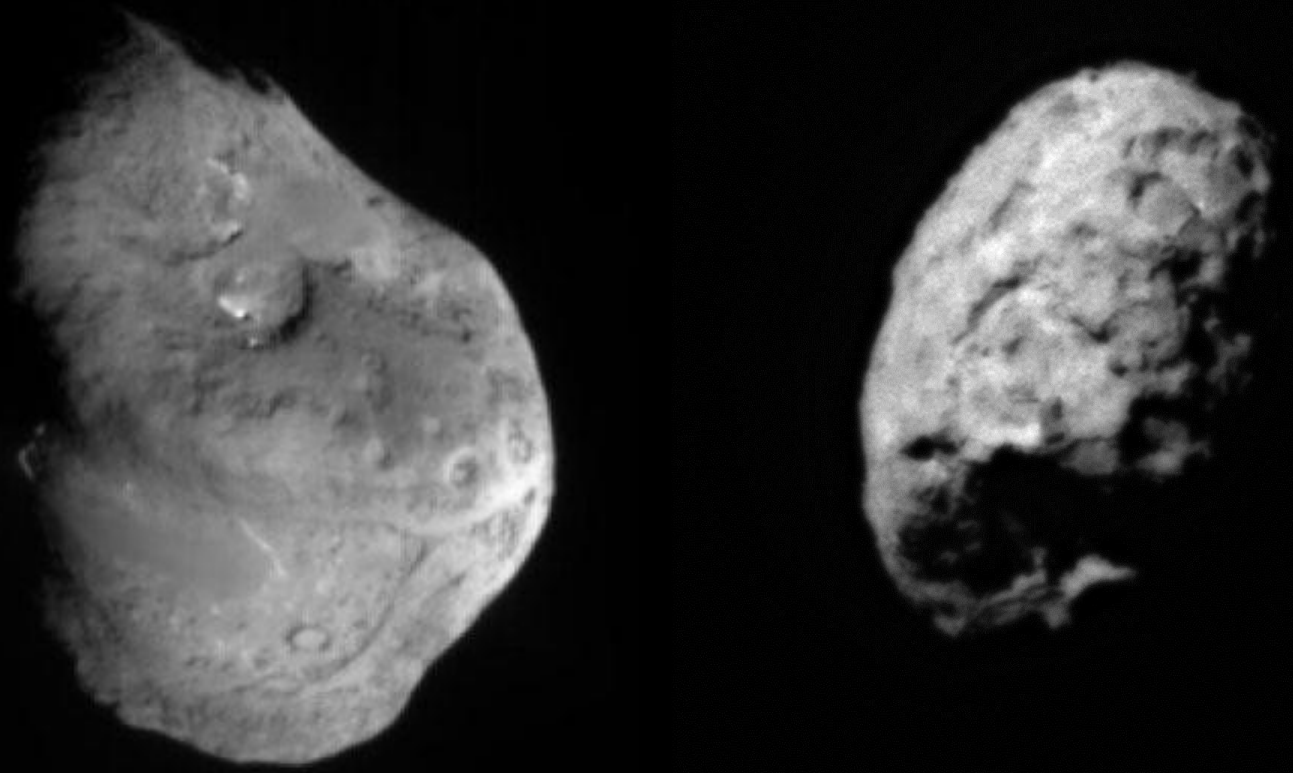
The Oort Cloud (comprising many billions of comets)

Oort Cloud cutaway drawing adapted from Donald K. Yeoman's illustraton (NASA, JPL)

Image credit: NASA/JPL-Caltech

Short Period Comets

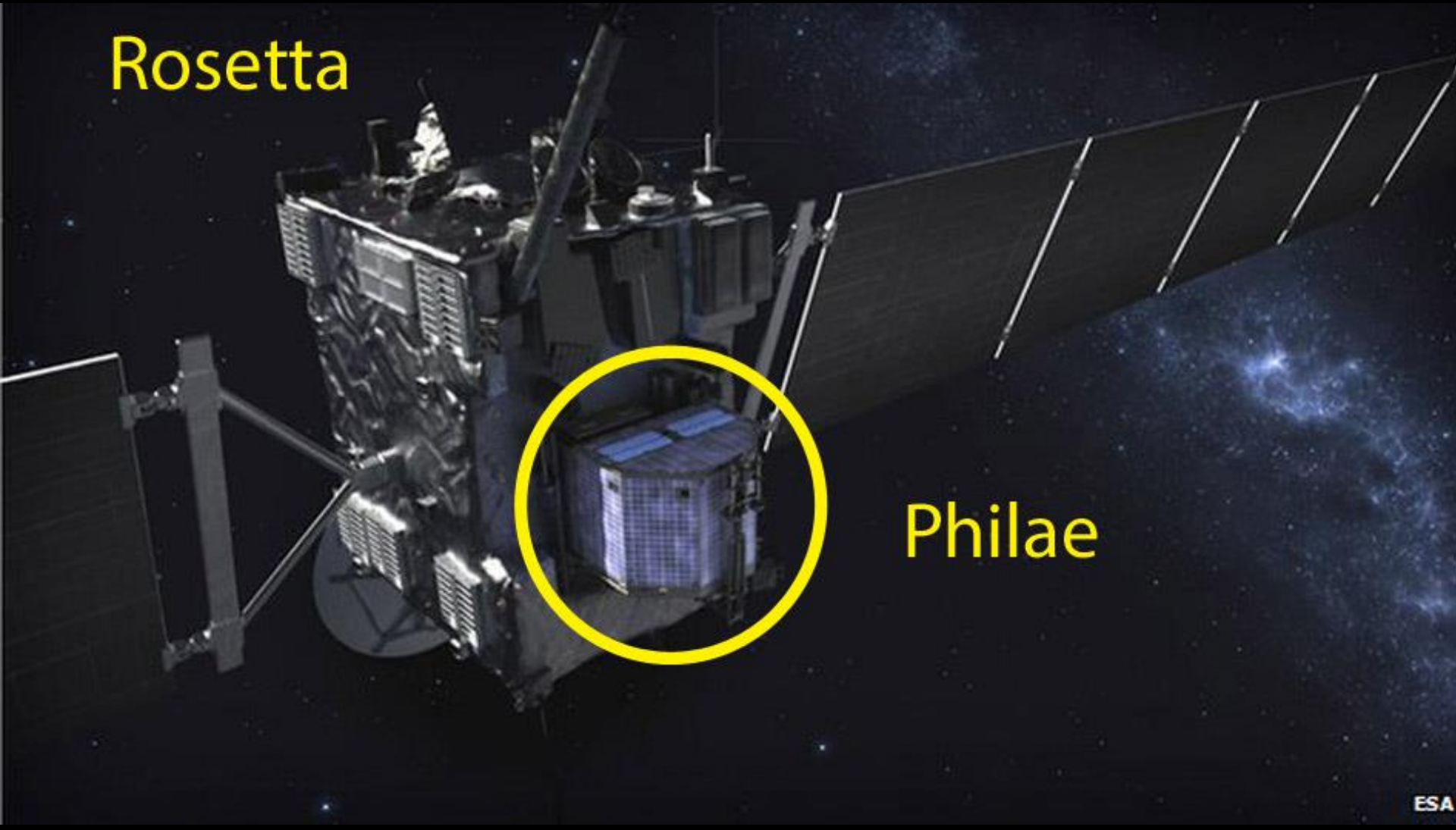
(Dirty Snow Balls from the Kuiper Belt)



Temple 1 **Wild 2**

Image credit: NASA/JPL-Caltech

Stardust



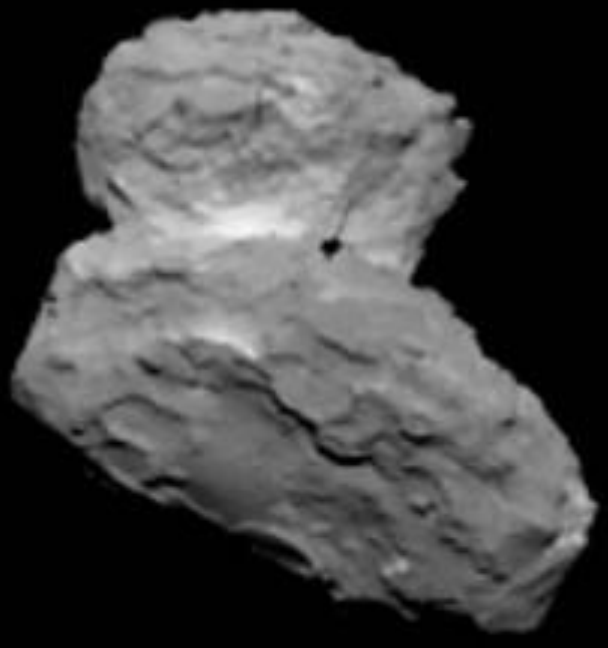
Rosetta – Mission to land on, and orbit a comet

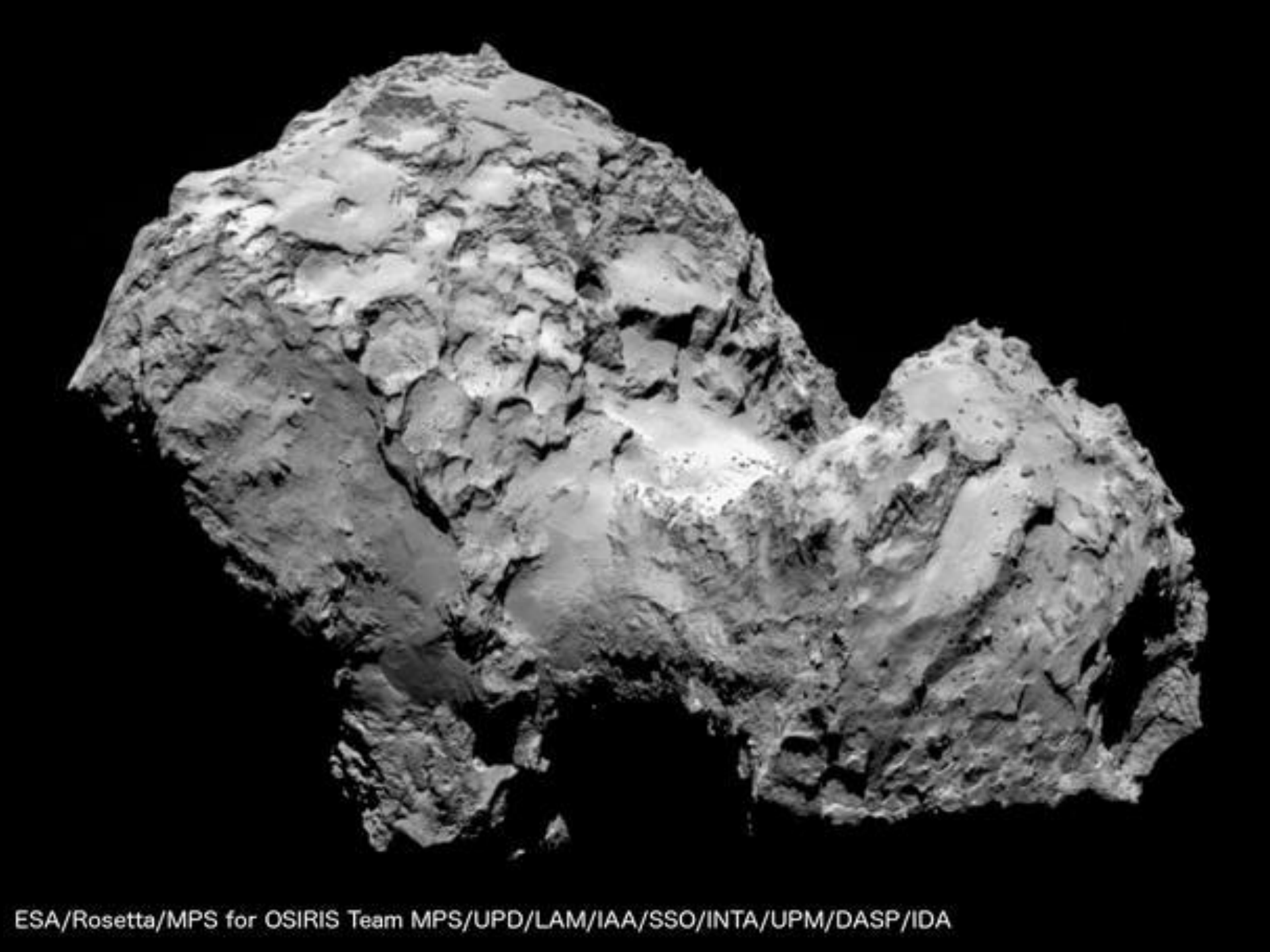
ESA mission to a Comet

- Launched: 2004
- COI (Comet Orbit Insertion): 8/6/2014
- Philae Landing: 11/12/2014

Image credit: ESA

Comet 67P/Churyumov-Gerasimenko
(6 Year Orbits around the sun)



