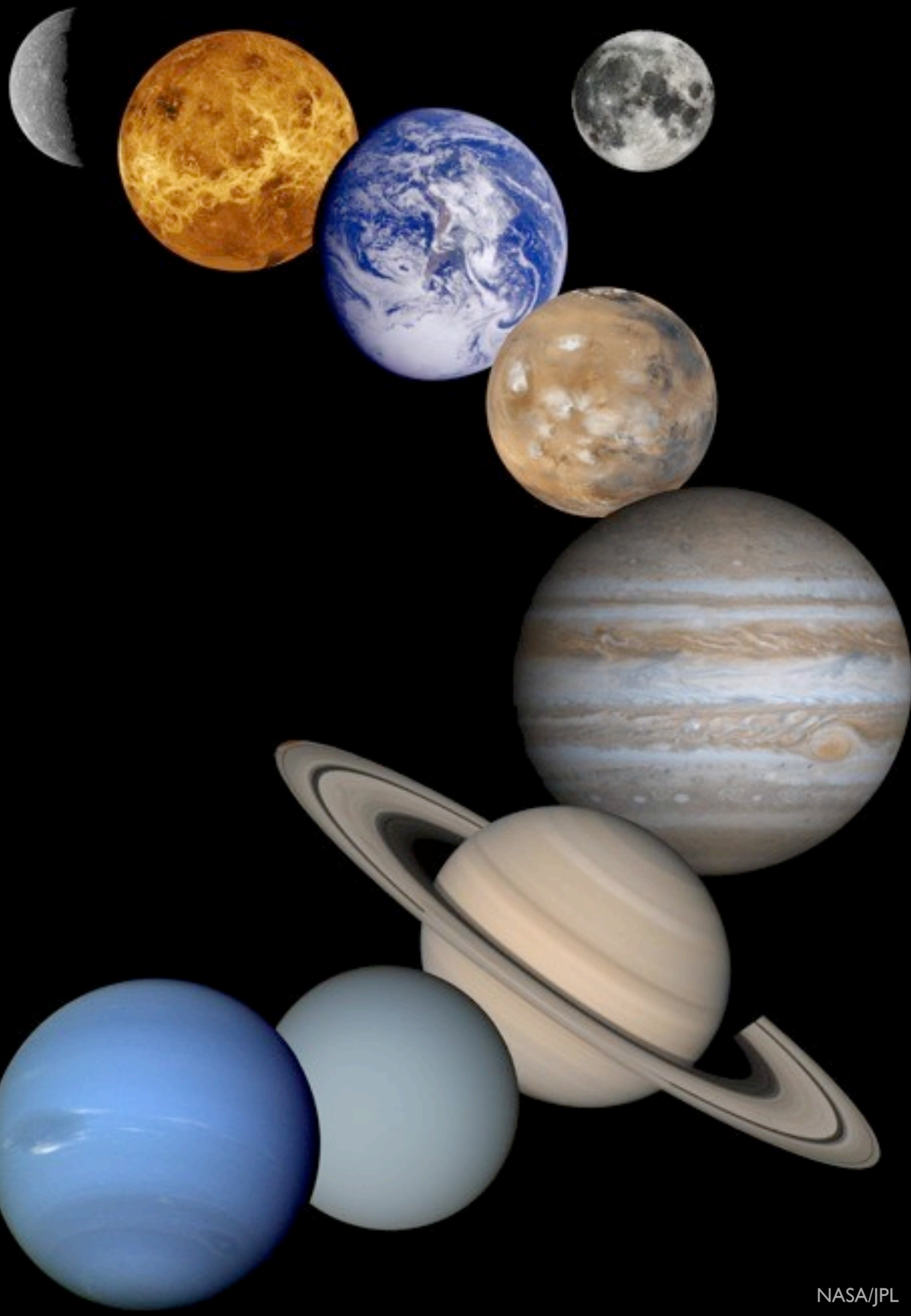
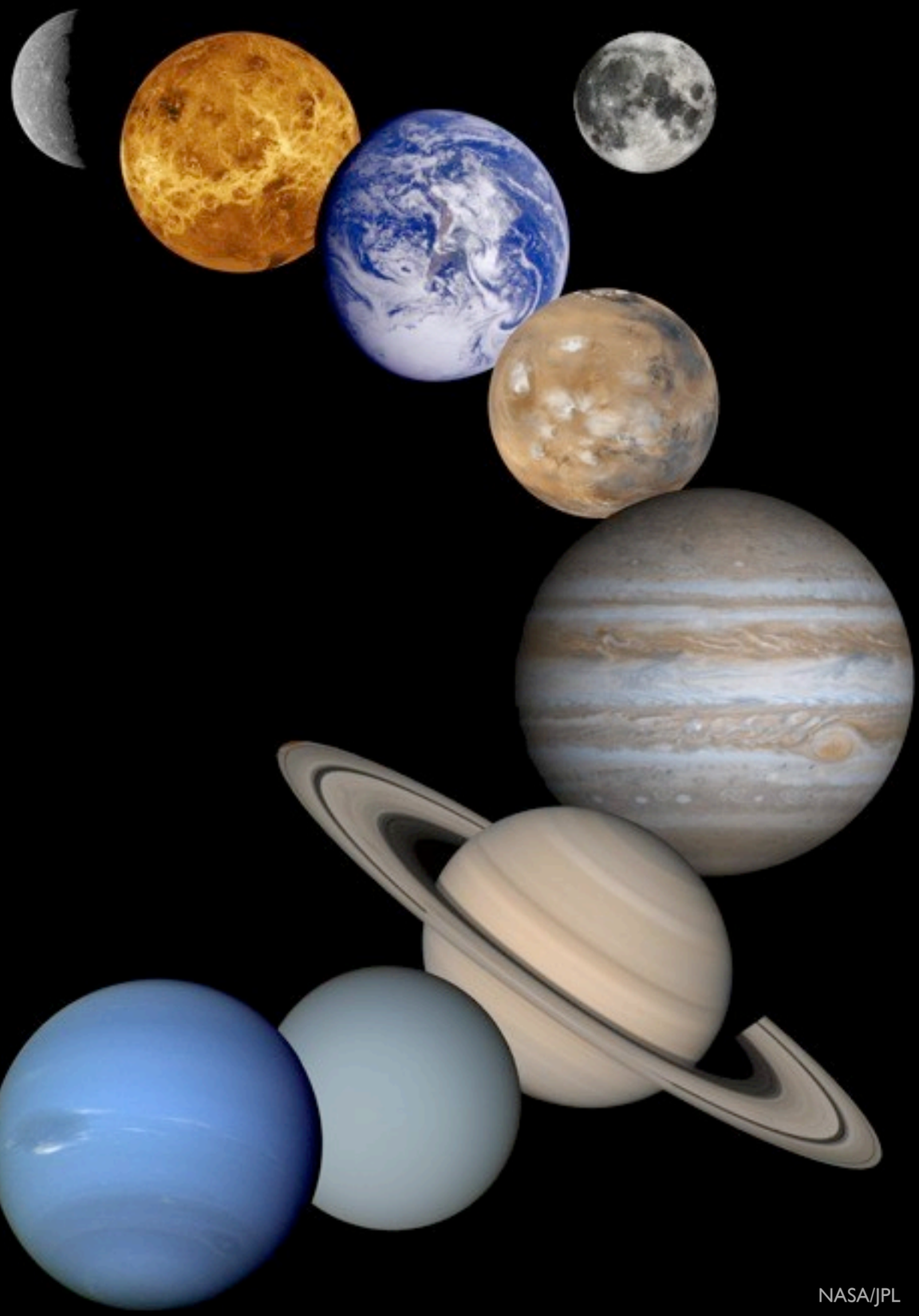
Exploring the Planets-
How we use robots to learn about them