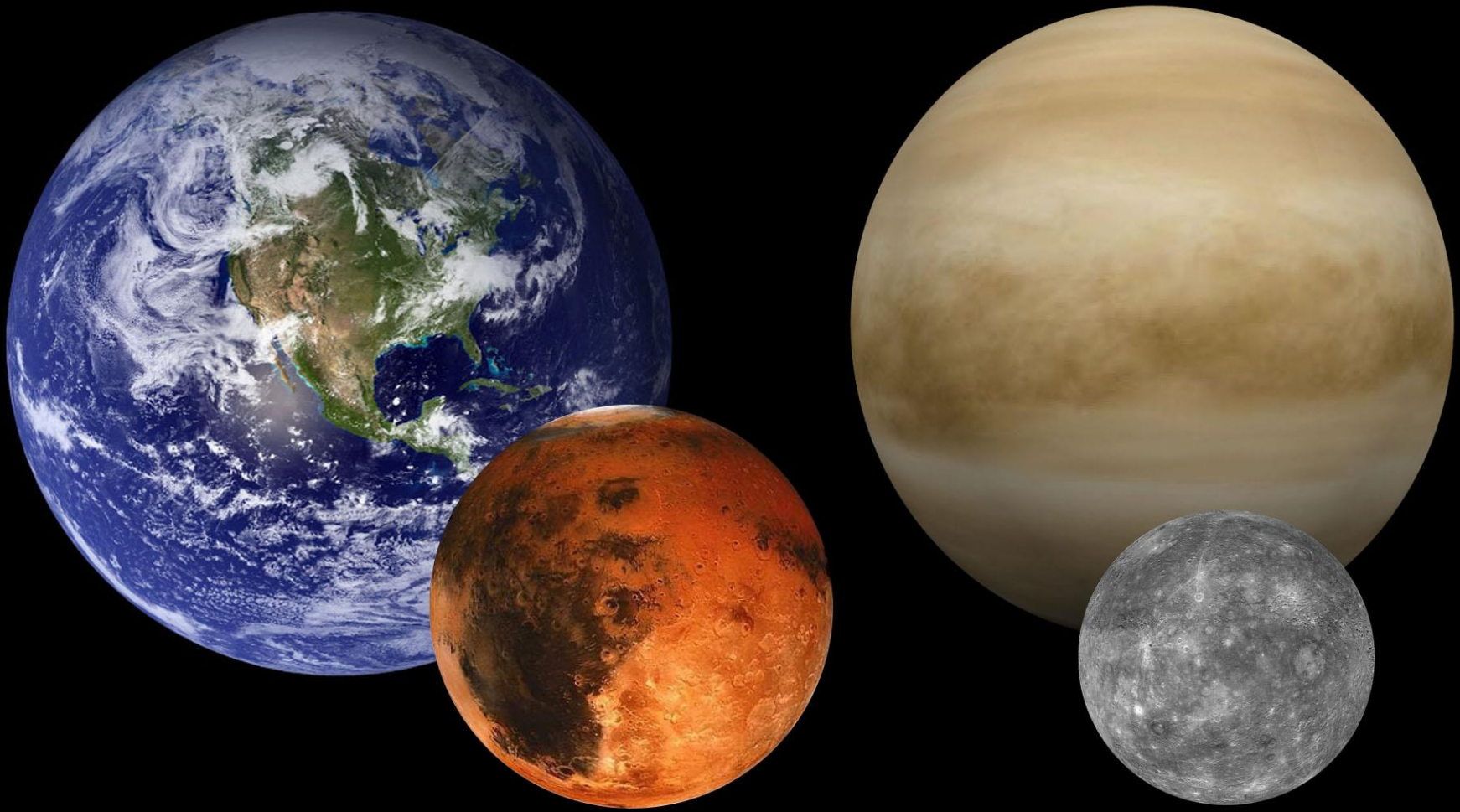


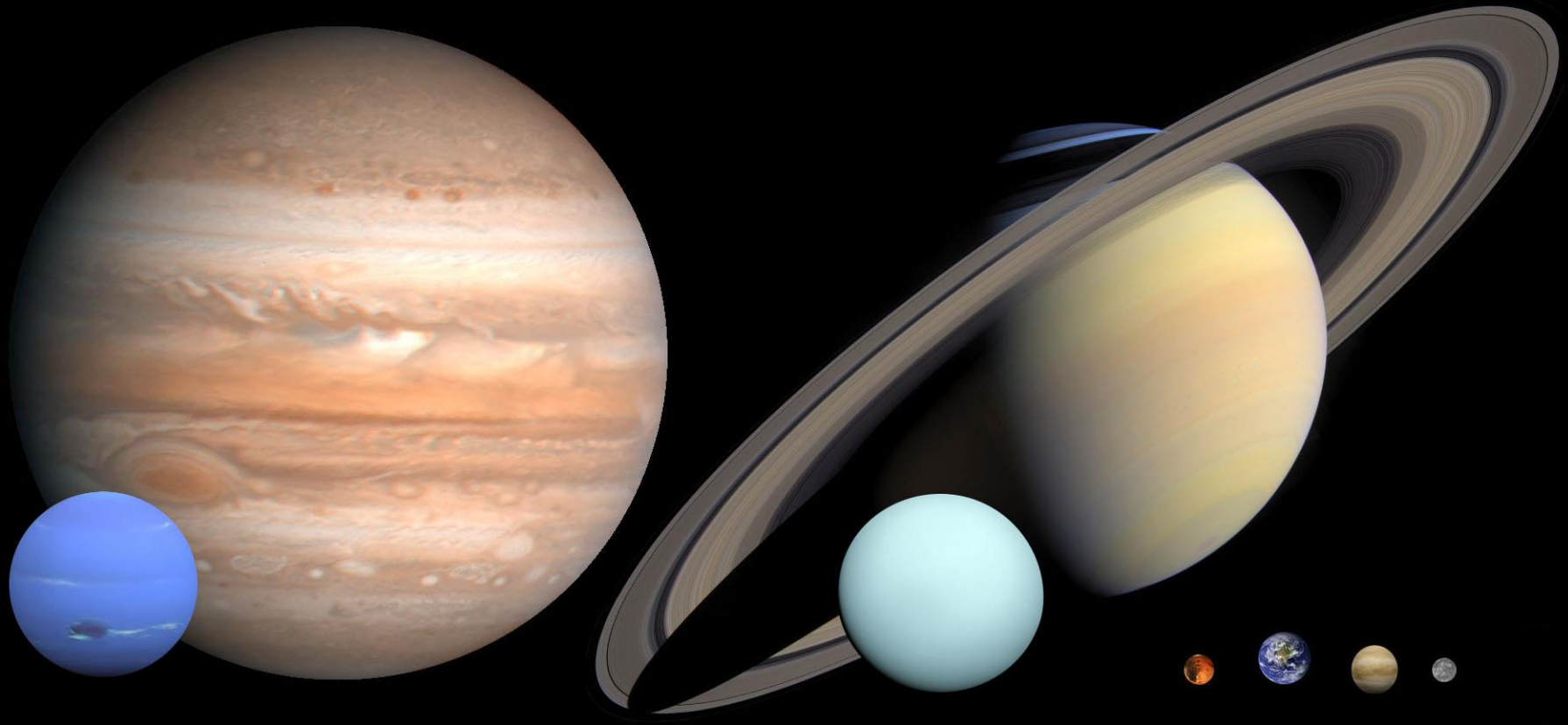
ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA


Philae photo of comet just before touchdown…

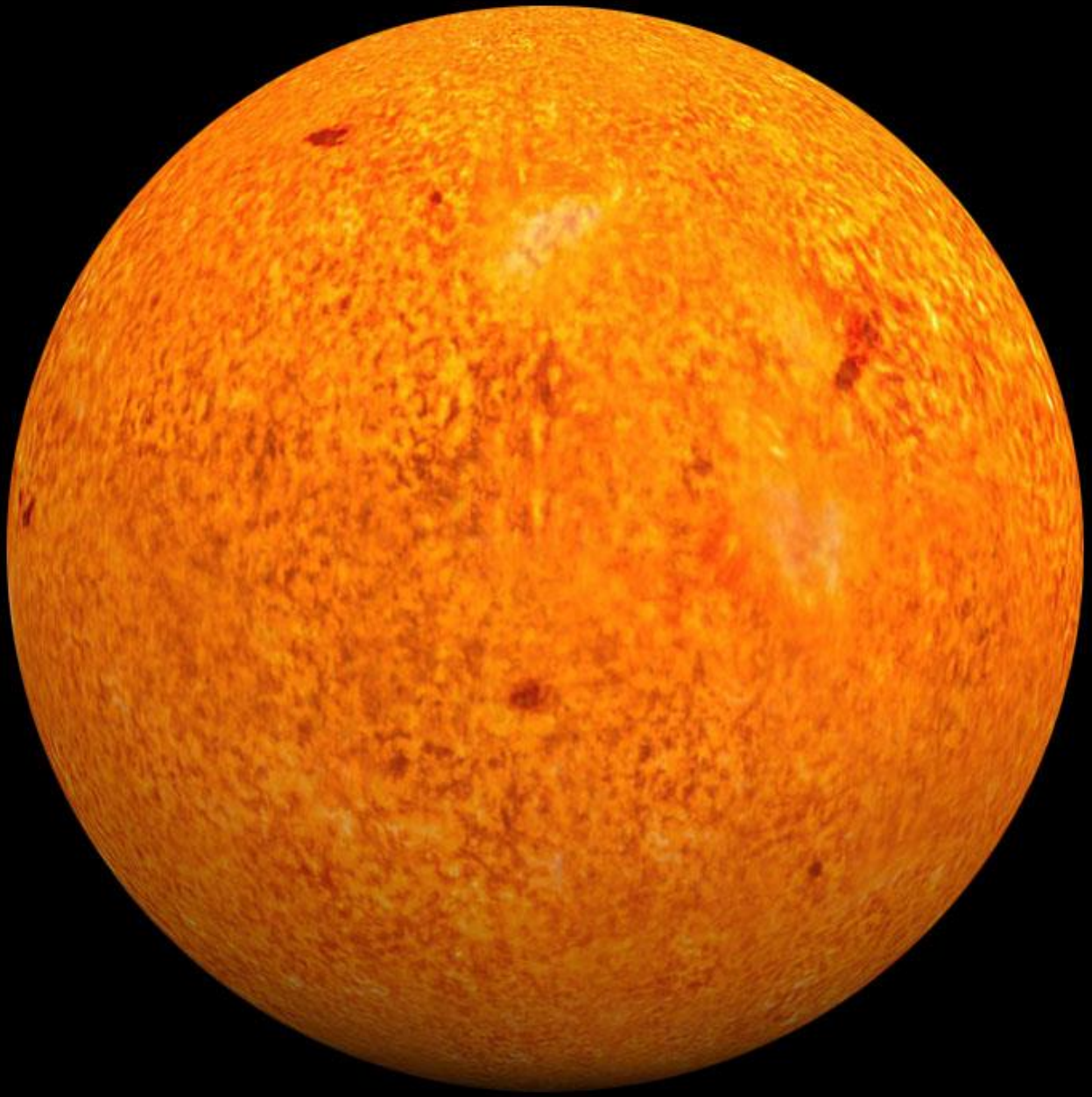
March 28 high res photo (1.7m/pixel)

What if the planets were side by side?

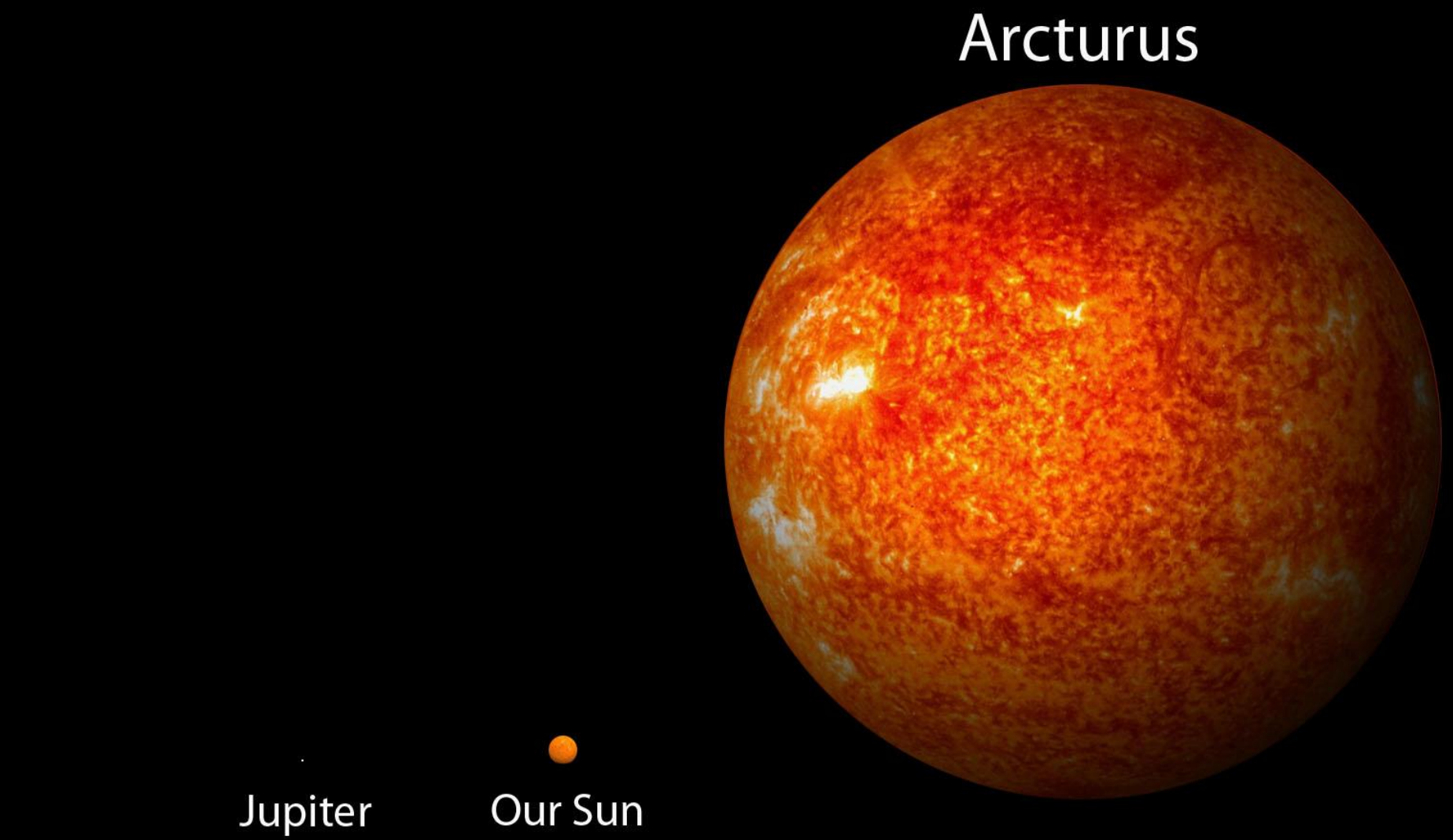




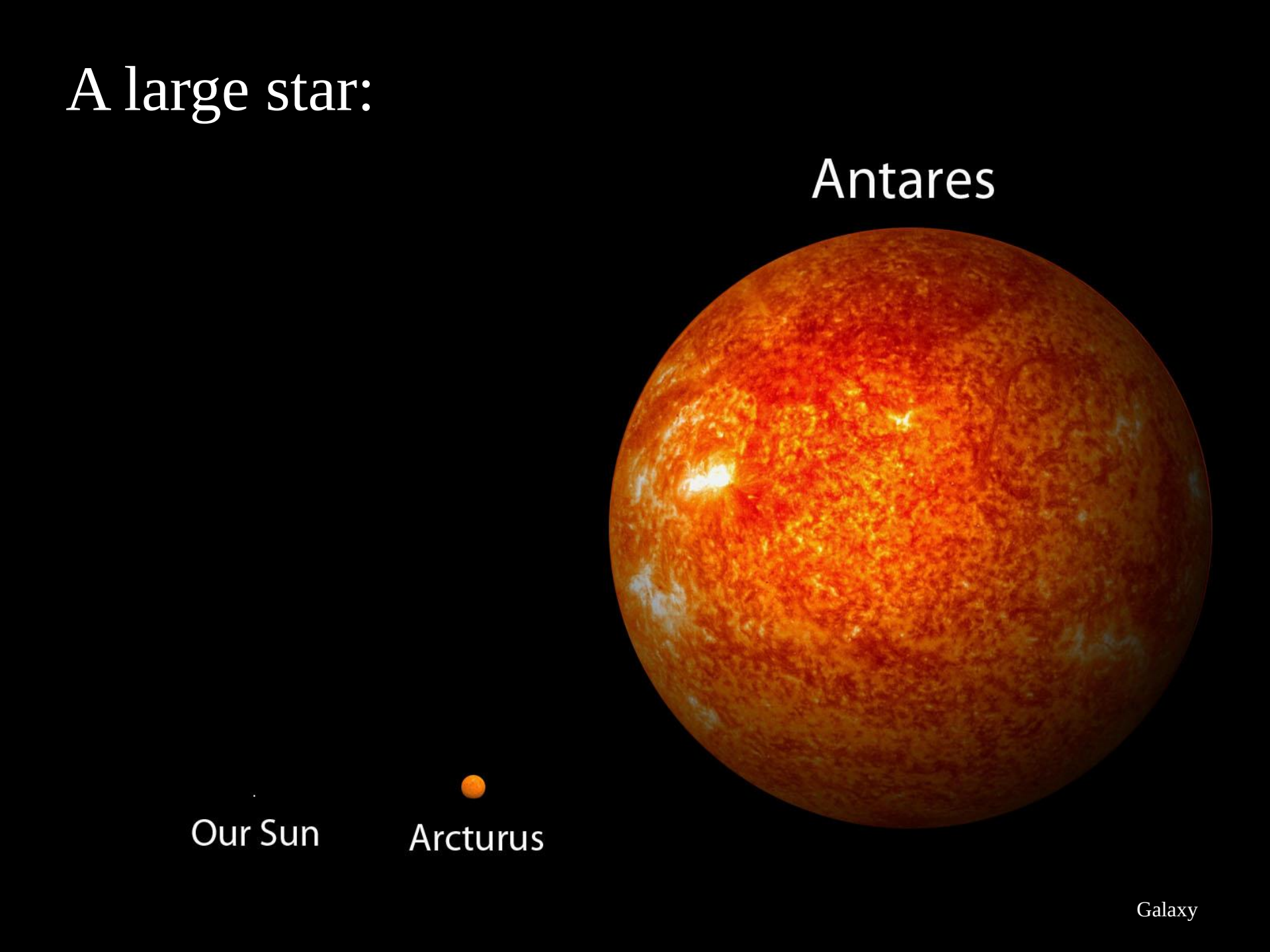
Our Sun



A medium sized star:



A large star:

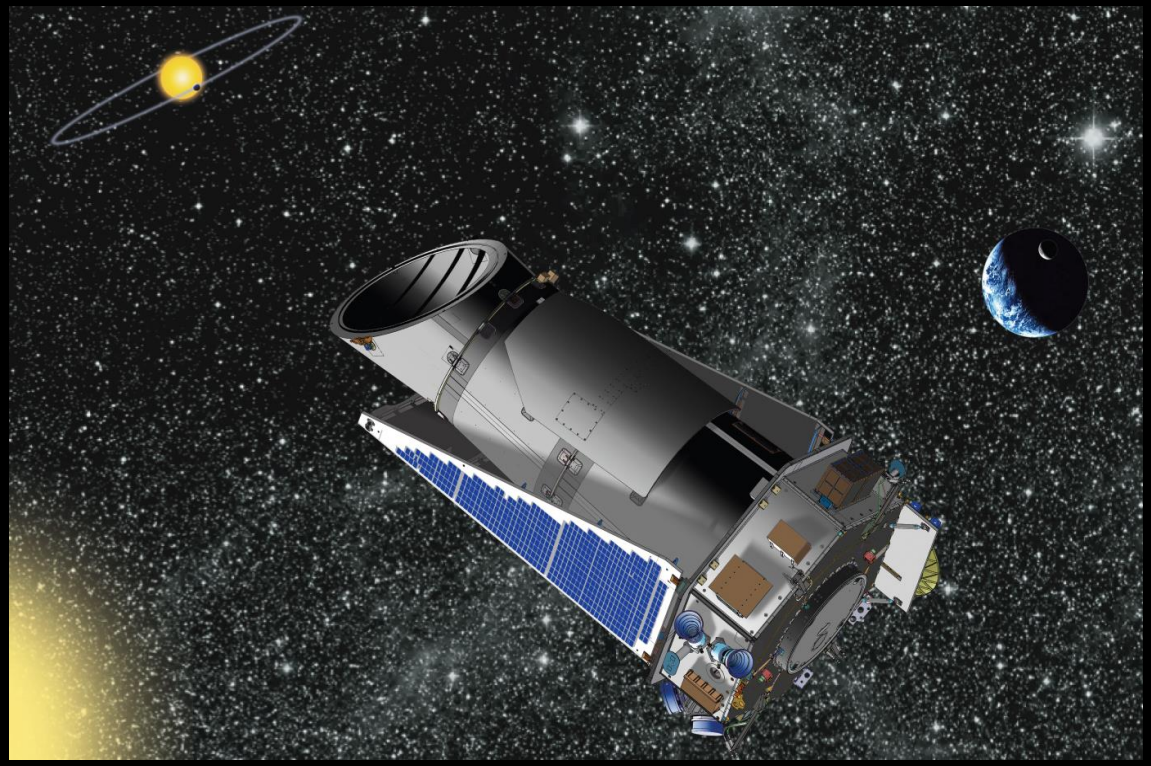


Milky Way Galaxy – As seen from Colorado

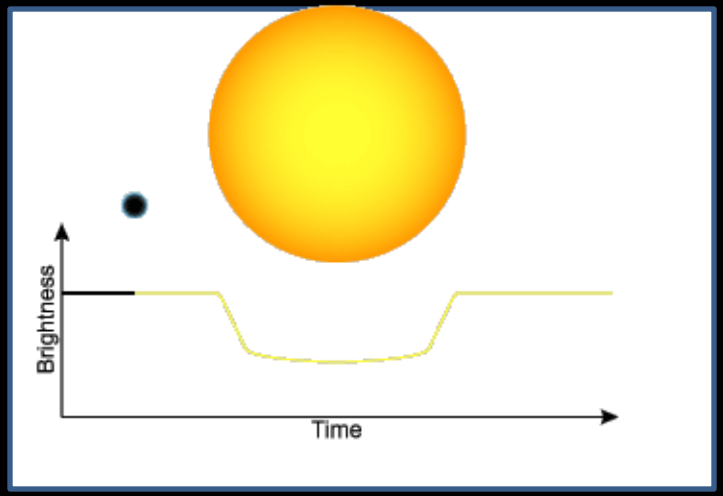
Slow animation

Wait - animation

Kepler Space Telescope - NASA's Planetary Transit Champion



Light Curves of a Star During Planetary Transit



Prime Mission ended 8/19/2013

Kepler

K2 Extended Mission in Progress

Images credit: NASA/JPL-Caltech

What Kepler has found so far…

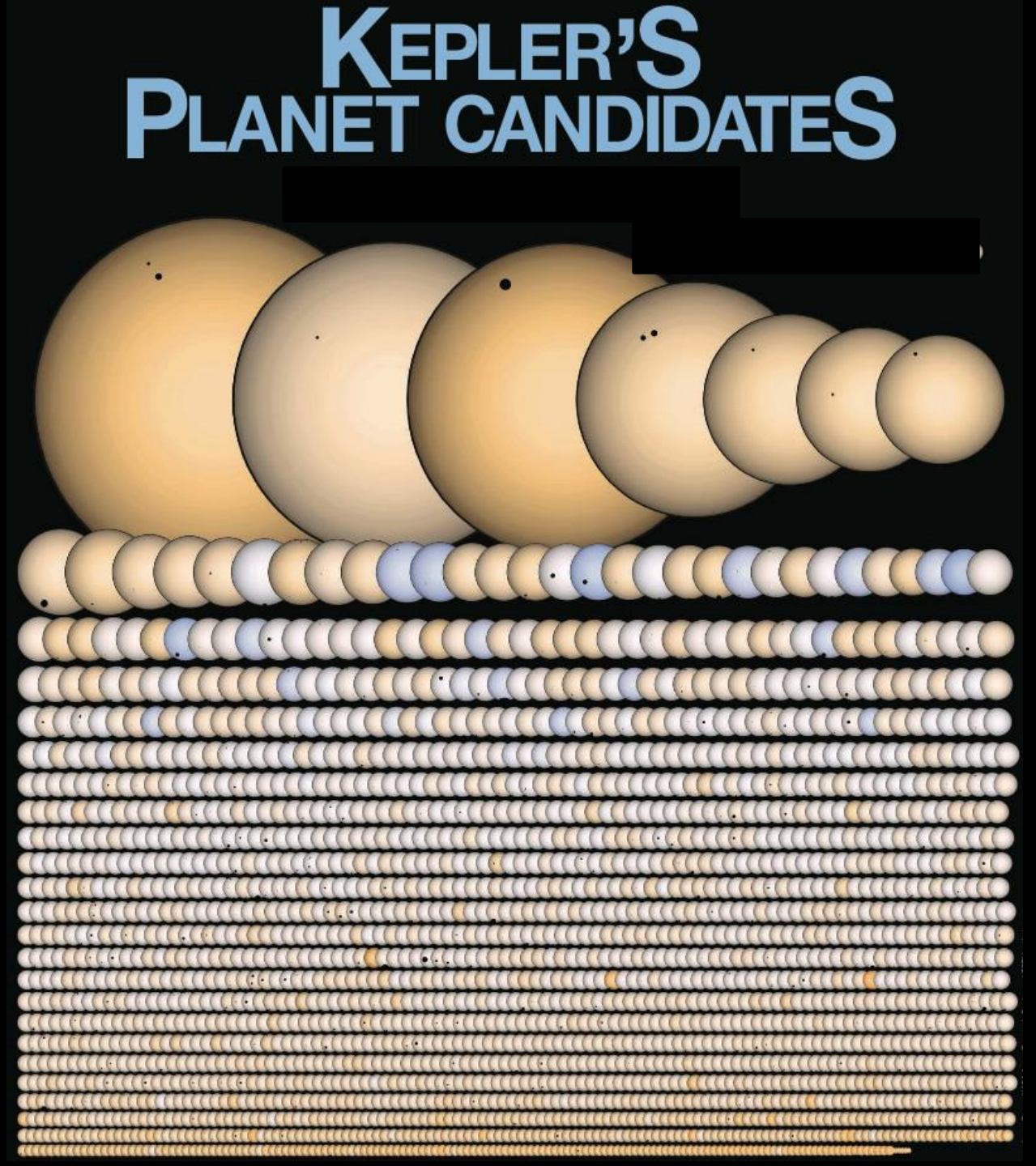
Exoplanet Count 2/19/2016

Candidates: 3,701

Confirmed: 1,941

Total Exoplanets: 5,642

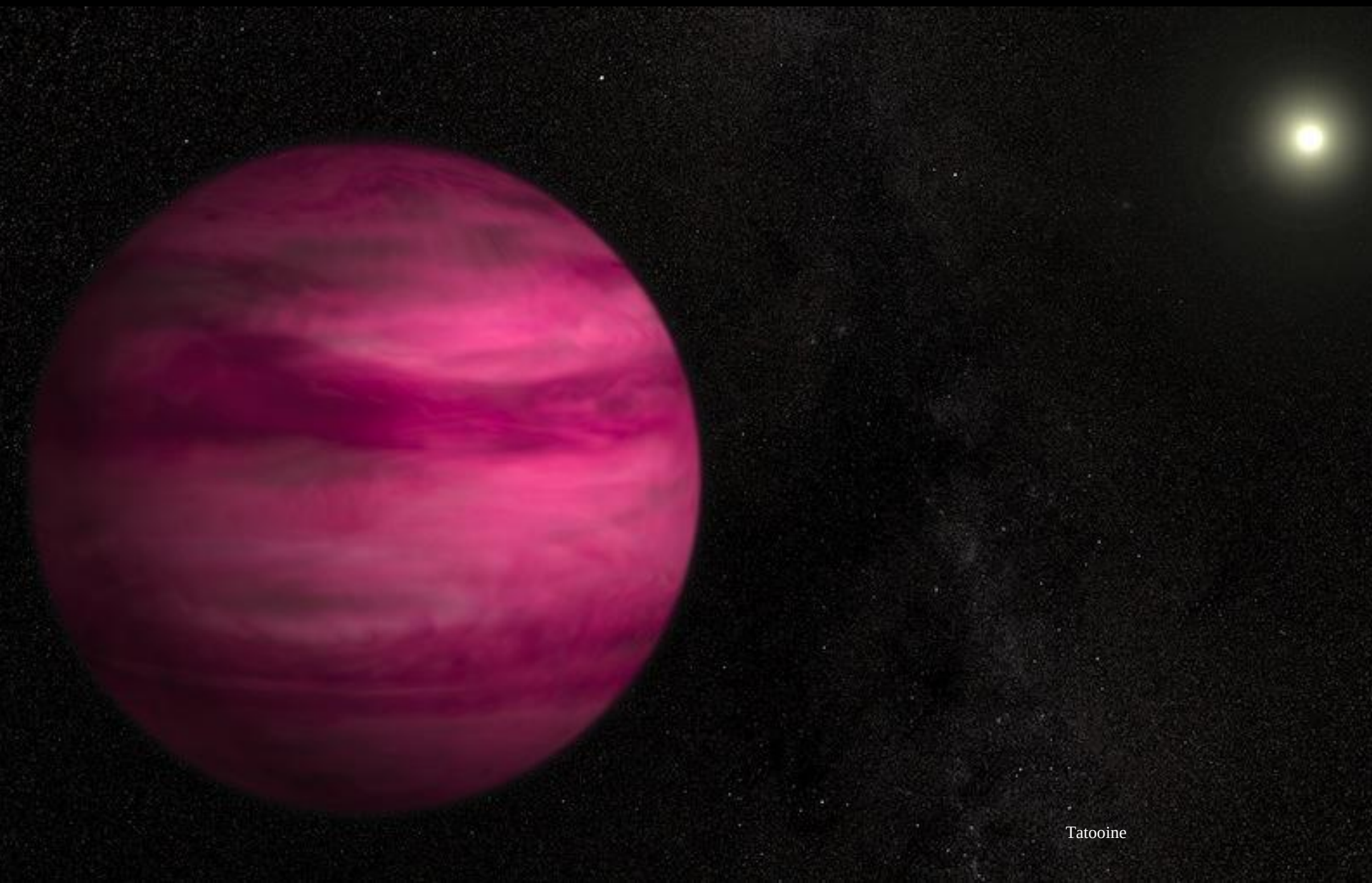
85% by Kepler



Cherry Blossom

GJ-504b, a “cherry blossom” planet orbiting a hot young sun

- 57 light years from Earth



Kepler Mission Discovers Worlds Orbiting Two Stars

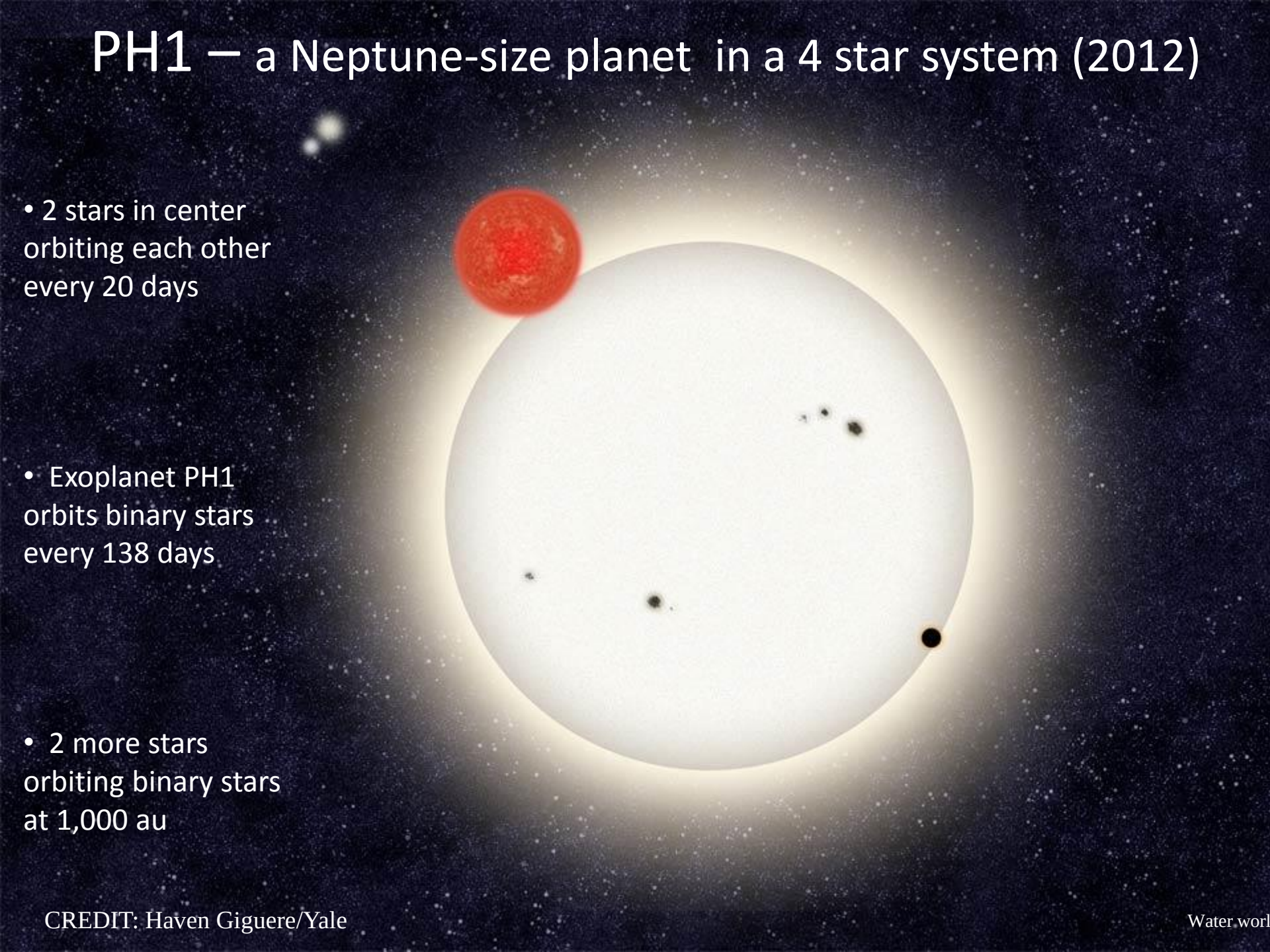
Kepler-16b – (9/15/2011)
Kepler-34b and **Kepler-35b** (1/11/2012)
Kepler-38b (Aug 20, 2012)
Kepler 47b and 4**7c** (Aug 28, 2012)

Tatooine from Star Wars:)

Images credit: NASA/JPL-Caltech

4 stars

PH1 – a Neptune-size planet in a 4 star system (2012)



- 2 stars in center orbiting each other every 20 days
- Exoplanet PH1 orbits binary stars every 138 days
- 2 more stars orbiting binary stars at 1,000 au

CREDIT: Haven Giguere/Yale

Water.worl

Hubble finds GJ1214b “Water world”
2/21/2012 - A whole new type of planet?