Anjali Tripathi
Institute of Astronomy
27 January 2010

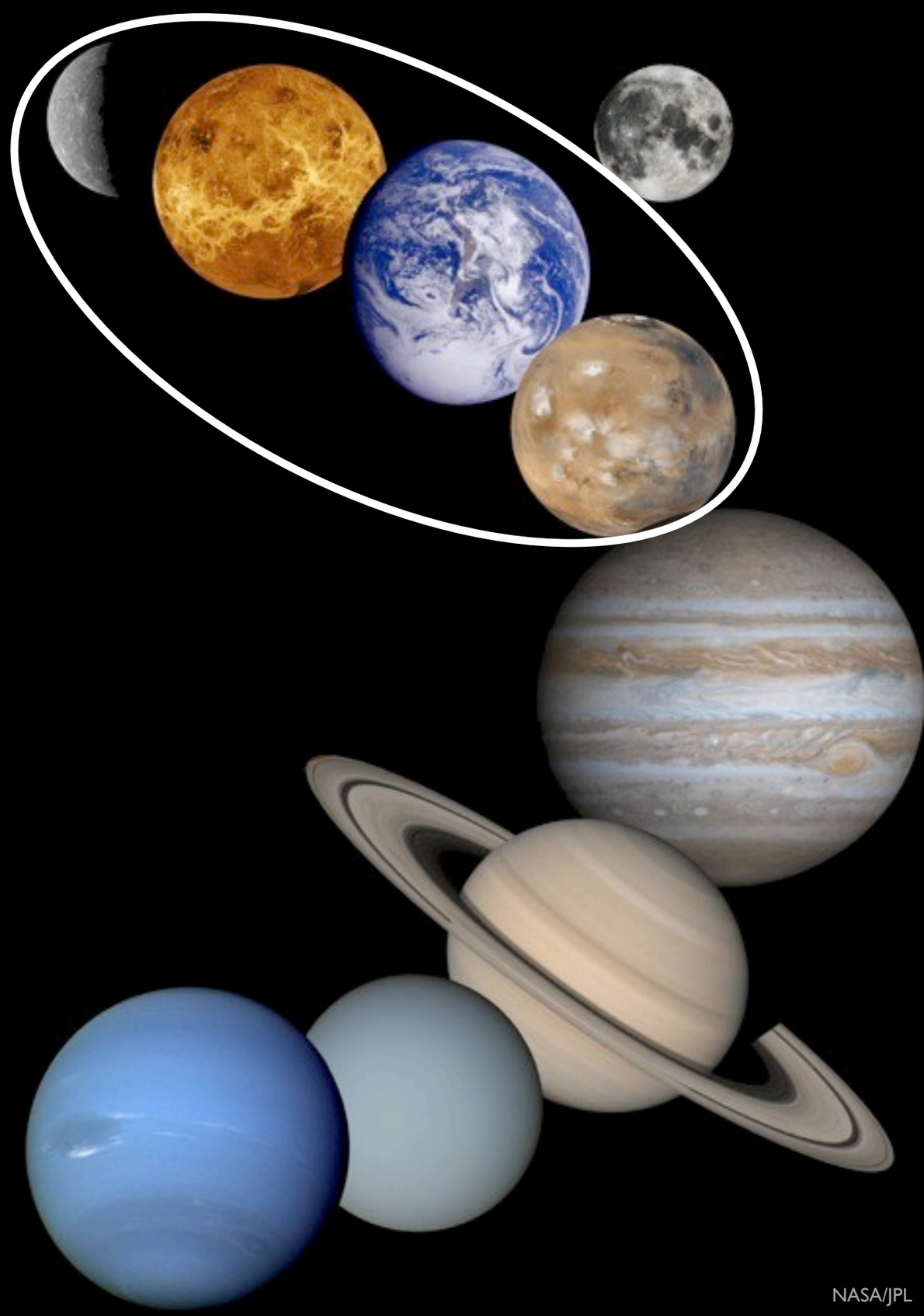


NASA/JPL



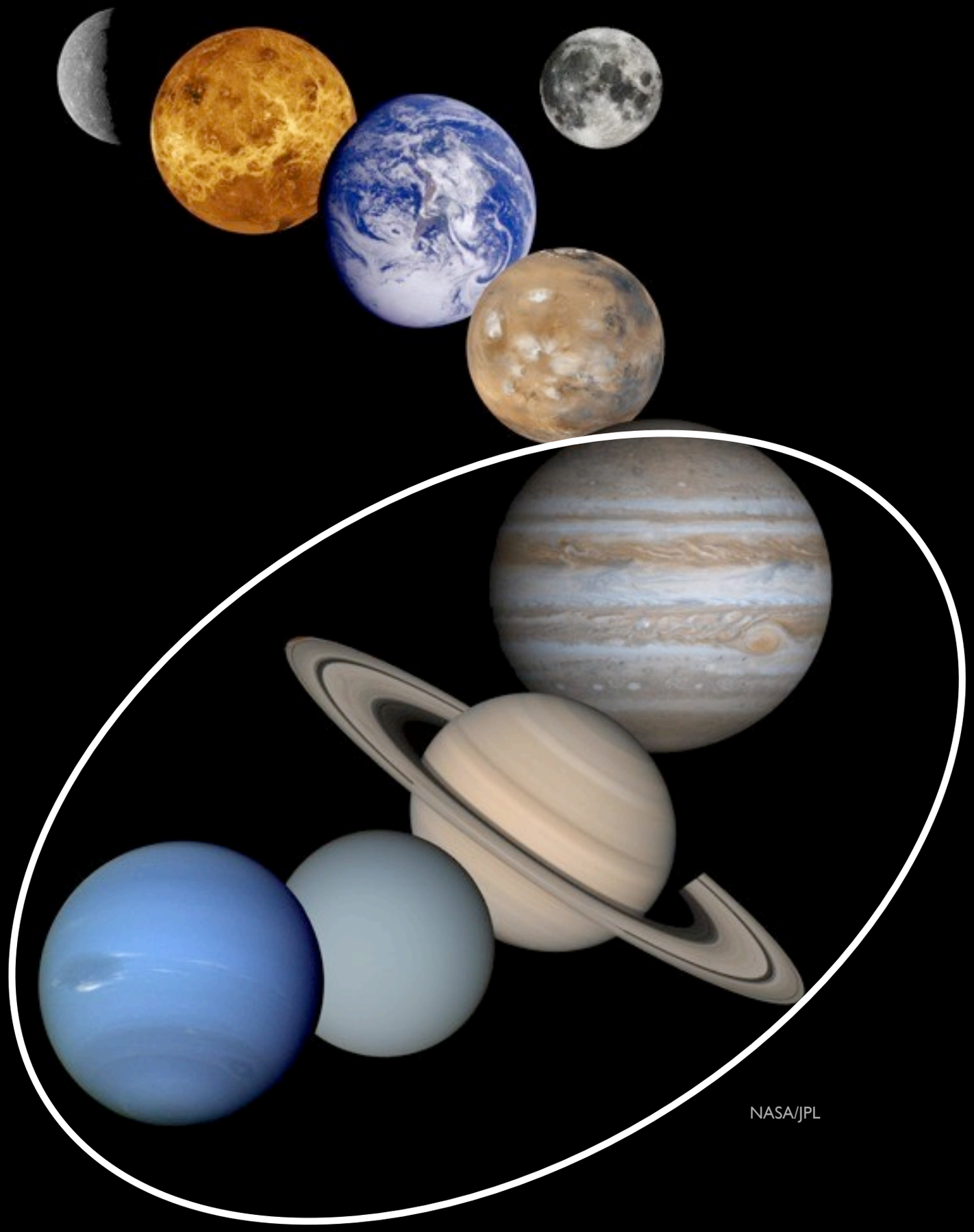
My **V**ery **E**ducated **M**other **J**ust **S**erved **U**s **N**ibbles

Rocky planets



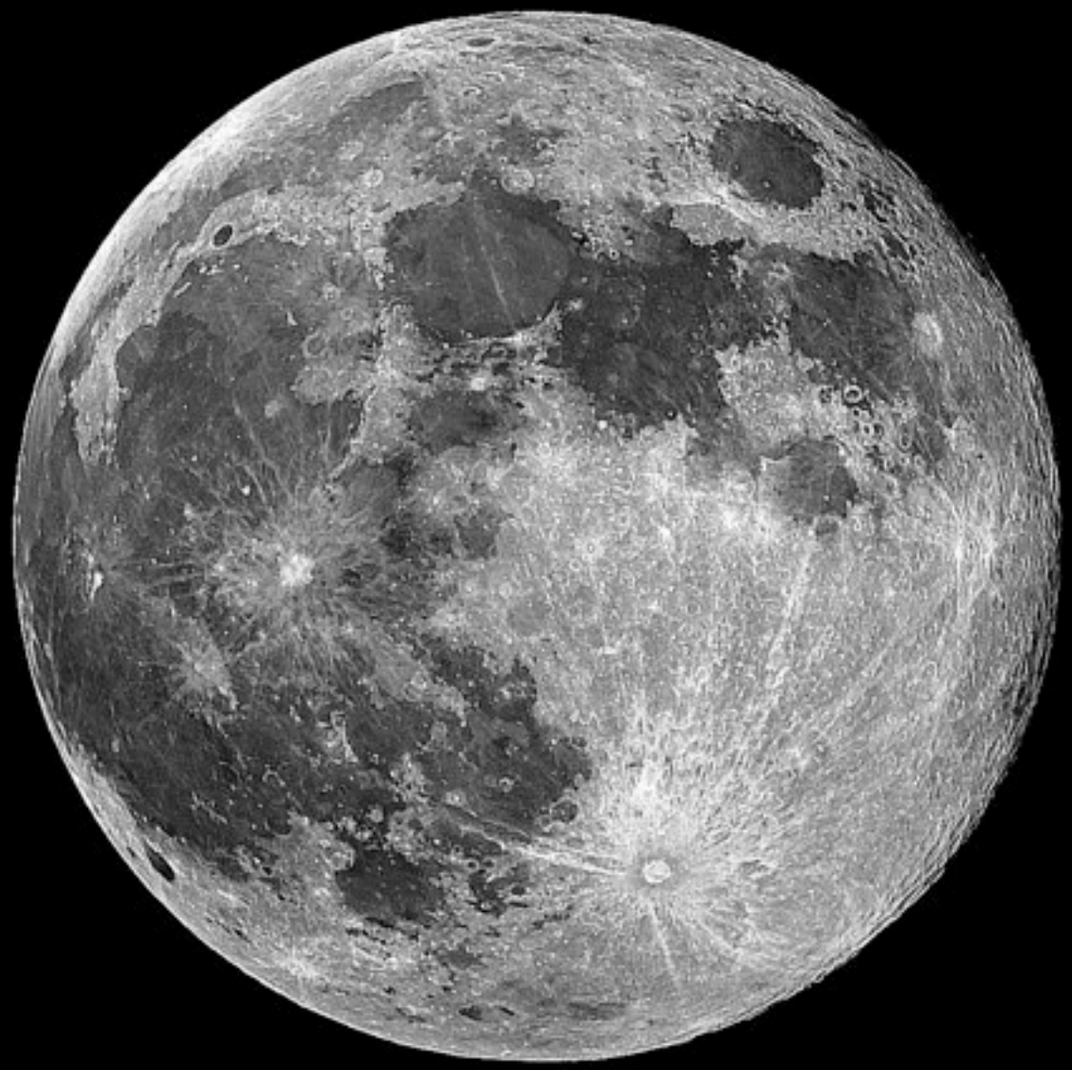
NASA/JPL

Gas giants



NASA/JPL

planets can have **moons**

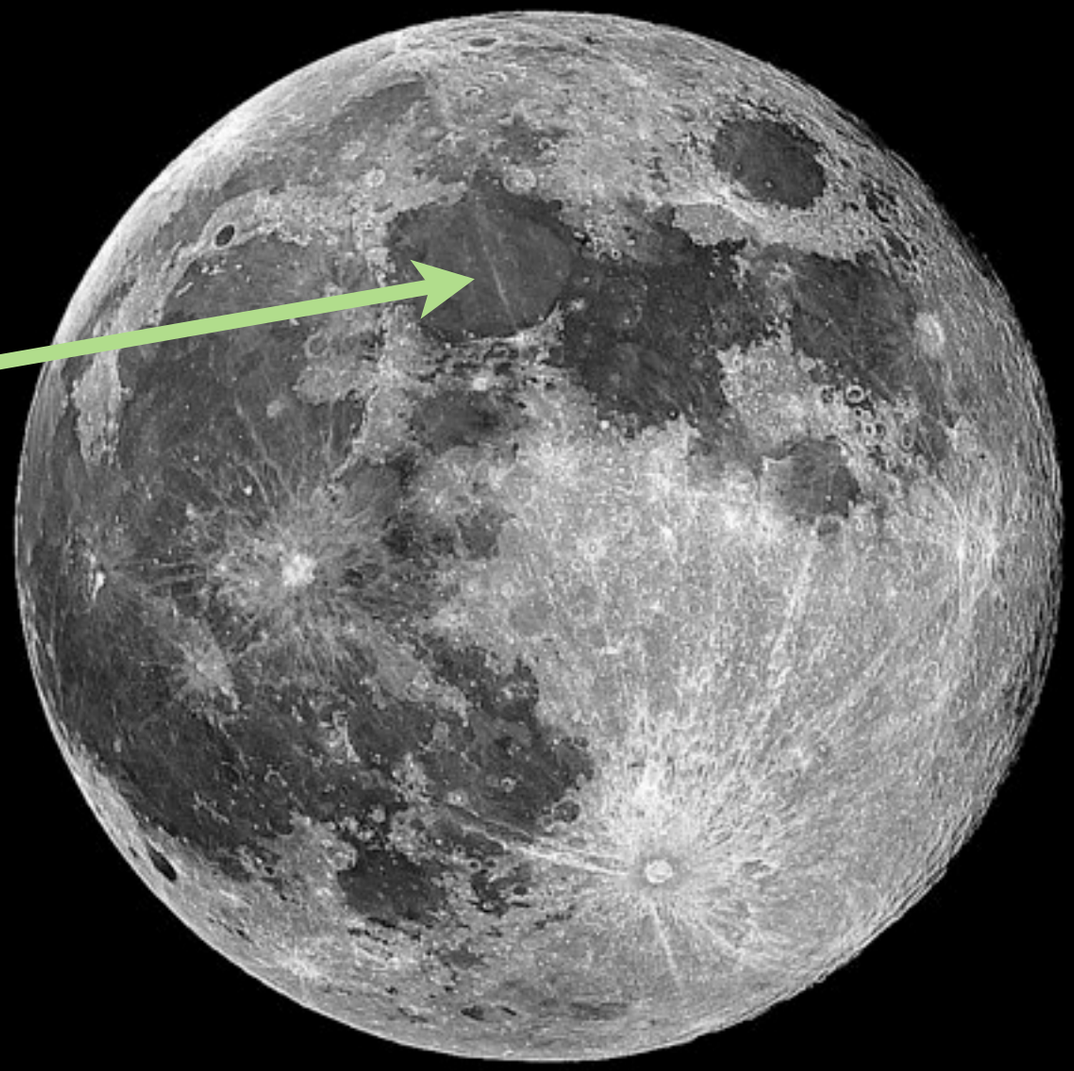


earth’s moon

craters

(planets can have them too)