Current Planet Types

- Rocky and Terrestrial (like Mars and Earth)
- Gas Giants (like Jupiter and Saturn)
- Ice Giants (Like Uranus and Neptune)

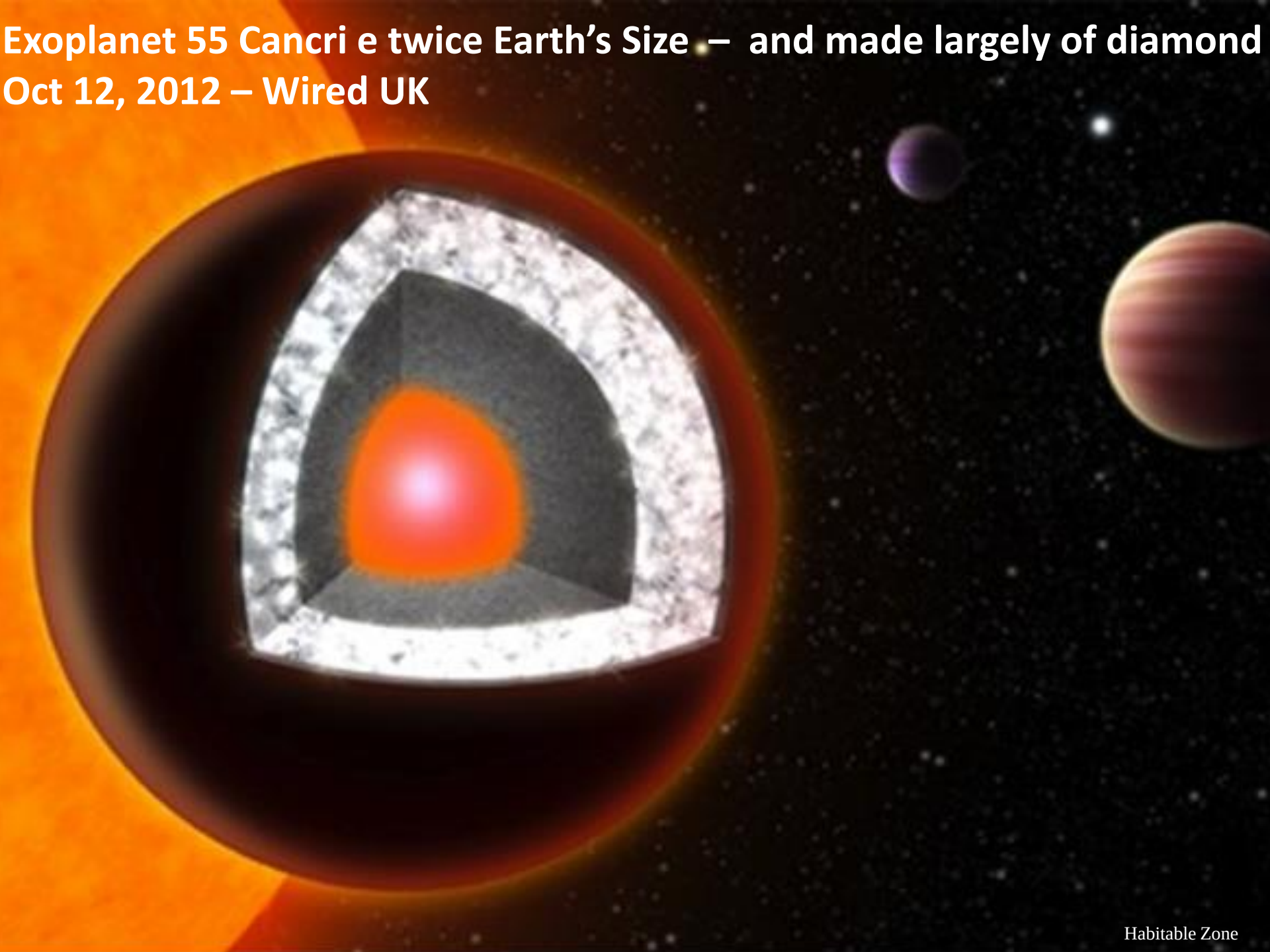
GJ1214b

- 2.7 x Earth’s diameter
- Orbits red-dwarf star every 38 hours
- Surface Temp is 450 degrees F
- Density is 2 g/cm^3
    - Earth density is 5.5 g/cm^3
- Data is consistent with dense water vapor atmosphere

diamonds

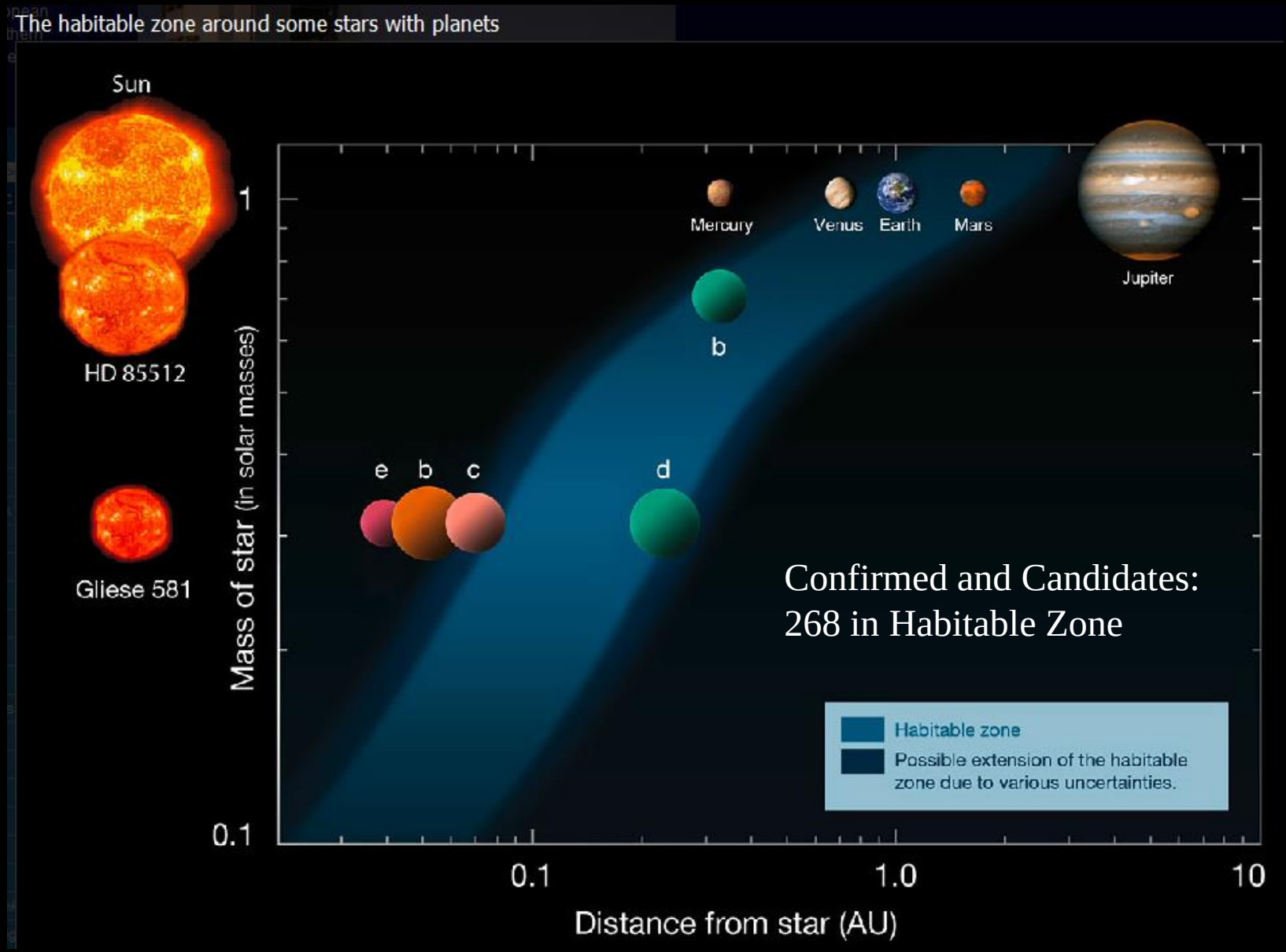
Exoplanet 55 Cancri e twice Earth's Size – and made largely of diamond

Oct 12, 2012 – Wired UK



Habitable Zone

Goldilocks/Habitable Zone (where liquid water could exist)

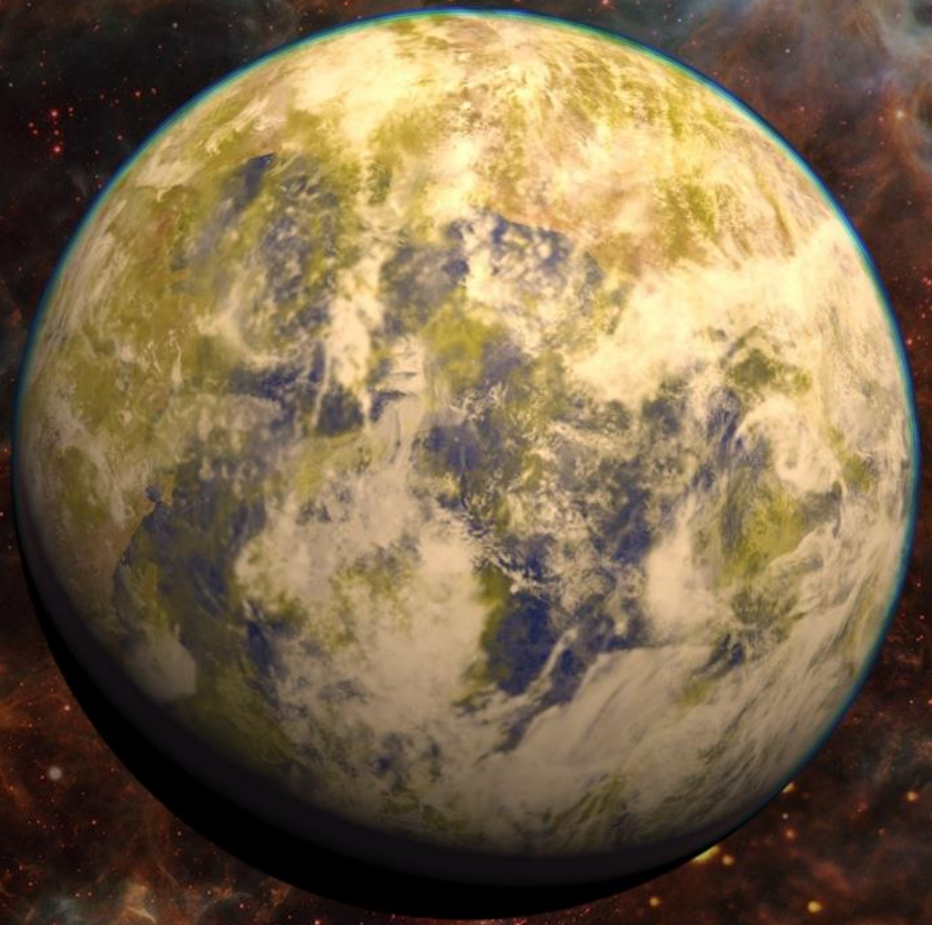


Images credit: NASA/JPL-Caltech

Earth-like

Gliese 832 c

Best Habitable World Candidate so far…
Same average energy as Earth from the Su
Earth-like temperatures
Earth-like terrestrial atmosphere
but…
5 times mass of Earth

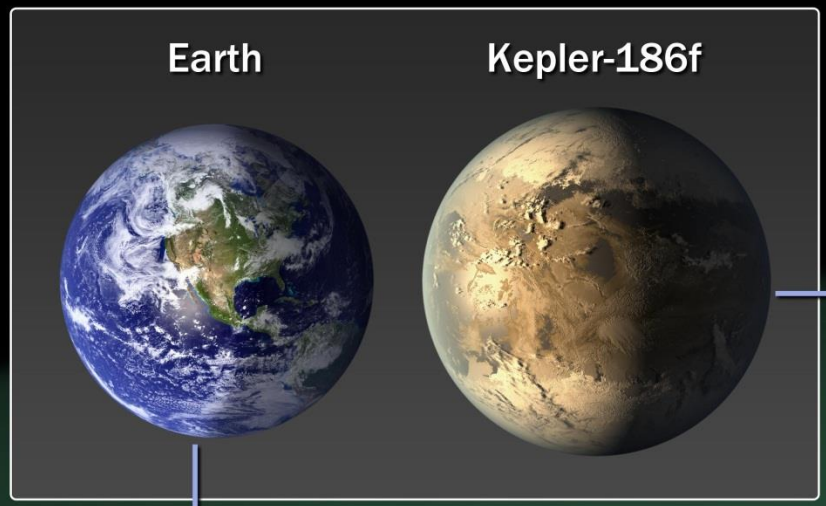


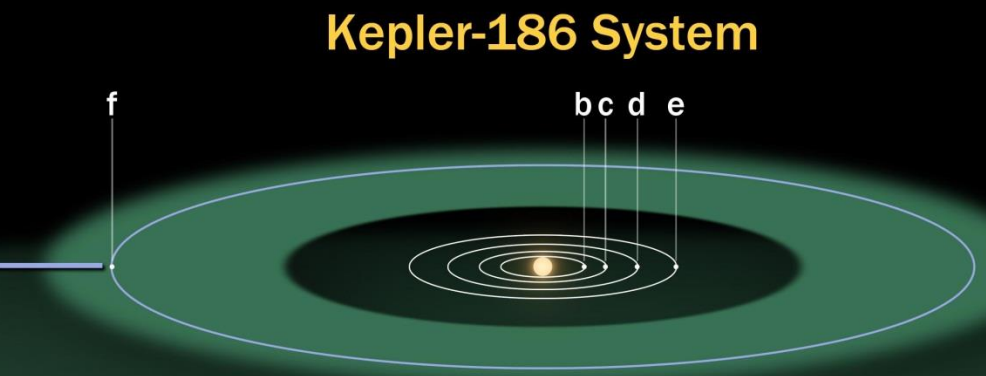
Exo-atmosphere

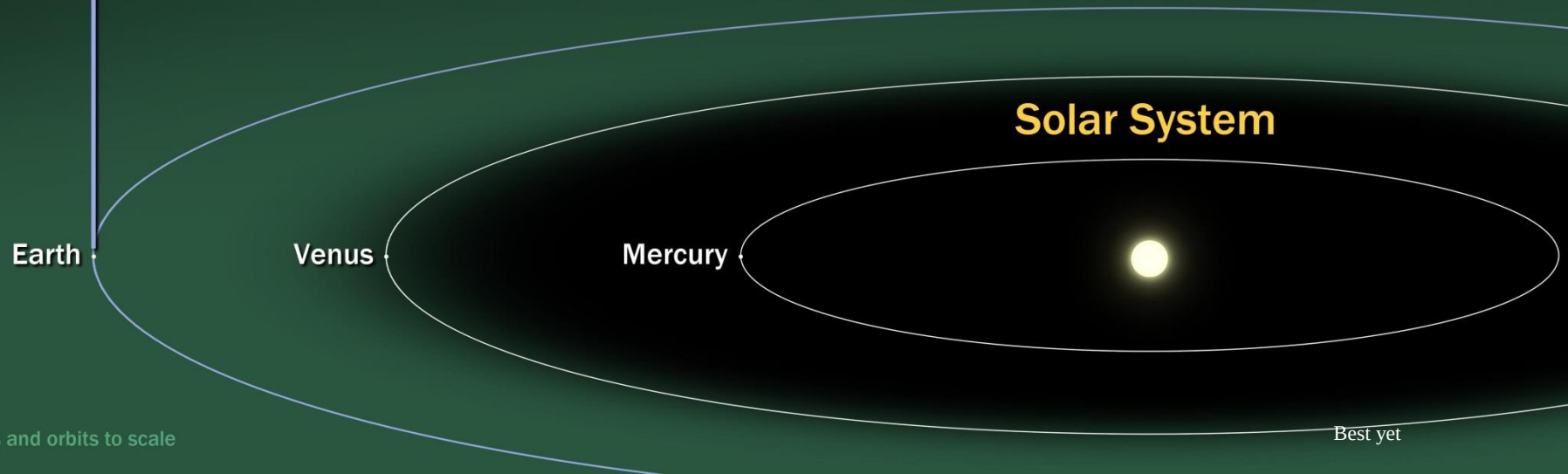
CRED

Kepler-186f Earth-like and in Habitable Zone (April 17, 2014)