mercury

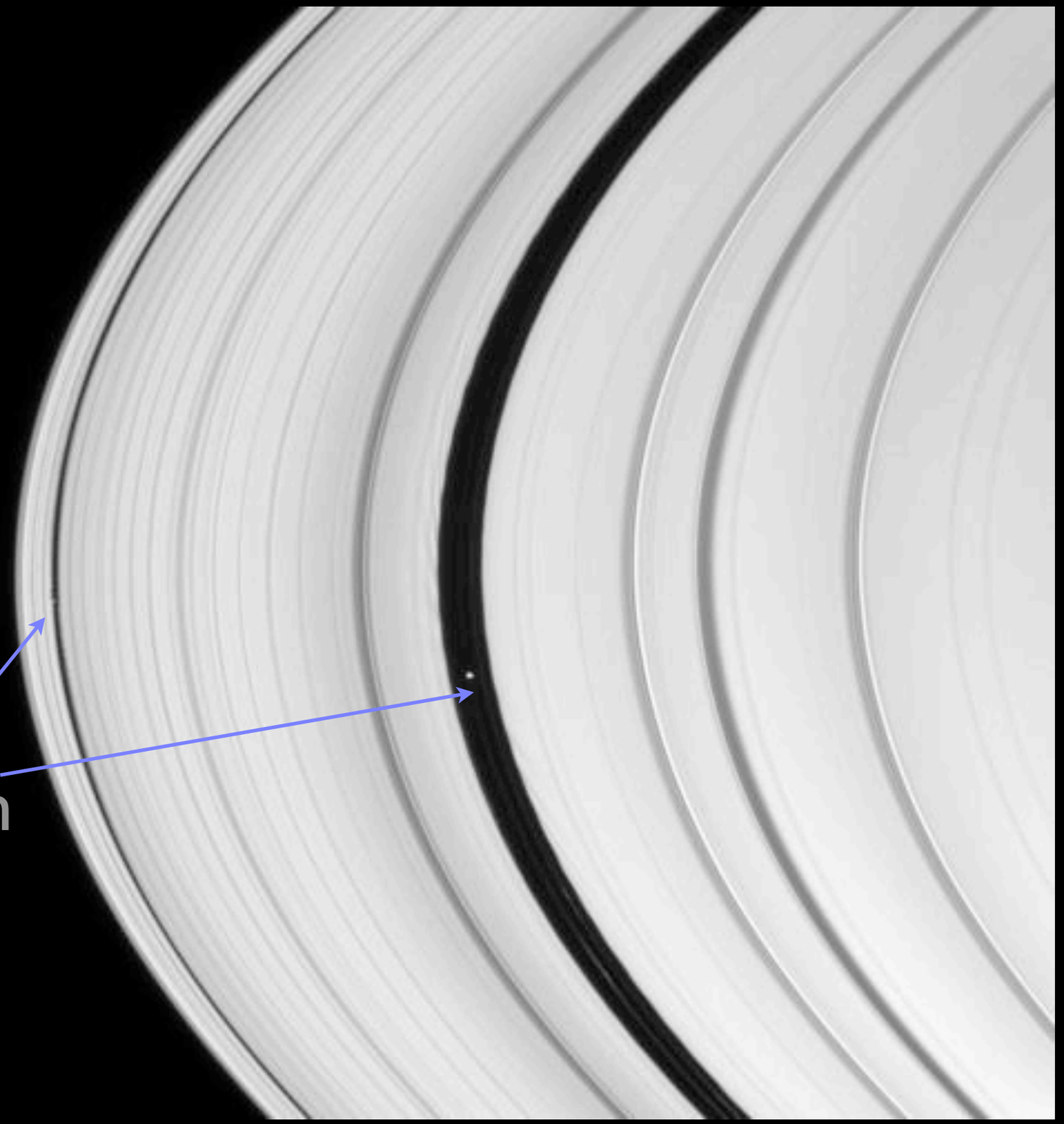


earth's moon

Moons

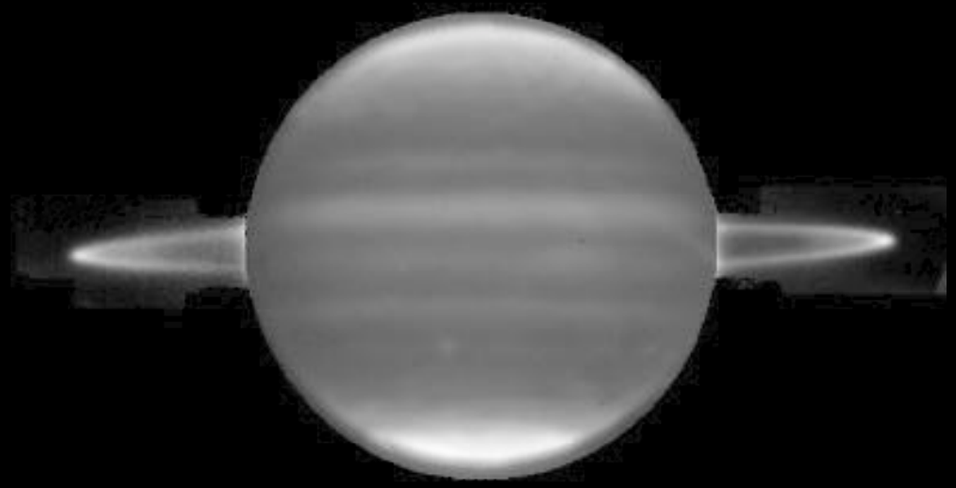
daphnis

pan

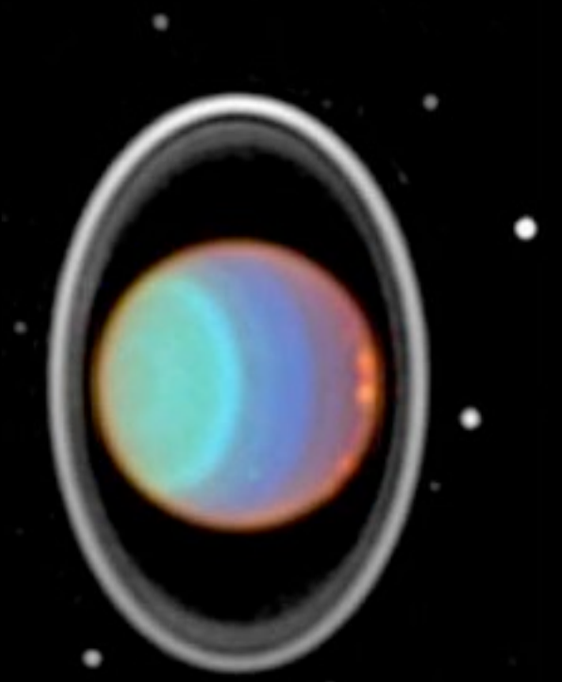


gas giants can have **rings**

saturn

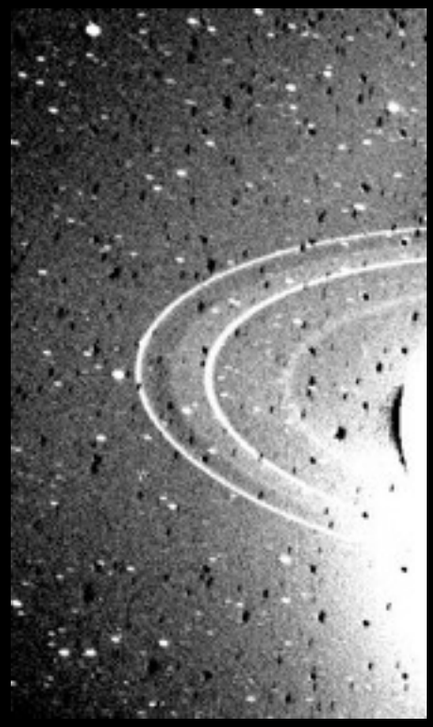


jupiter



uranus

saturn

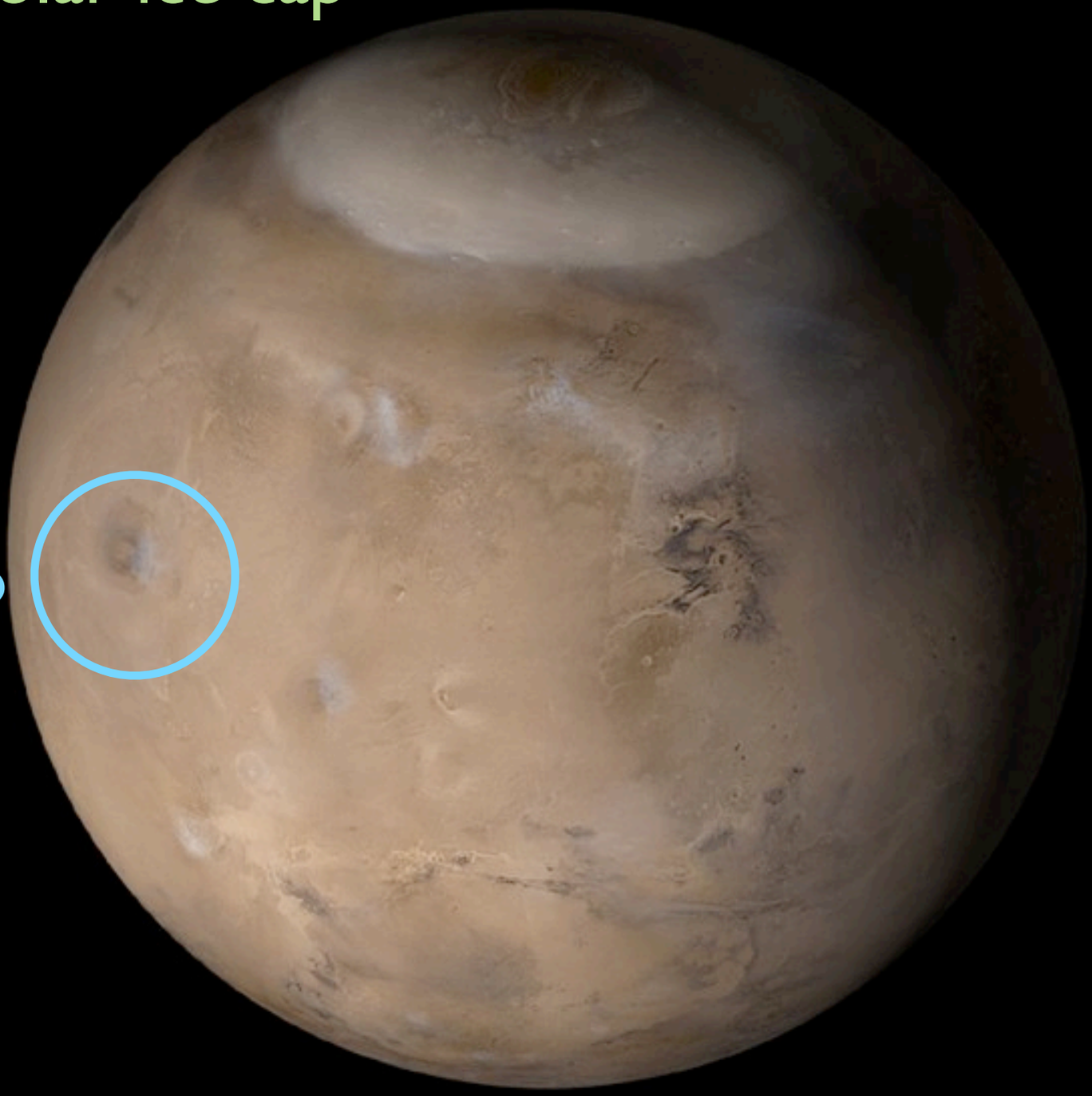


neptune

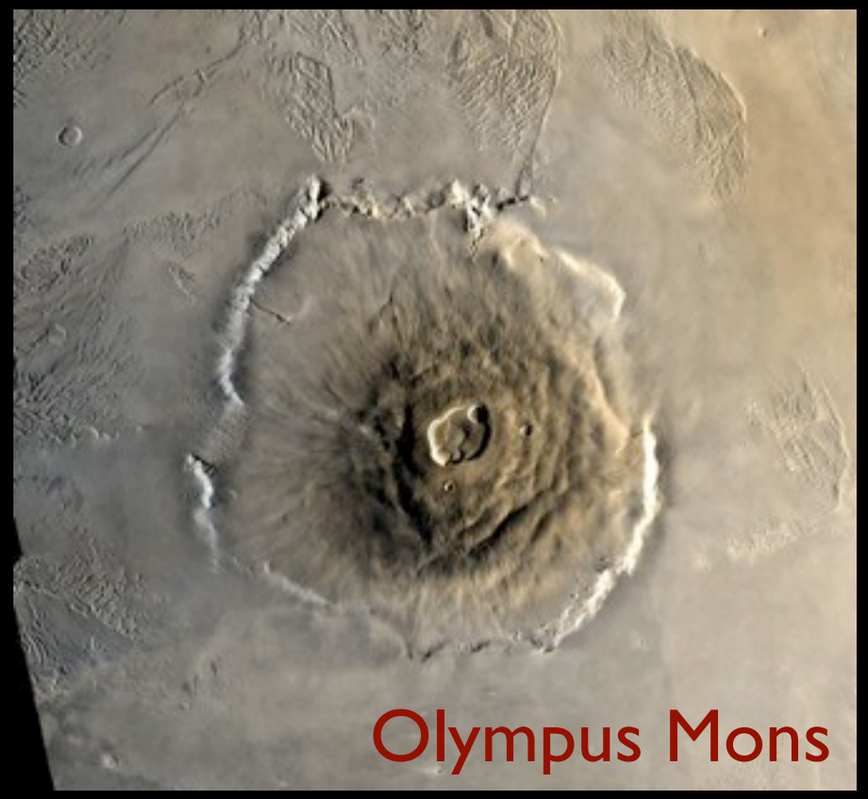
rocky planets can have **volcanoes** & **ice caps**

polar ice cap

volcano



mars



Olympus Mons

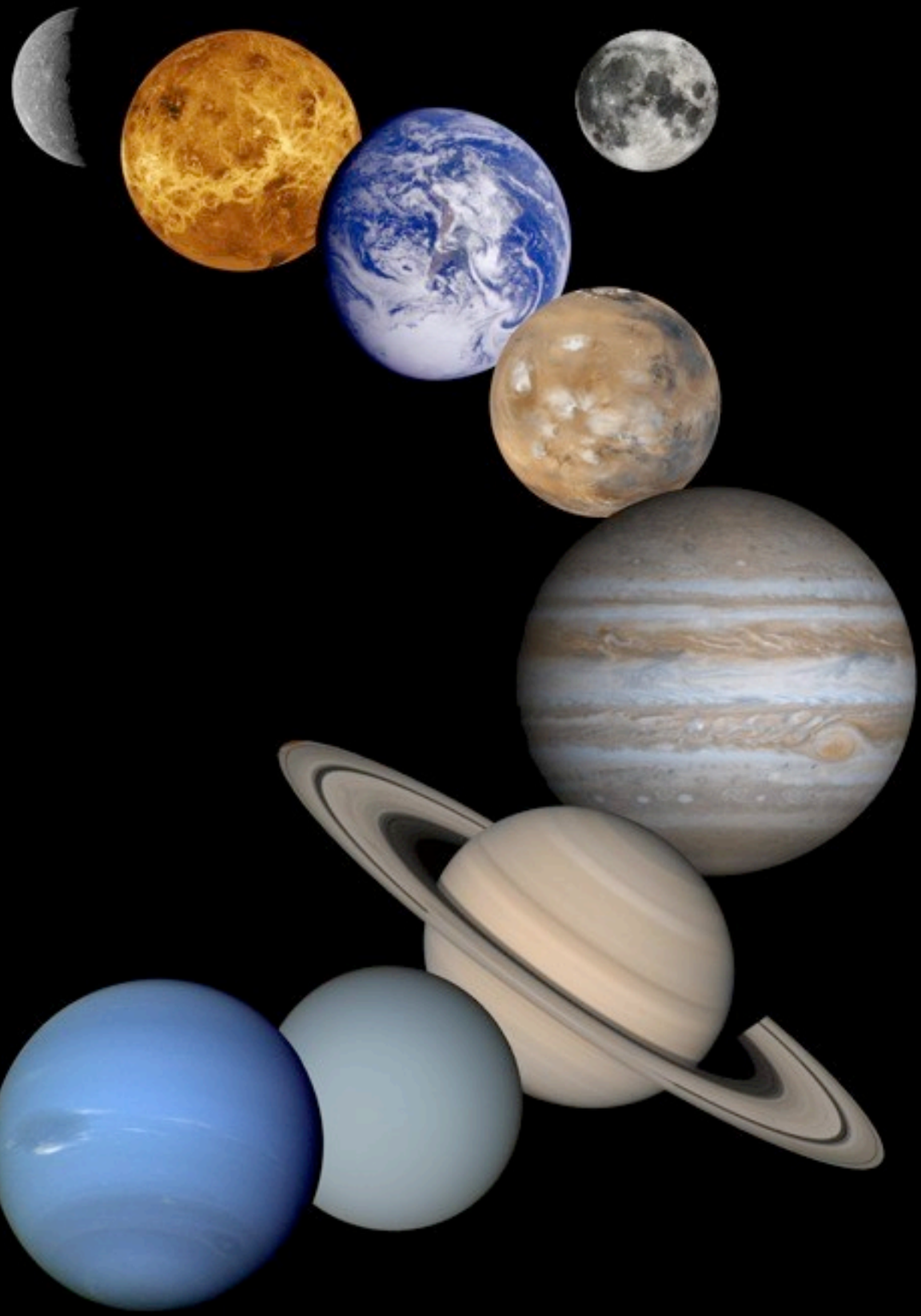
How do we learn about the planets?

The Naked Eye

Telescopes

1610

Galileo discovered four of Jupiter's moons



Spacecraft!