- 490 light-years from Earth
- Orbits it's star every 130 days



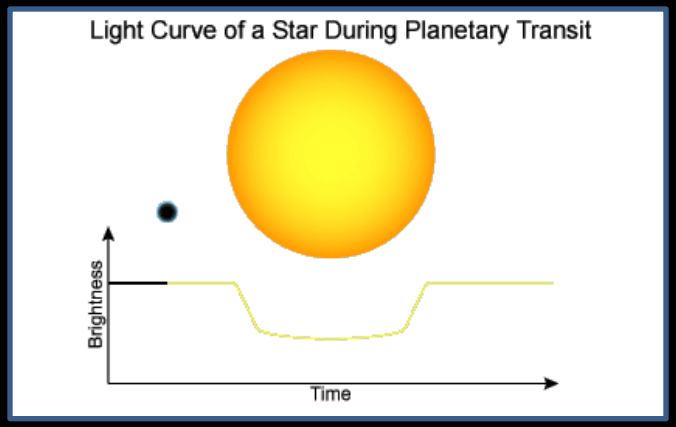


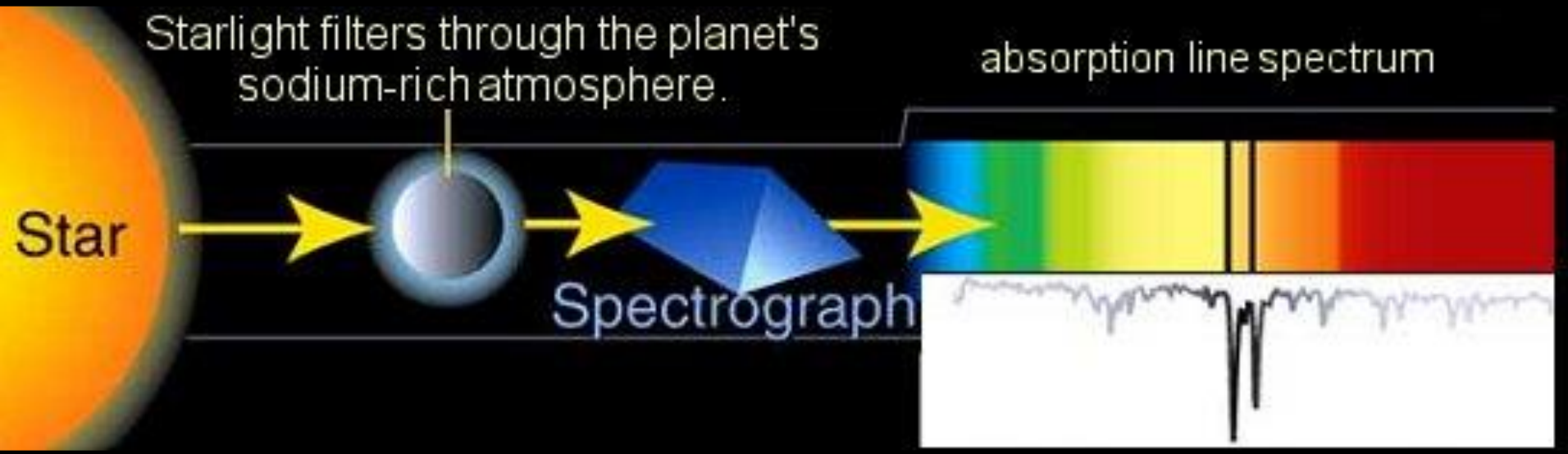


Planets and orbits to scale

Best yet

Spectroscopy – can determine if exoplanet has atmosphere and if yes, can analyze Exoplanet atmospheres during the transit

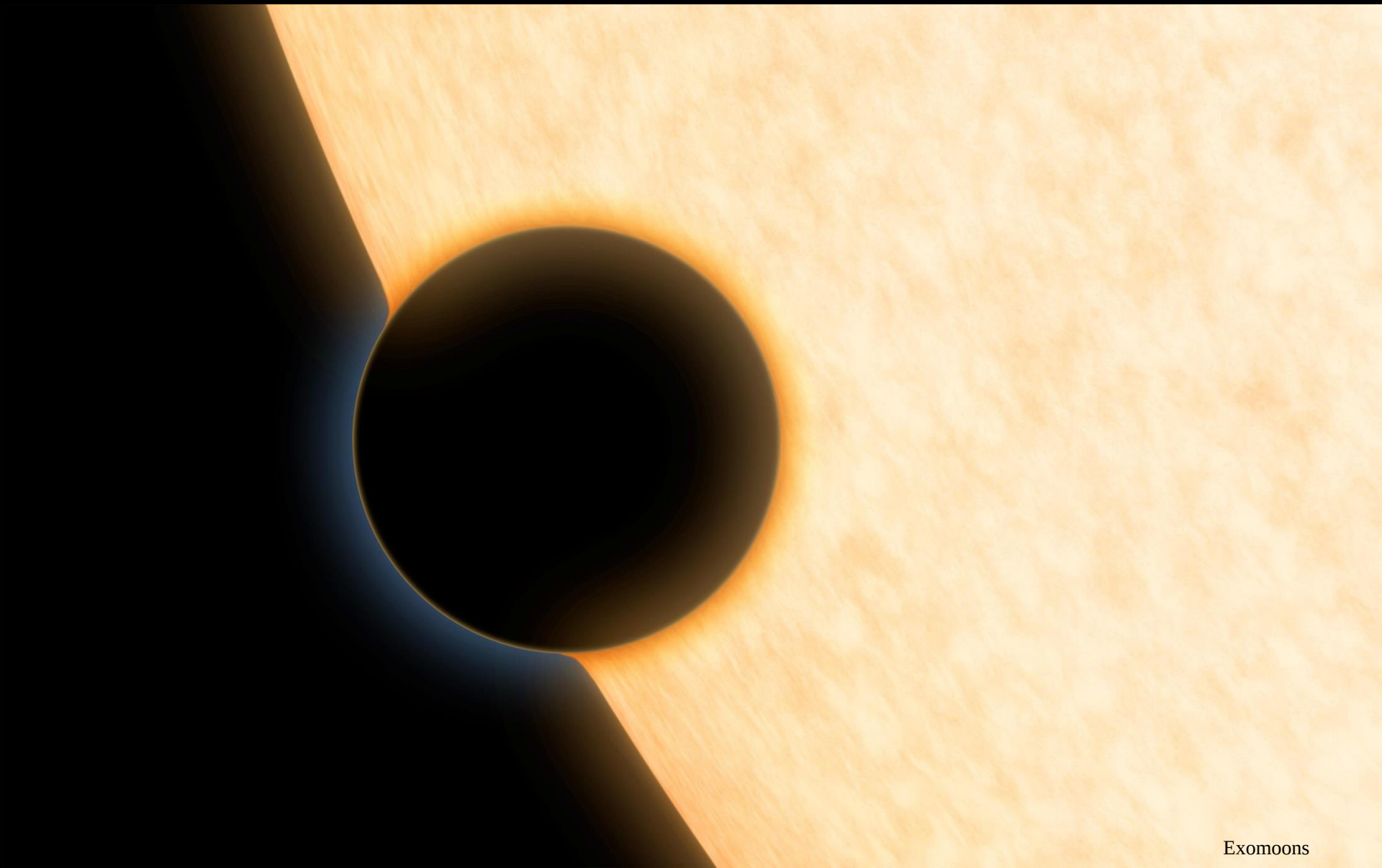




Images credit: NASA/JPL-Caltech

HAT-P-11b **Sept 24, 2014 – A Neptune sized exoplanet with…**

water vapor molecules detected in the planet's clear atmosphere



Summary: What We Have Found So Far…

5,642 Exoplanets
In small circle area

Milky Way Estimates
Stars: 100-700 Billion

Planets: At least 500 Billion

Earth-like in Habitable Zone: >20 Billion

Galaxy Count: >125 Billion

Earth-like Habitable Zone Planets: **2,500,000,000,000,000,000,000**

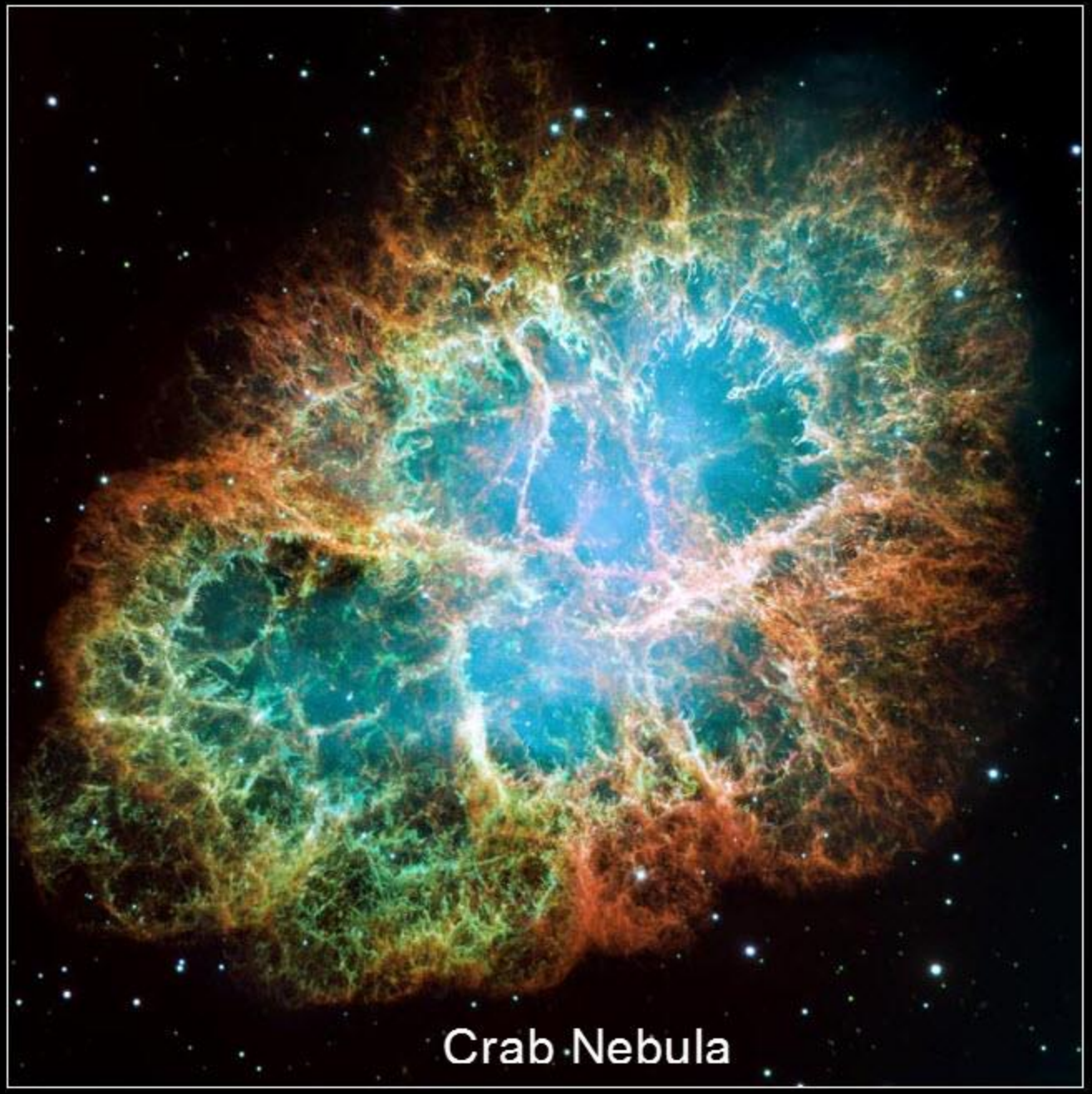
Images credit: NASA/JPL-Caltech

Hubble Telescope

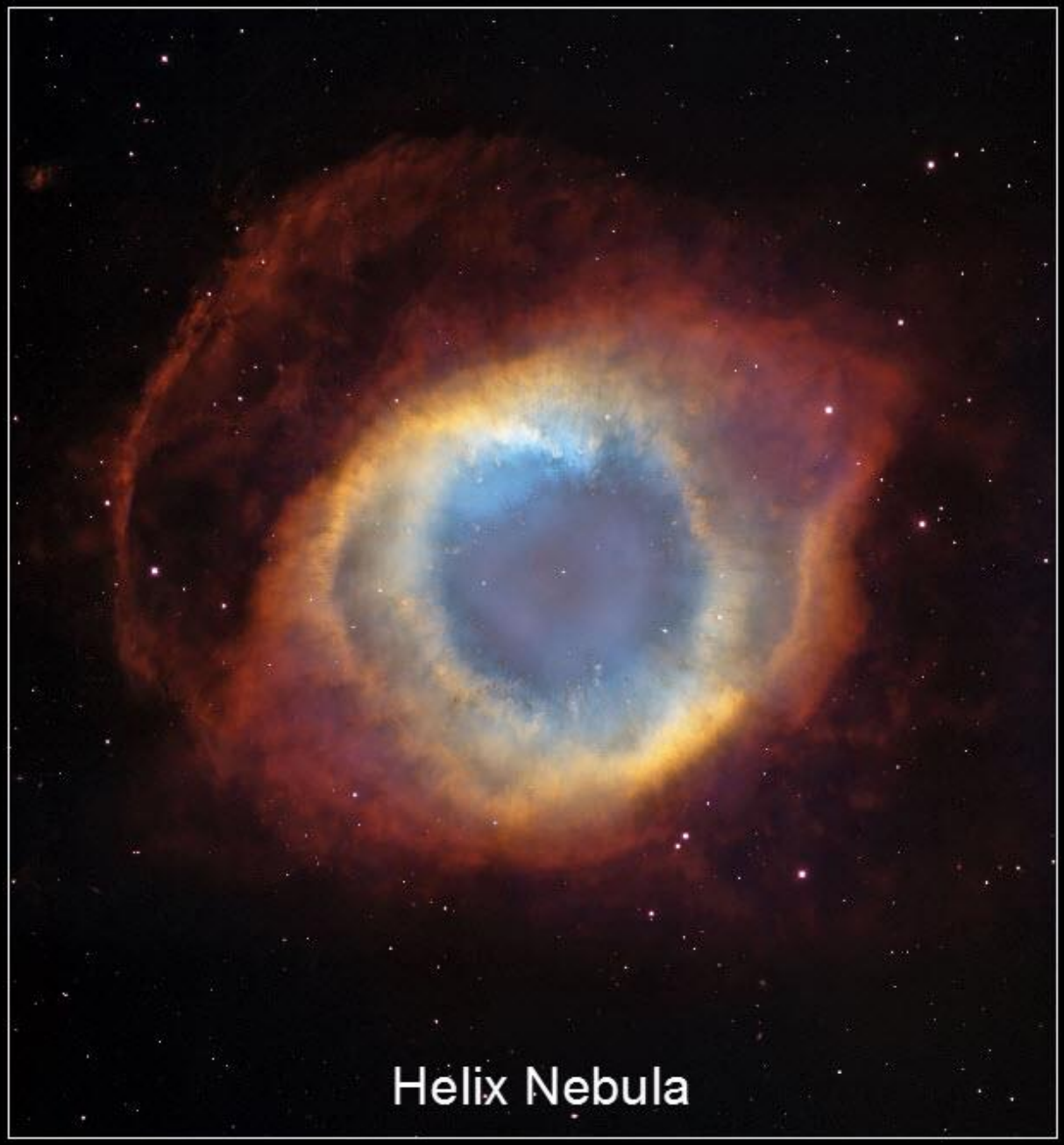
HUBBLE Space Telescope

1st of 4 Great Observatories
Launched 24 April 1990

Images credit: NASA/JPL-Caltech



Images credit: NASA/JPL-Caltech



Images credit: NASA/JPL-Caltech

Spiral Galaxy M81

Two Galaxies Colliding

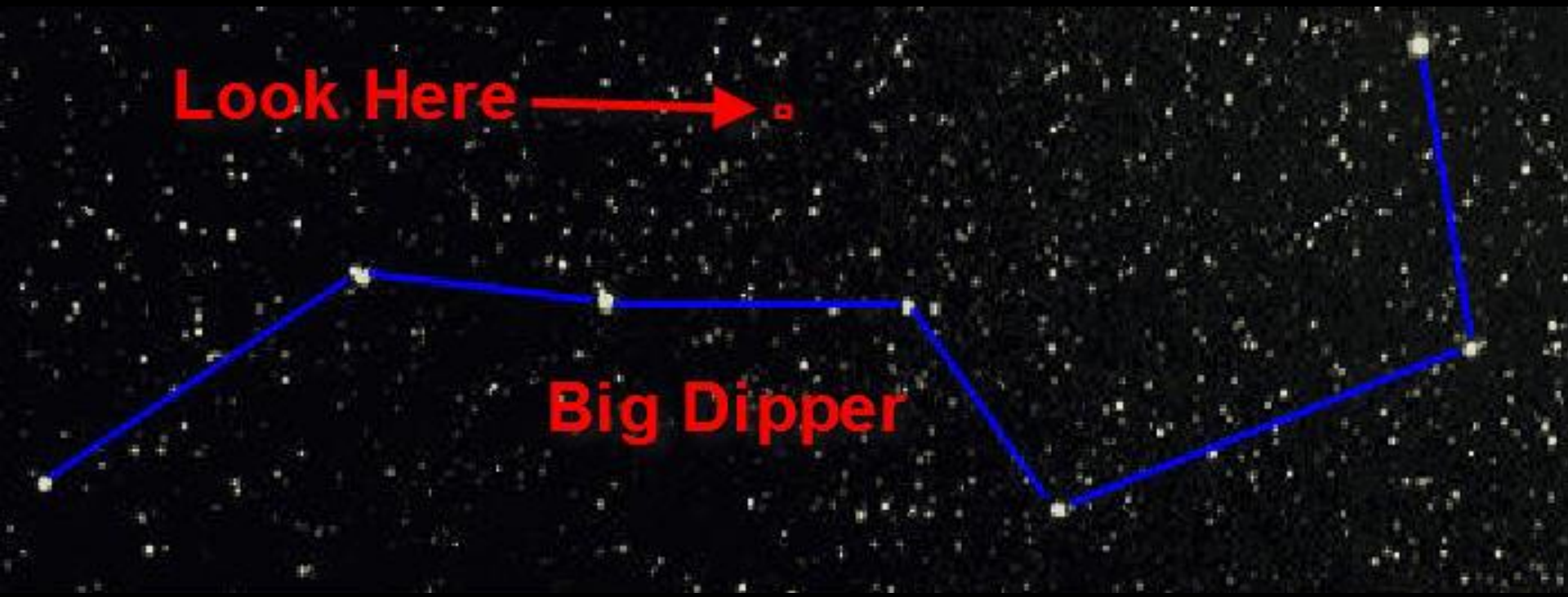
Images credit: NASA/JPL-Caltech

Images credit: NASA/JPL-Caltech

So…….How good is Hubble?

Images credit: NASA/JPL-Caltech

After servicing……How good is Hubble?

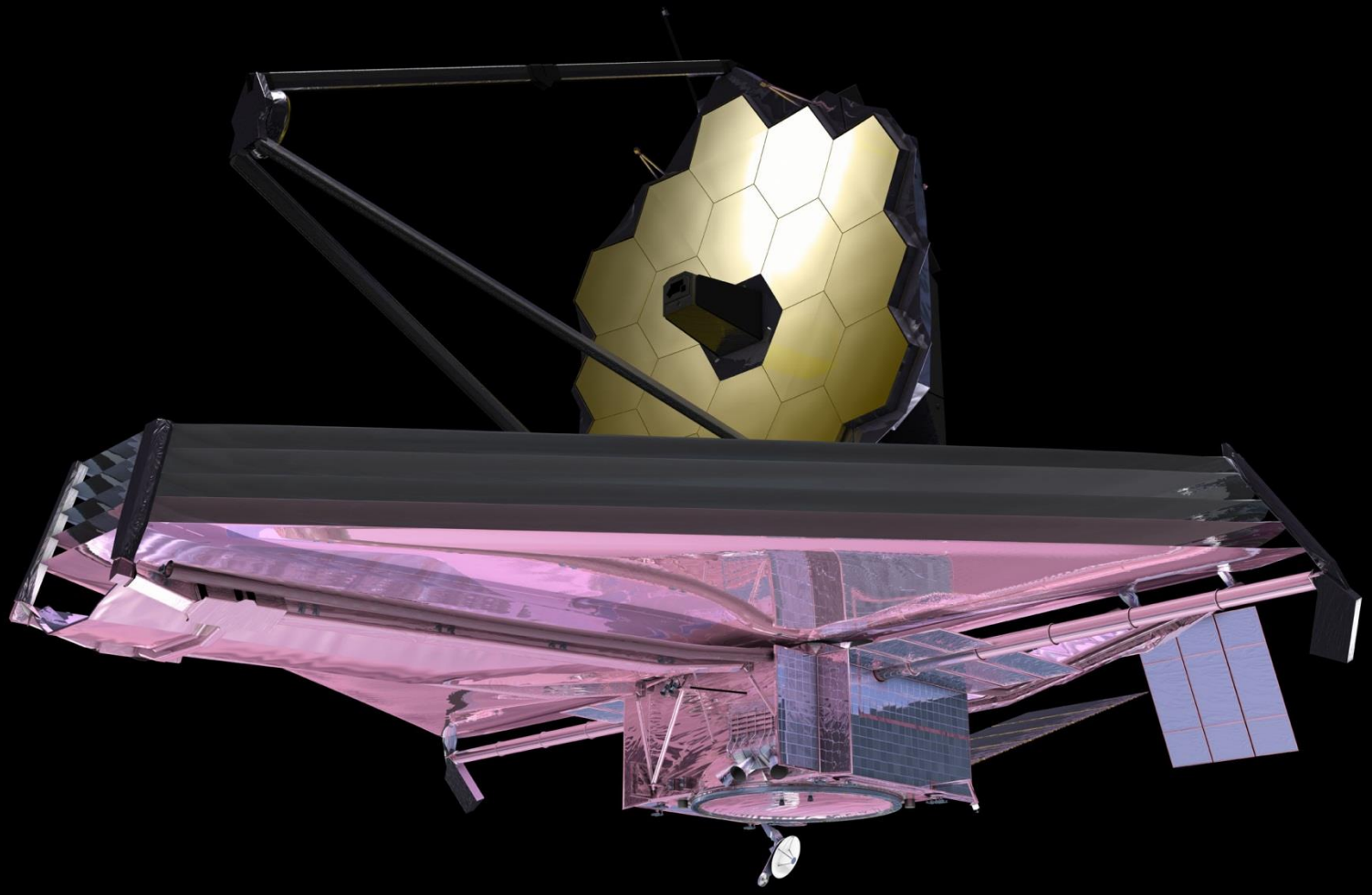


No Earth-based telescopes can see anything in the red square, so…

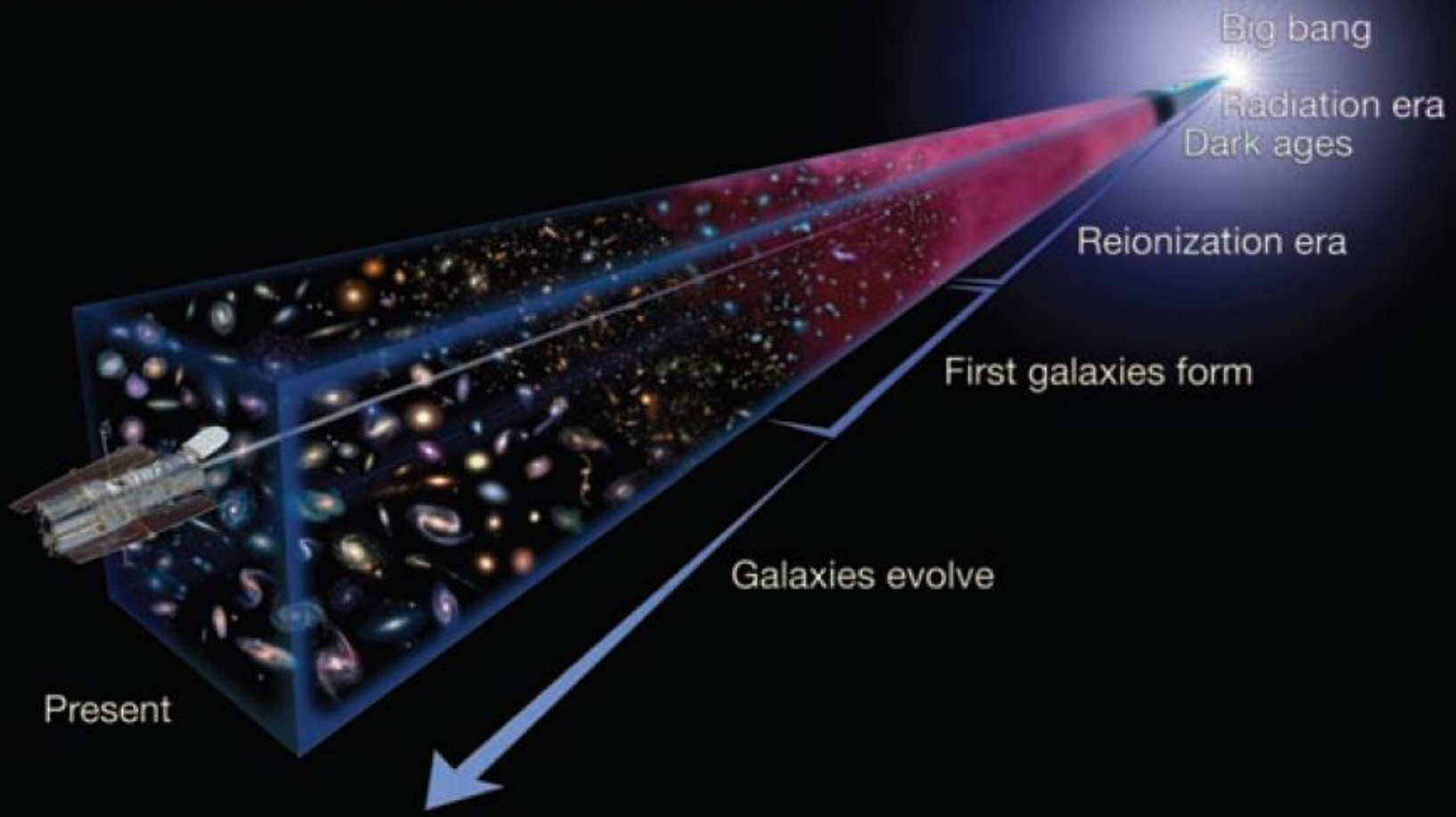
let’s have Hubble look there

Images credit: NASA/JPL-Caltech

James Webb – 2018 (will be parked at L2)



Hubble's Deep Core Sample of the Universe

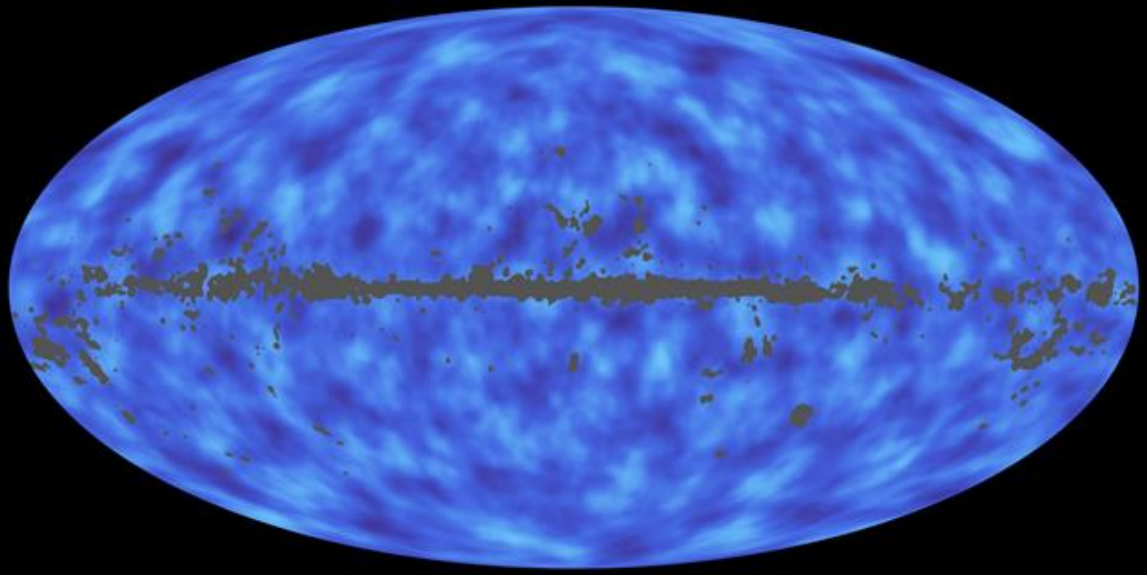


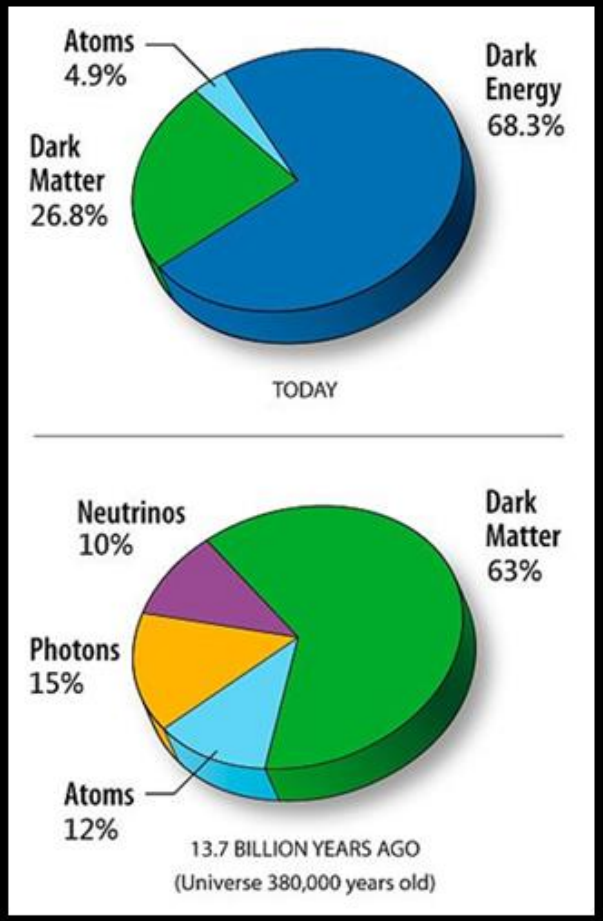
Year	Image Name	Total Exposure	Oldest Galaxy Age
2004	Hubble Deep Field	11.3 days	**12.9 B years**
2009	Hubble Ultra Deep Field	Added Infrared	**13.0 B years**
2012	Hubble eXtreme Deep Field	22 days	**13.2 B years**
2018	James Webb Space Telescope	<4 days	**13.5 B years**

The Universe

Age of the Universe		
Year	Source	Age (Years)
1700	Isaac Newton	6,000
1929	Edwin Hubble	2B
1955	Walter Baade	6B
1965	Alan Sandage	15-25B
1993	Hubble Telescope	12-20B
1997	Hubble Telescope	13-14B
2006	Hubble Telescope	13.7B
2012	WMAP Probe	13.77B
2013	Planck Telescope	13.82B

Composition of Universe		
Ordinary Stuff	Dark Energy	Dark Matter
4.60%	71.40%	24.00%
4.90%	68.30%	26.80%





Human Exploration Update

LOCKHEED MARTIN

Why Human Exploration?

International Space Station (ISS)

This is the furthest we have gone in 42 years

The Old: Space Shuttle (now retired)

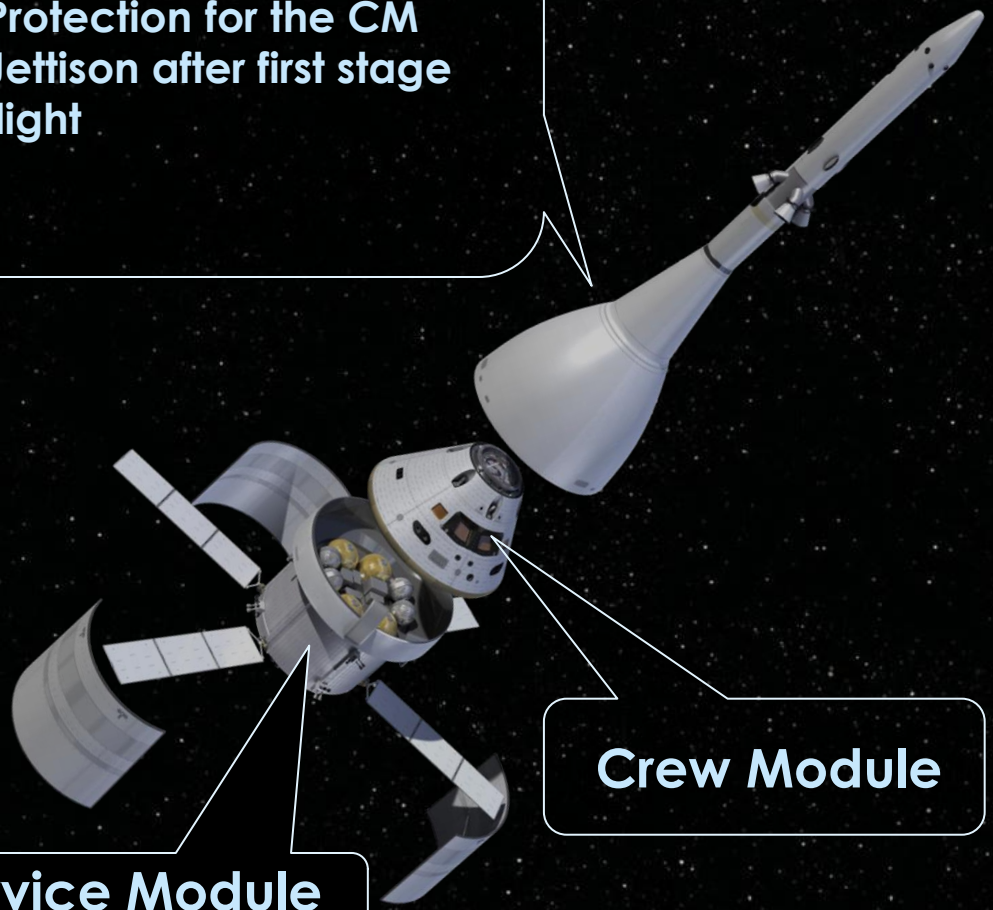
The New - Exploration Systems Development

- Orion Program
- Space Launch System (SLS)
- Ground System Development

Orion

Launch Abort System

- Protection for the CM
- Jettison after first stage flight



Objective:

Take humans safely beyond LEO …

… and return them safely back to Earth

June 23, 2014 Aviation Week

Image Credit: Lockheed Martin

Completed Orion Demonstrations

- Launch Abort System
- Parachute Deployment
- Landing & Recovery
- Human Factors - Suits
- Acoustic Vibration
- Up-righting System
- Hardware/Software Integration
- Controls Evaluation
- Thermal Protection Systems
- Proof Pressure & Structural Loads
- Power-on

Image Credit: Lockheed Martin

Pad Abort Test

Orion Pad Abort Test (2010)

Enhances crew safety
by providing crew escape capability in the event of pad or ascent emergencies

Expands the envelope
of survivable abort conditions over previous abort systems by providing active attitude control during aborts.