Unmanned, or robotic missions

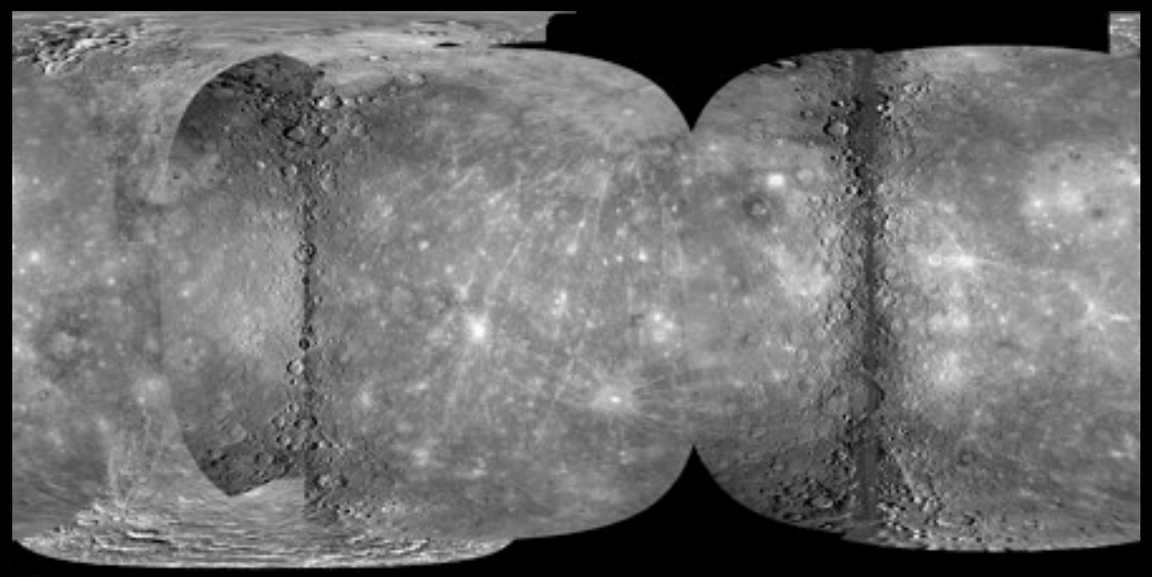
- Allow us to get a closer view

- Get *in-situ*, or in place, measurements

Flight Operations

MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



Encounter

Flyby

Orbit

(Land)