3 new solid rocket motors, successfully fired and operated together as a system during the successful Pad Abort 1 flight test

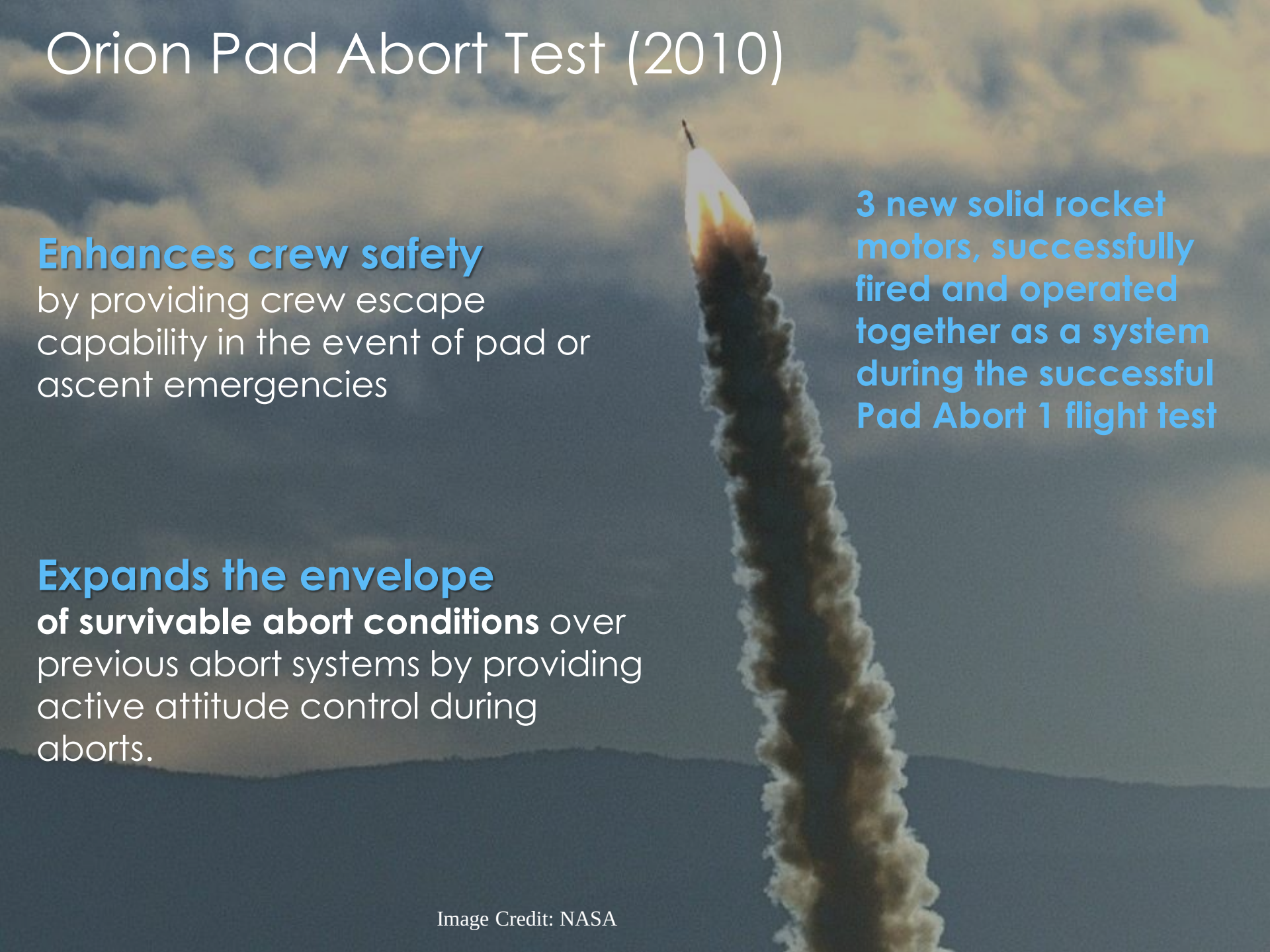


Image Credit: NASA

Service Module Fairing Separation Test

Image Credit: NASA

Parachute Drop Tests

ARMY YUMA PROVING GROUND, AZ

Image Credit: NASA

HIB Drop Tests

Image Credit: NASA

Forward Bay Cover Separation Test

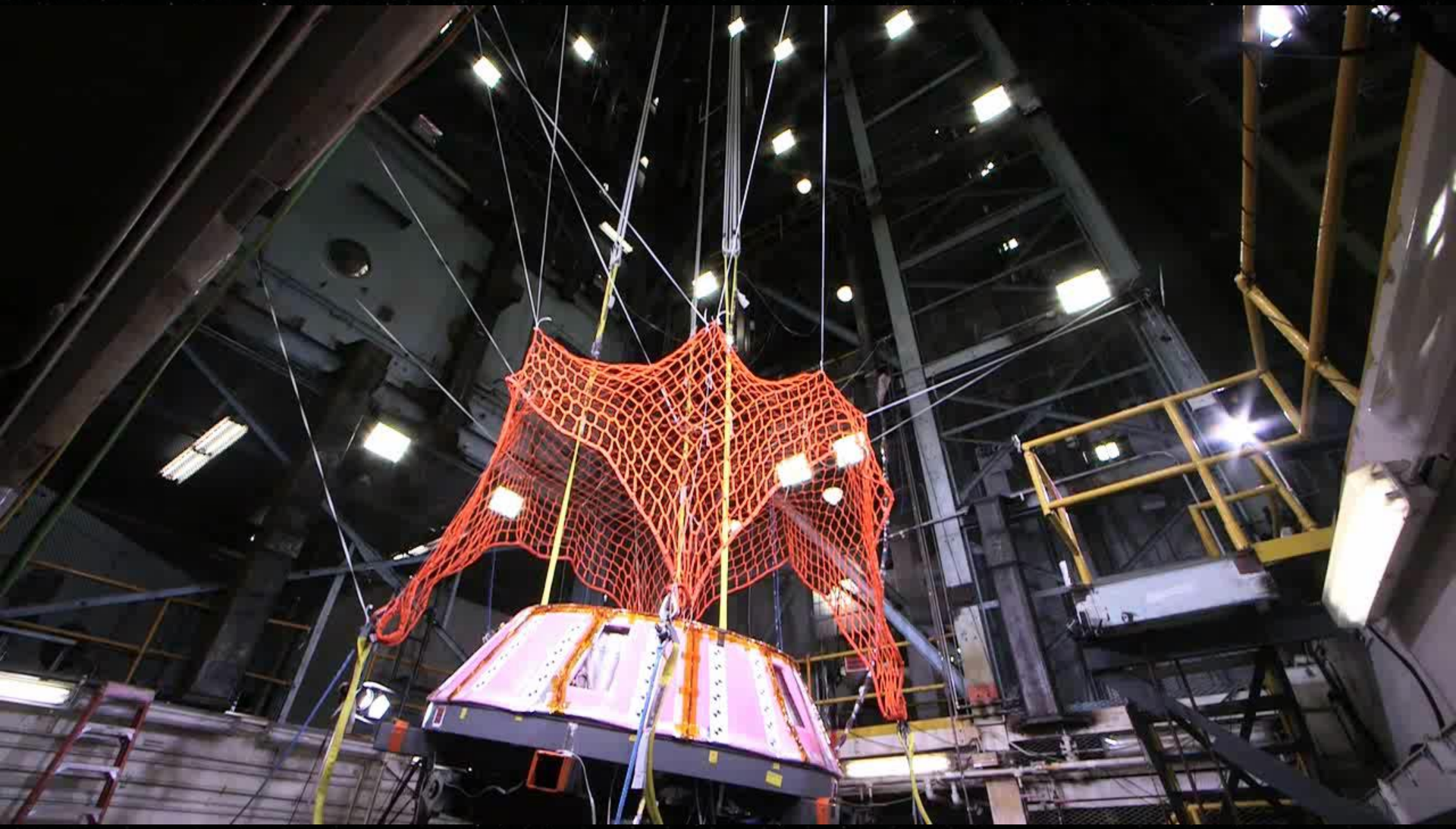
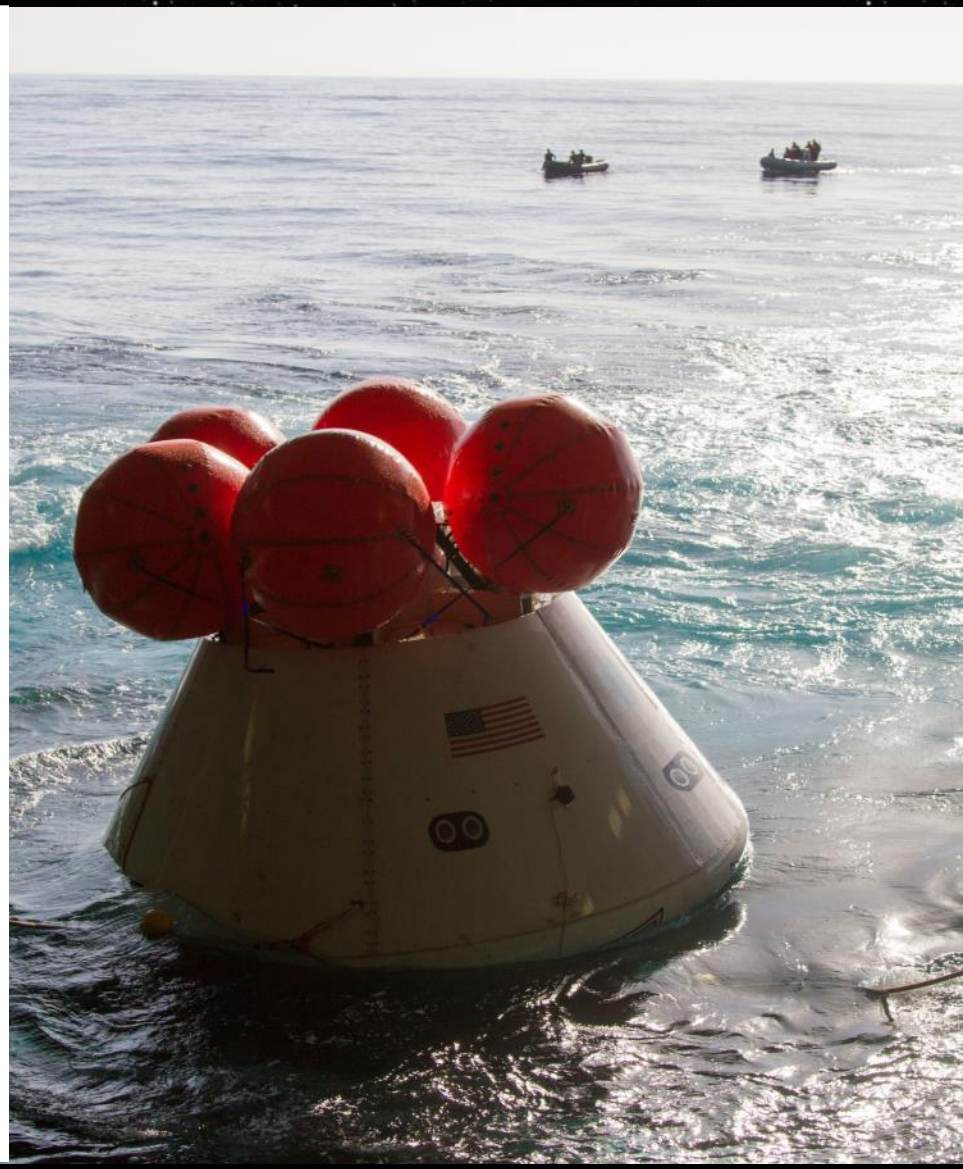


Image Credit: NASA

Recovery Testing Complete



SAN DIEGO, CA

Image Credit: NASA

Crew Ascent Simulations

JOHNSON SPACE CENTER, TX

Image Credit: NASA

Mission Control Center Ready

JOHNSON SPACE CENTER, TX

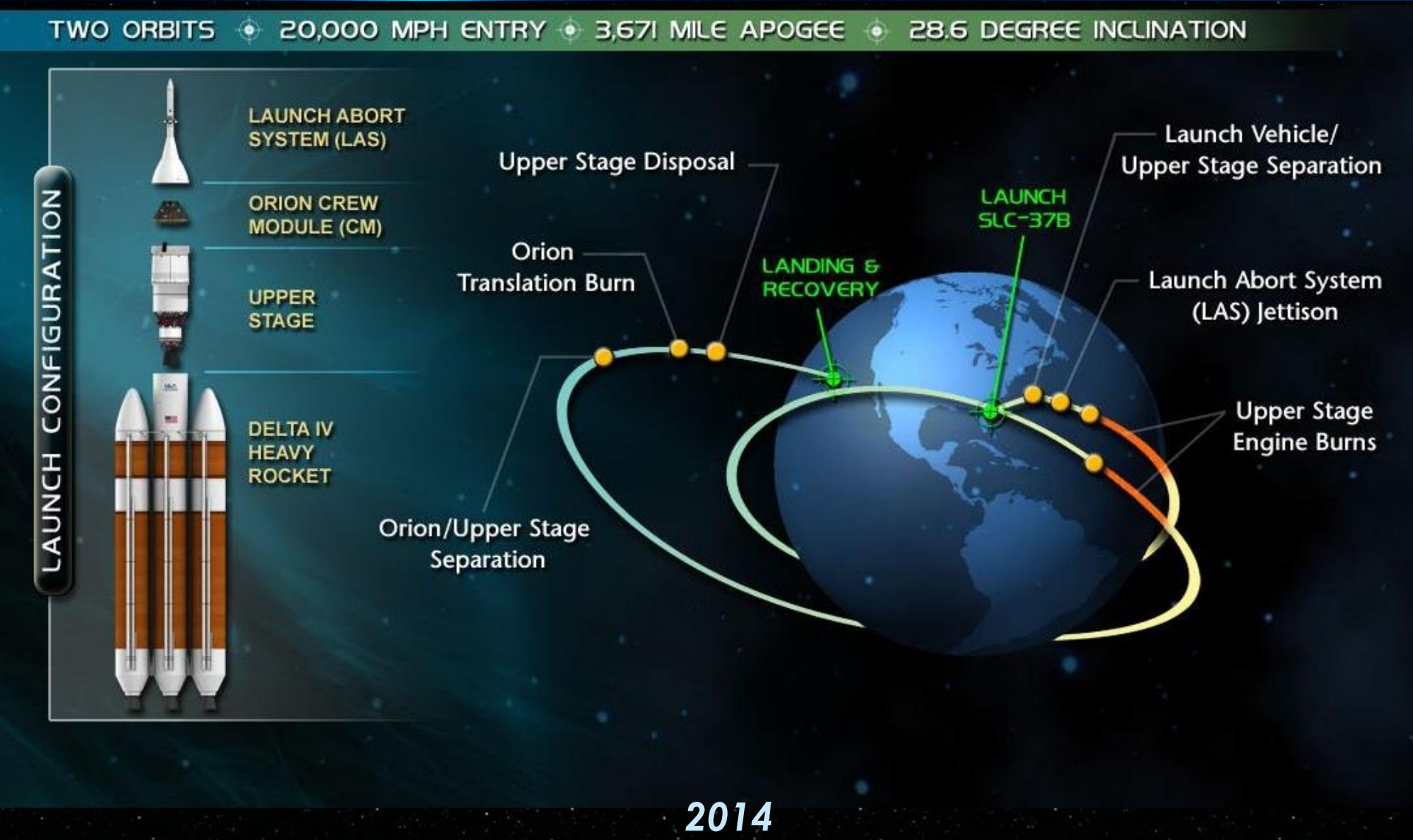
Image Credit: NASA

Orion Exploration Flight Test – 1

- America's first space vehicle specifically designed for human deep space exploration
- Launched on a Delta IV Heavy Rocket on Dec 5, 2014
- The beginning of a new era in human space flight
- Will travel to interplanetary destinations on the NASA Space Launch System (SLS)