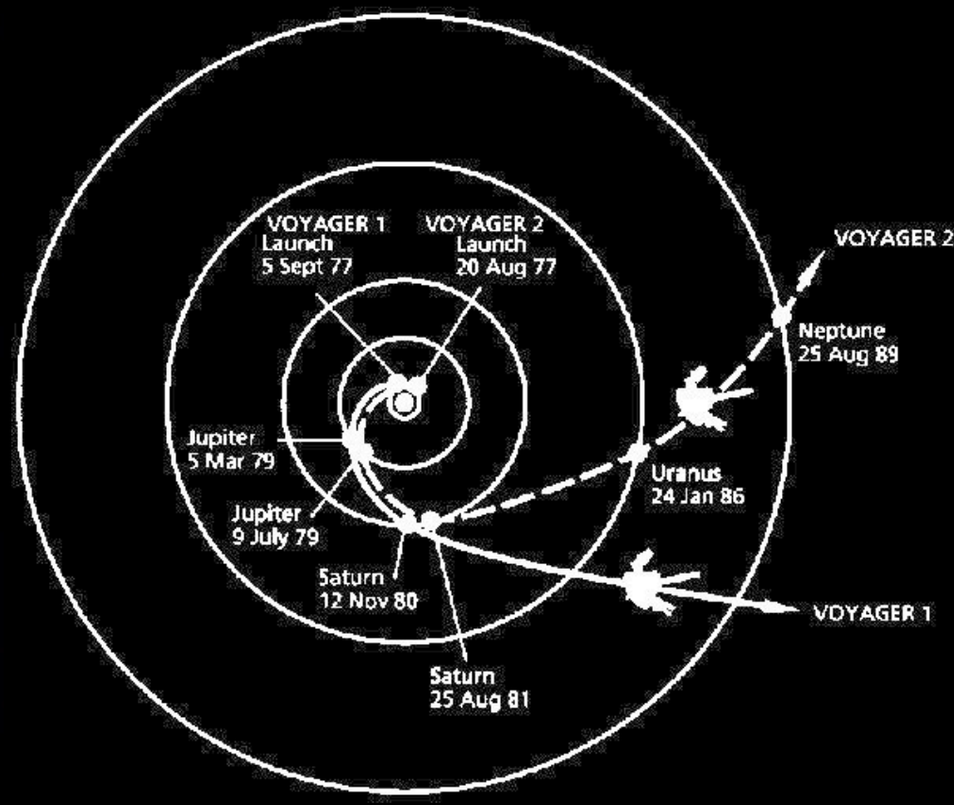
Launch

Cruise

Data return

Voyager I & II

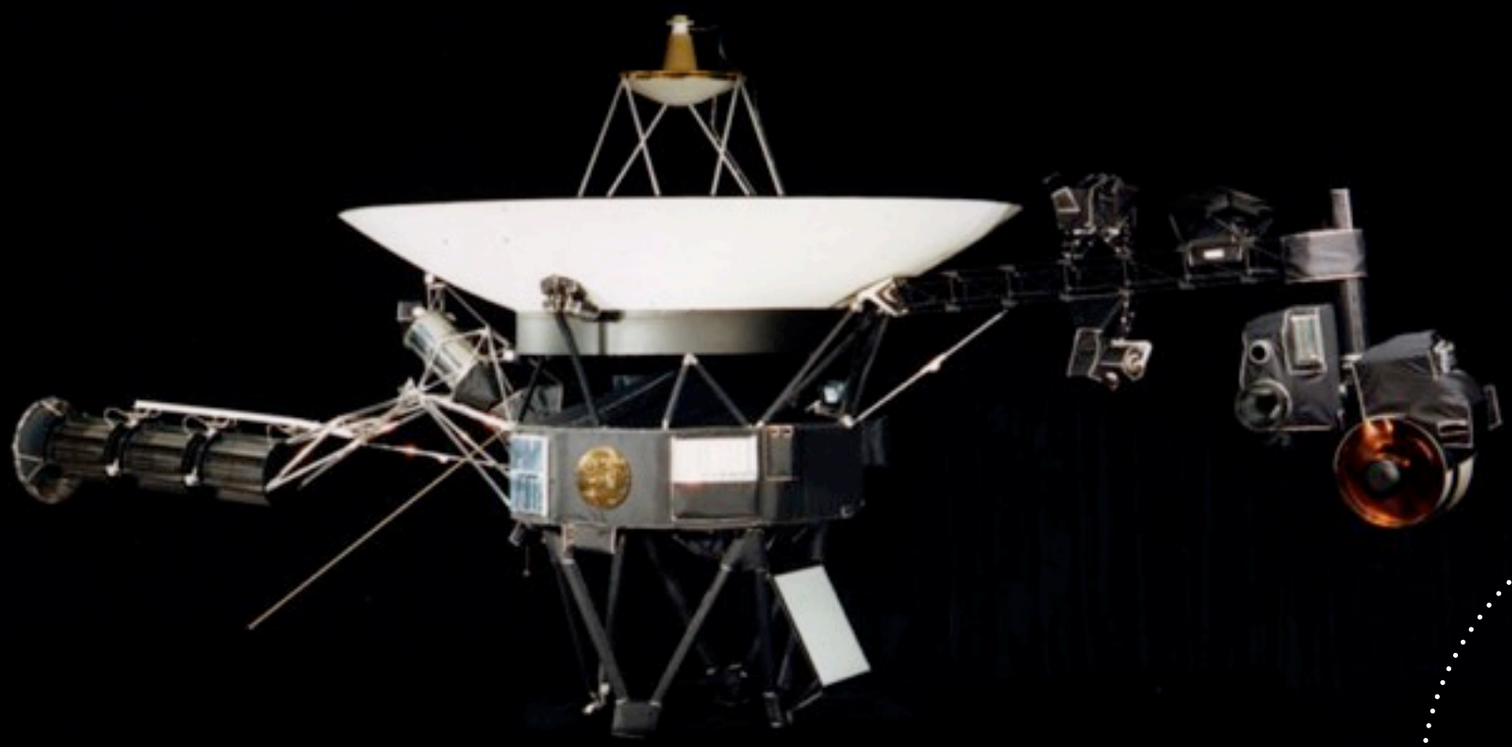
Flying by the Outer Solar System

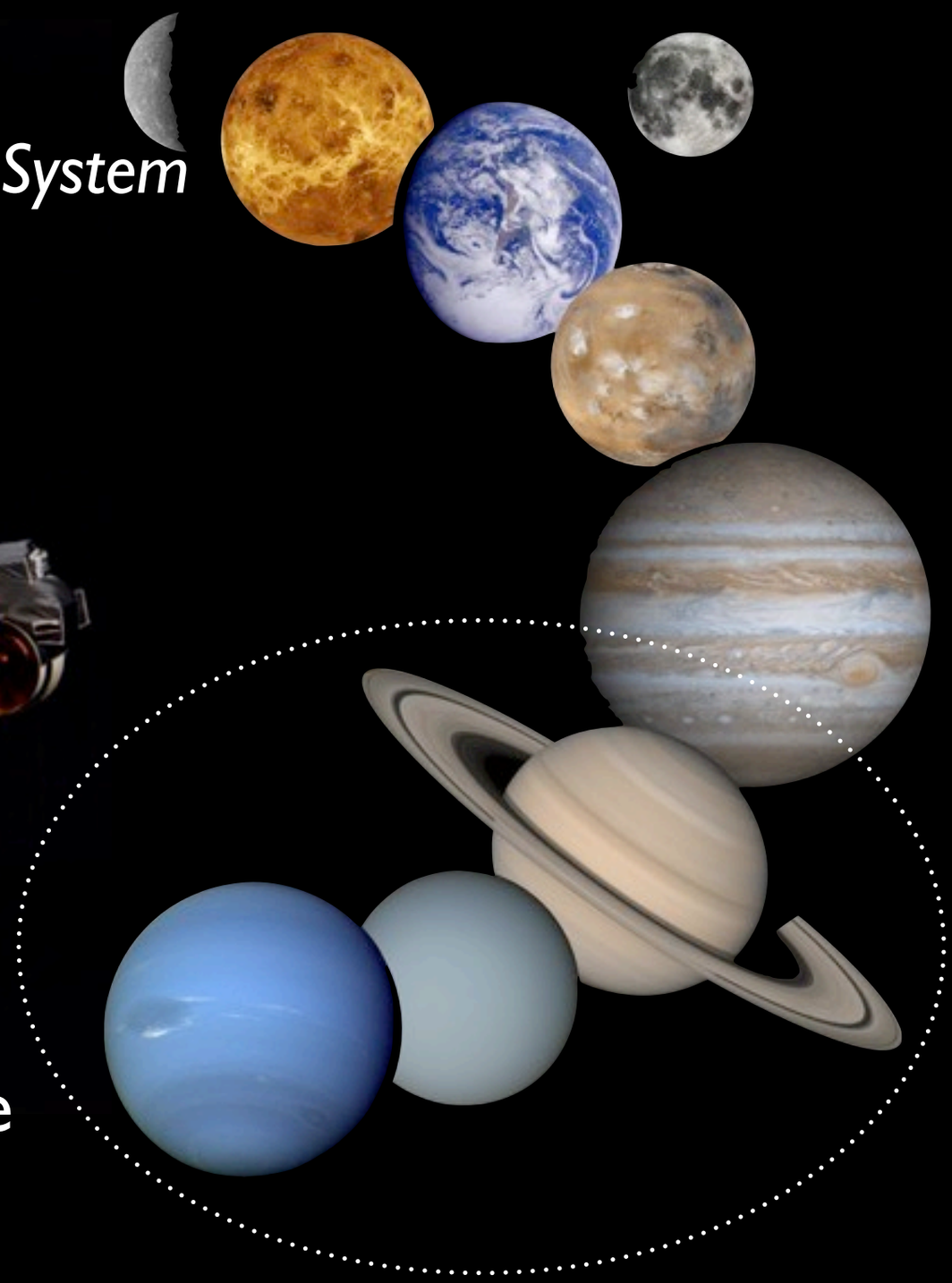


Launched in 1977 (and still going!)