Image Credit: ULA

Exploration Flight Test – 1



2014

Image Credit: NASA

Re-Entry

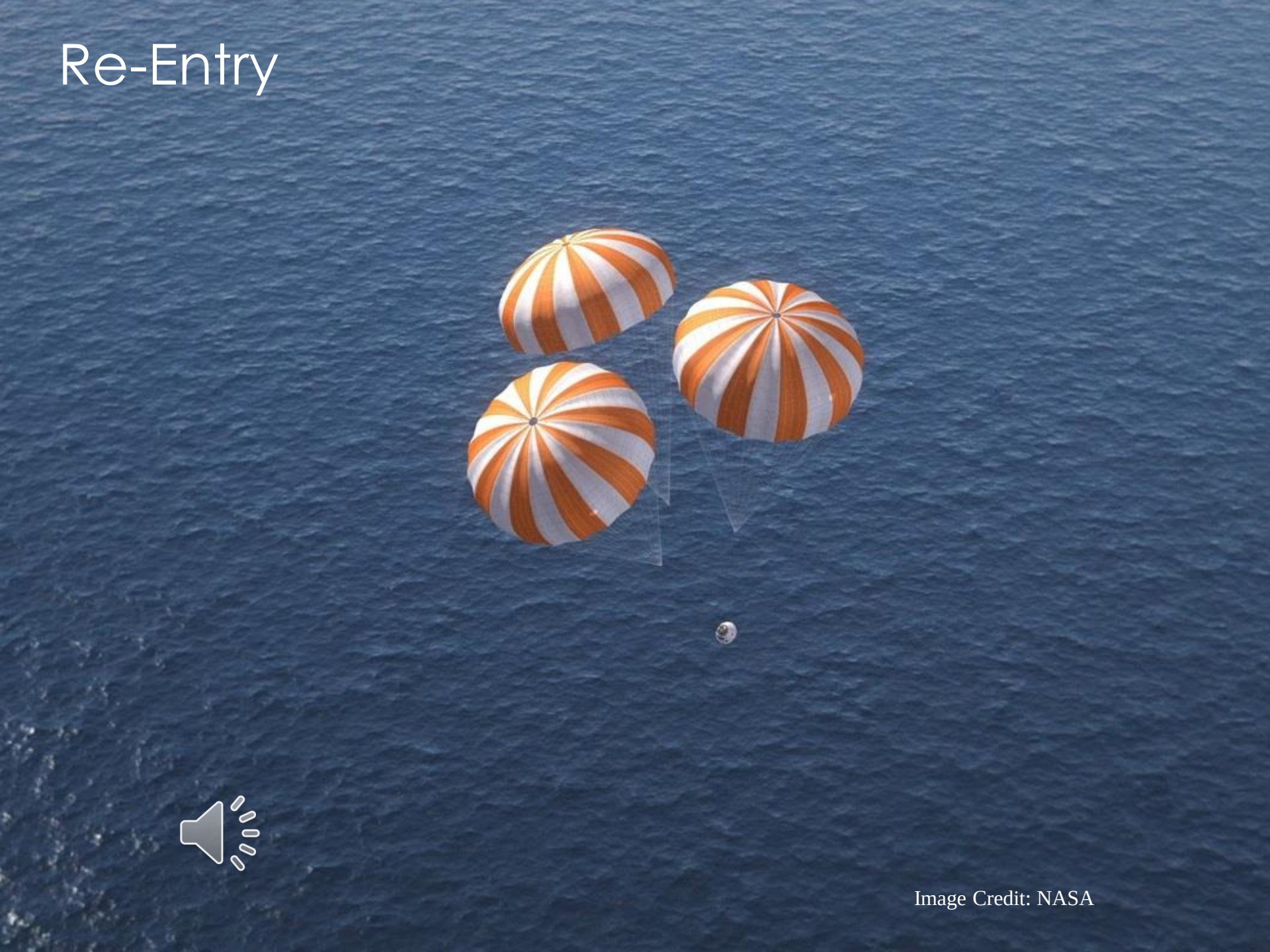


Image Credit: NASA

Image Credit: US Navy

US Navy Well Deck ship (Pacific Ocean)

Image Credit: US Navy

Successful Retrieval

Image Credit: US Navy

Cross-Country Road Trip

Image Credit: US Navy

Orion back at KSC

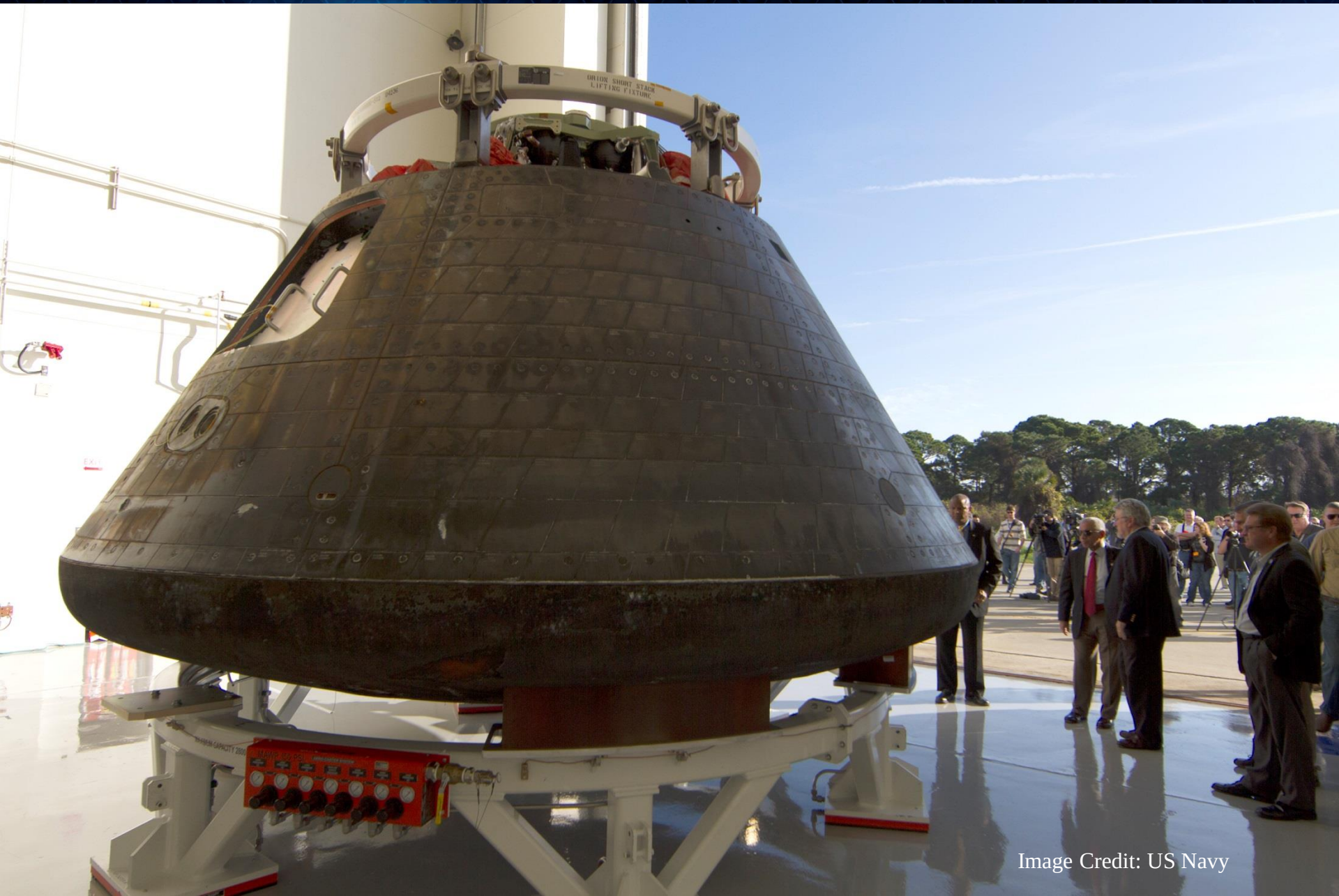


Image Credit: US Navy

What's Next? Orion Mission Timeline

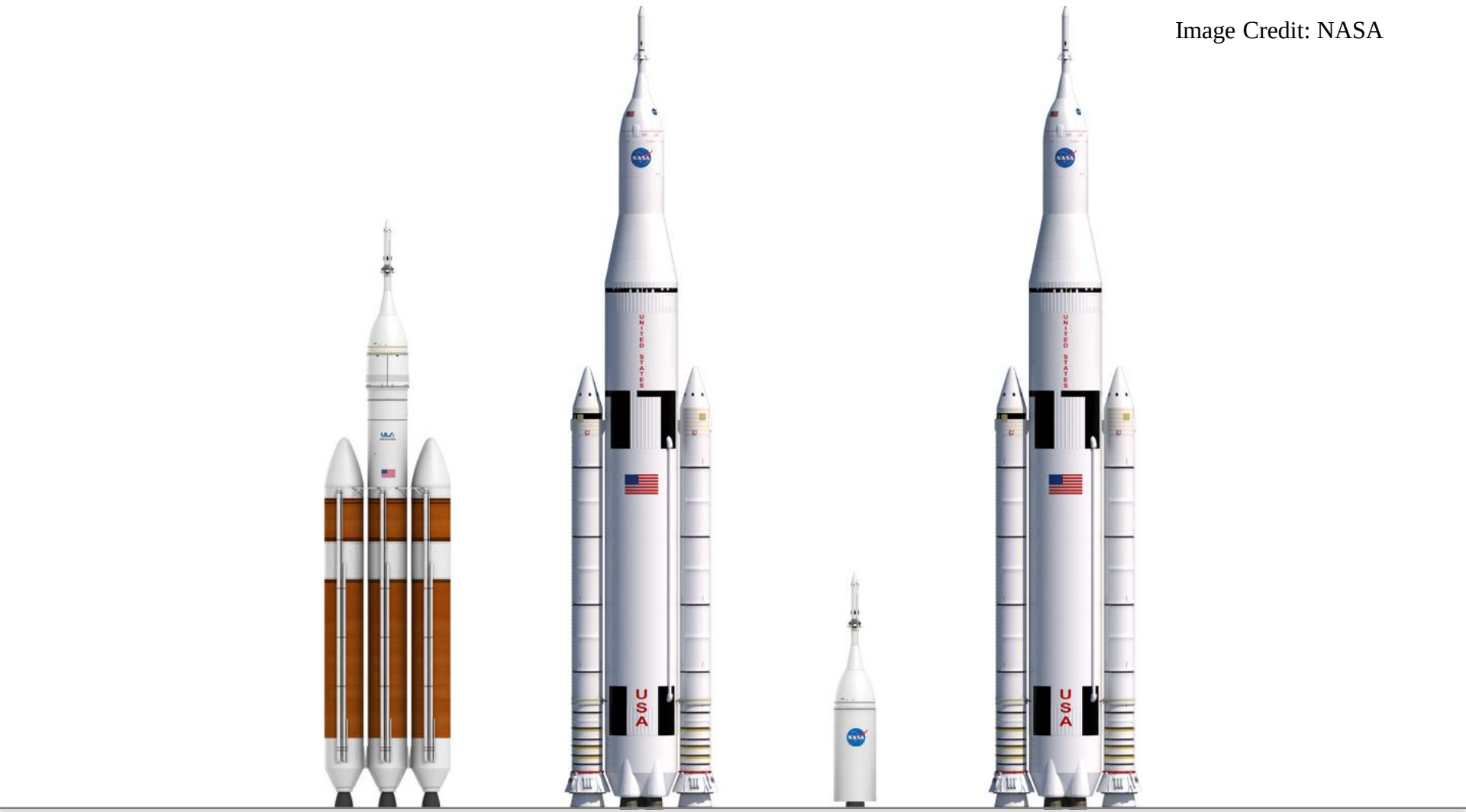


Image Credit: NASA

2014
EFT-1

2018
EM-1

2018
AA2

2021
EM-2

Stepping Stones

A series of exploration missions building incrementally towards the long term goal of exploring Mars.

Each mission will address science objectives relating to the formation of the solar system and the origins of life.

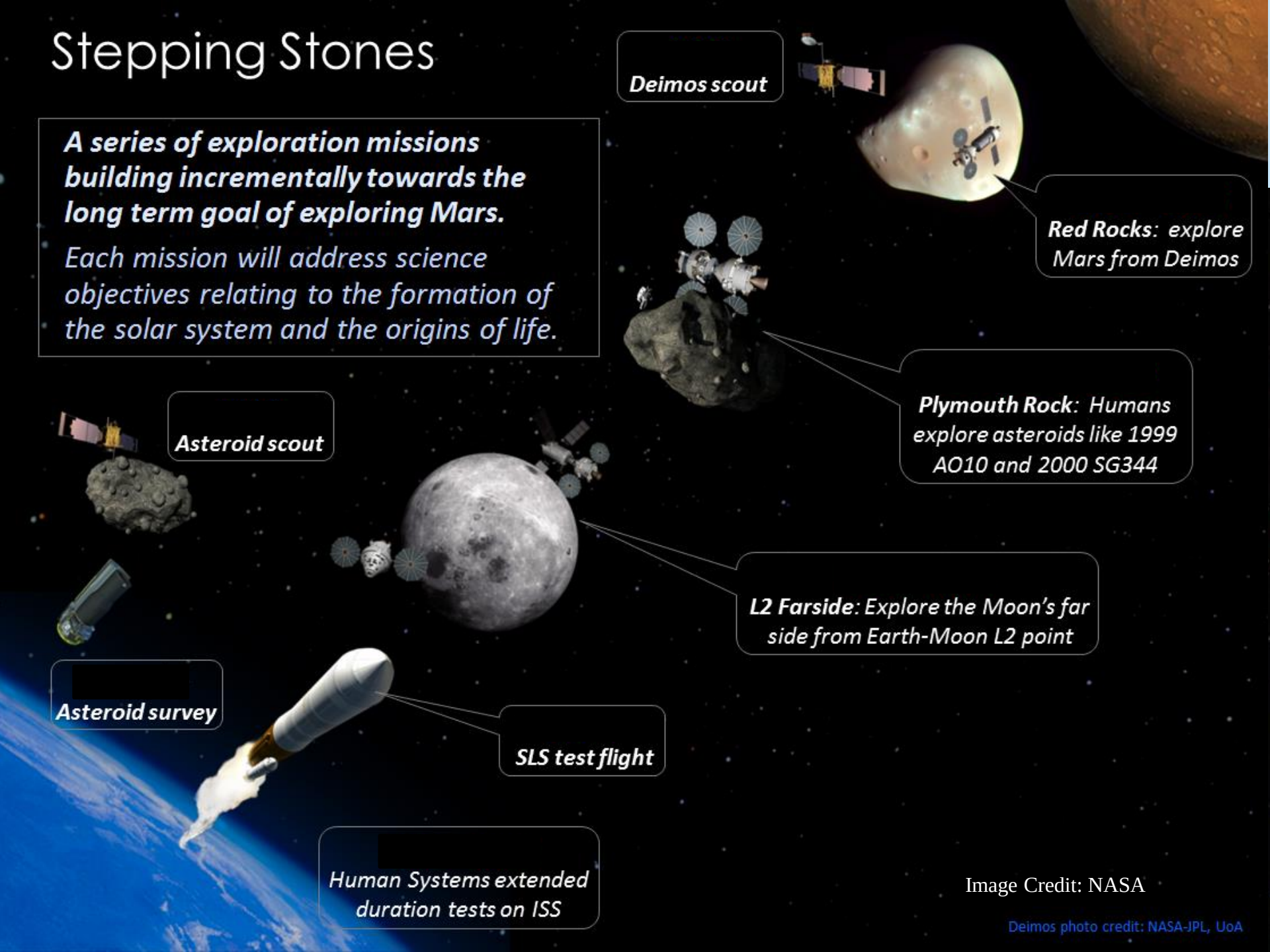


Image Credit: NASA

Deimos photo credit: NASA-JPL, UoA

EM-2 Let's Finish with a ride on Orion