Voyager I & II

Flying by the Outer Solar System

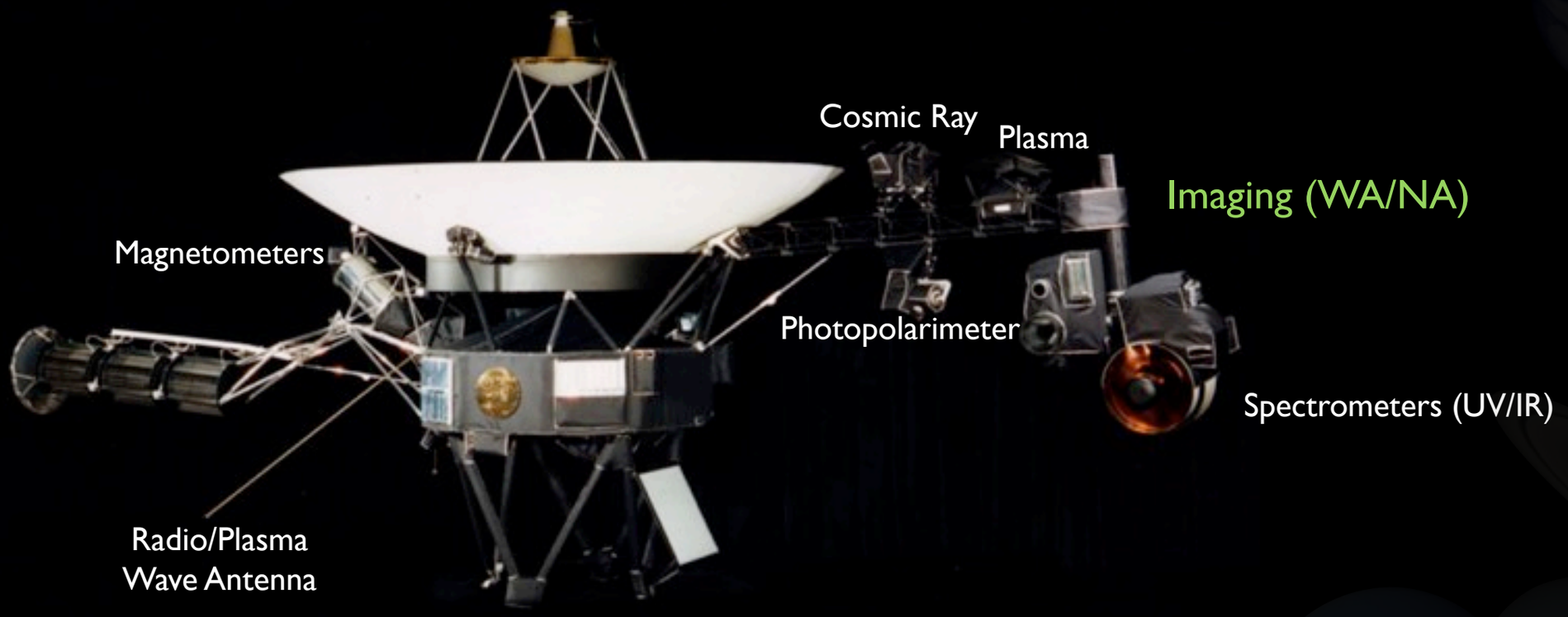




Visited Jupiter, Saturn, Uranus & Neptune

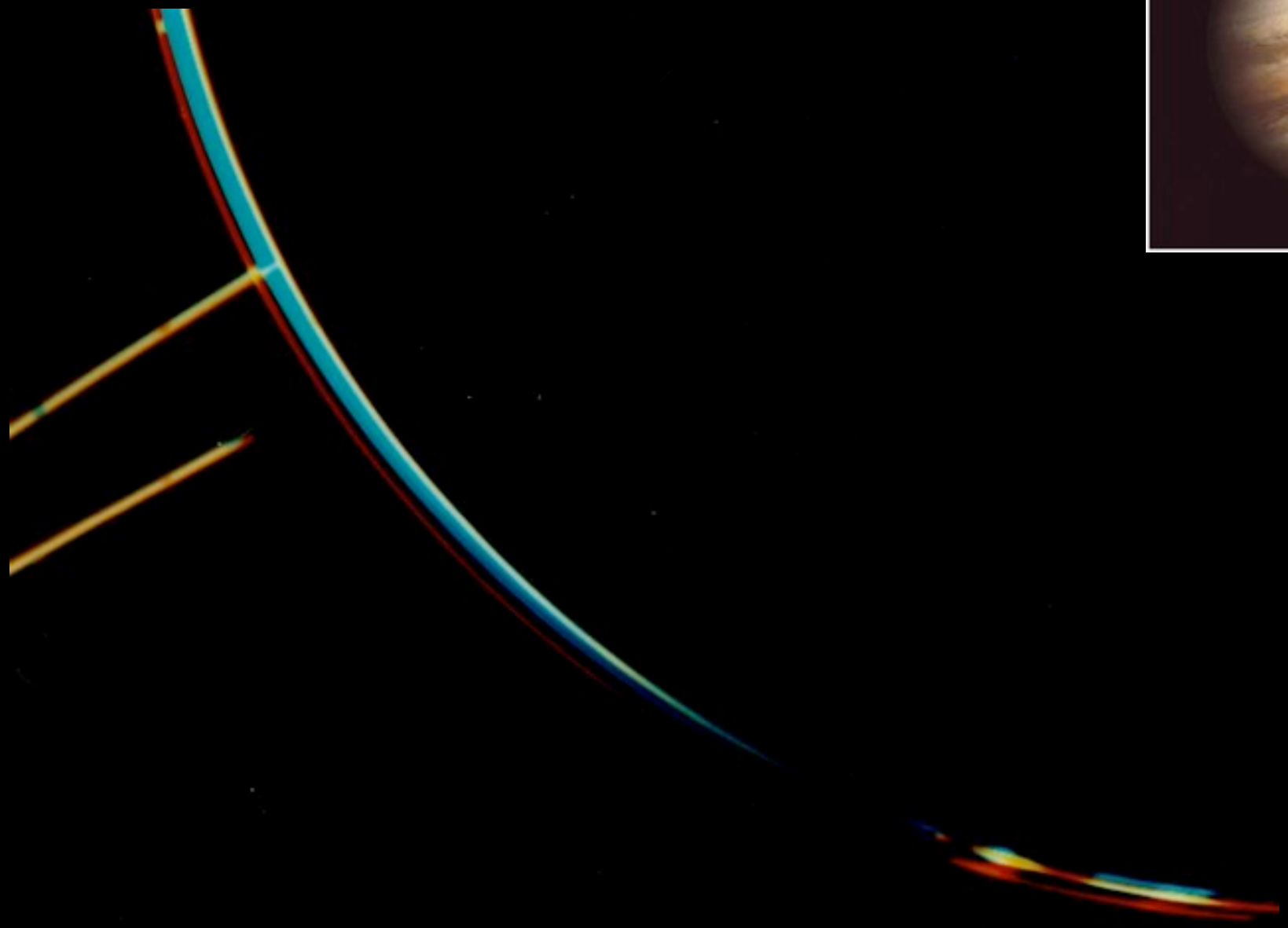
Voyager I & II

Flying by the Outer Solar System



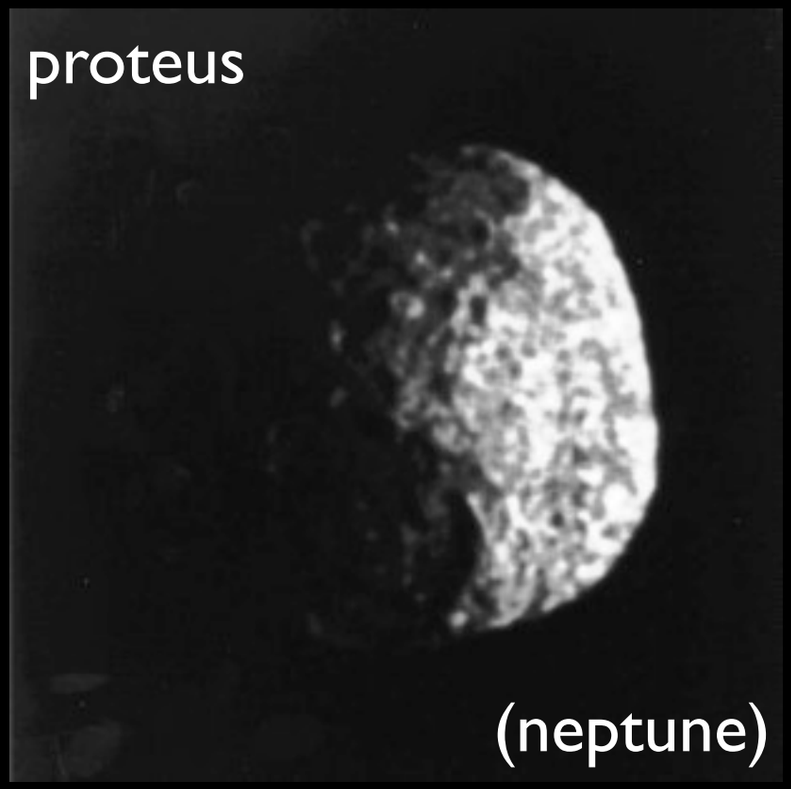
Science Instruments

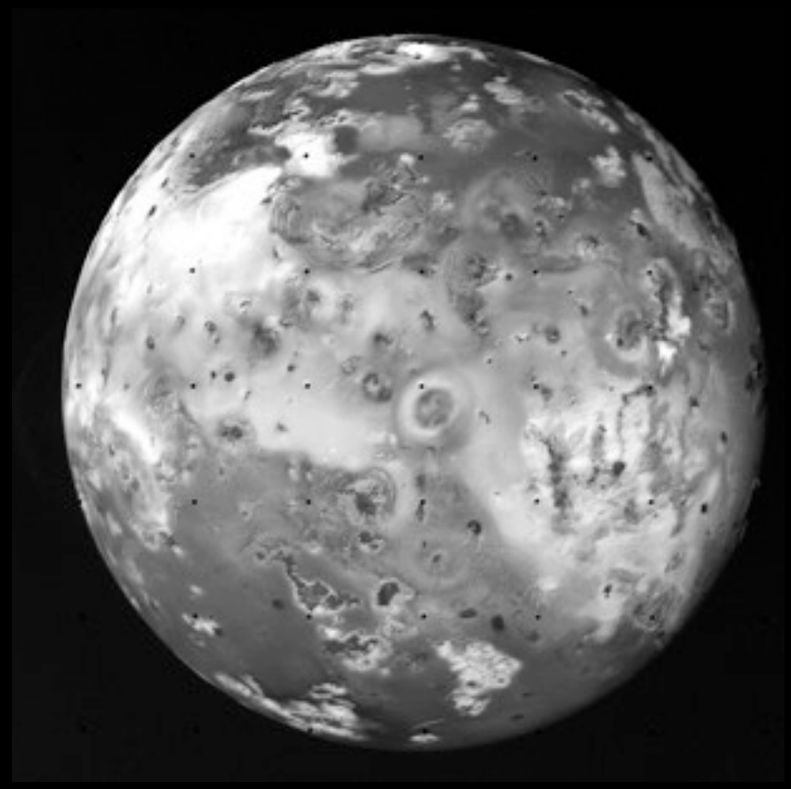
discovery:



jupiter has **rings**

discovery:



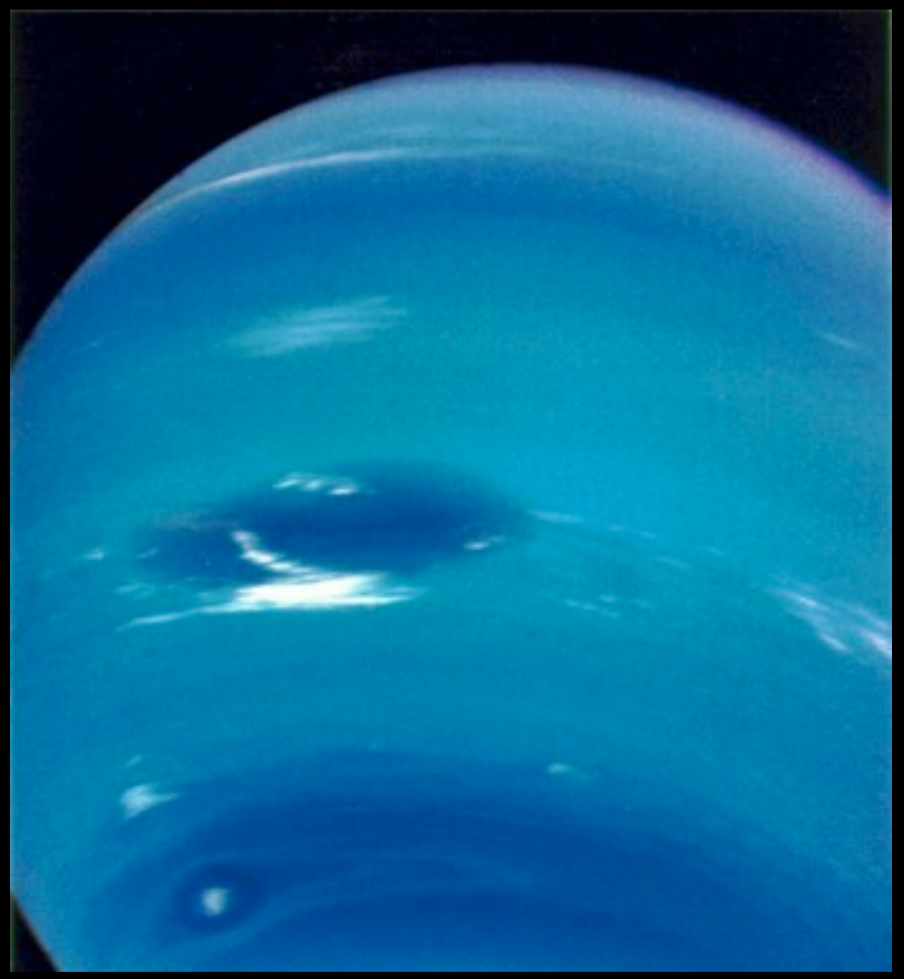


more **moons**

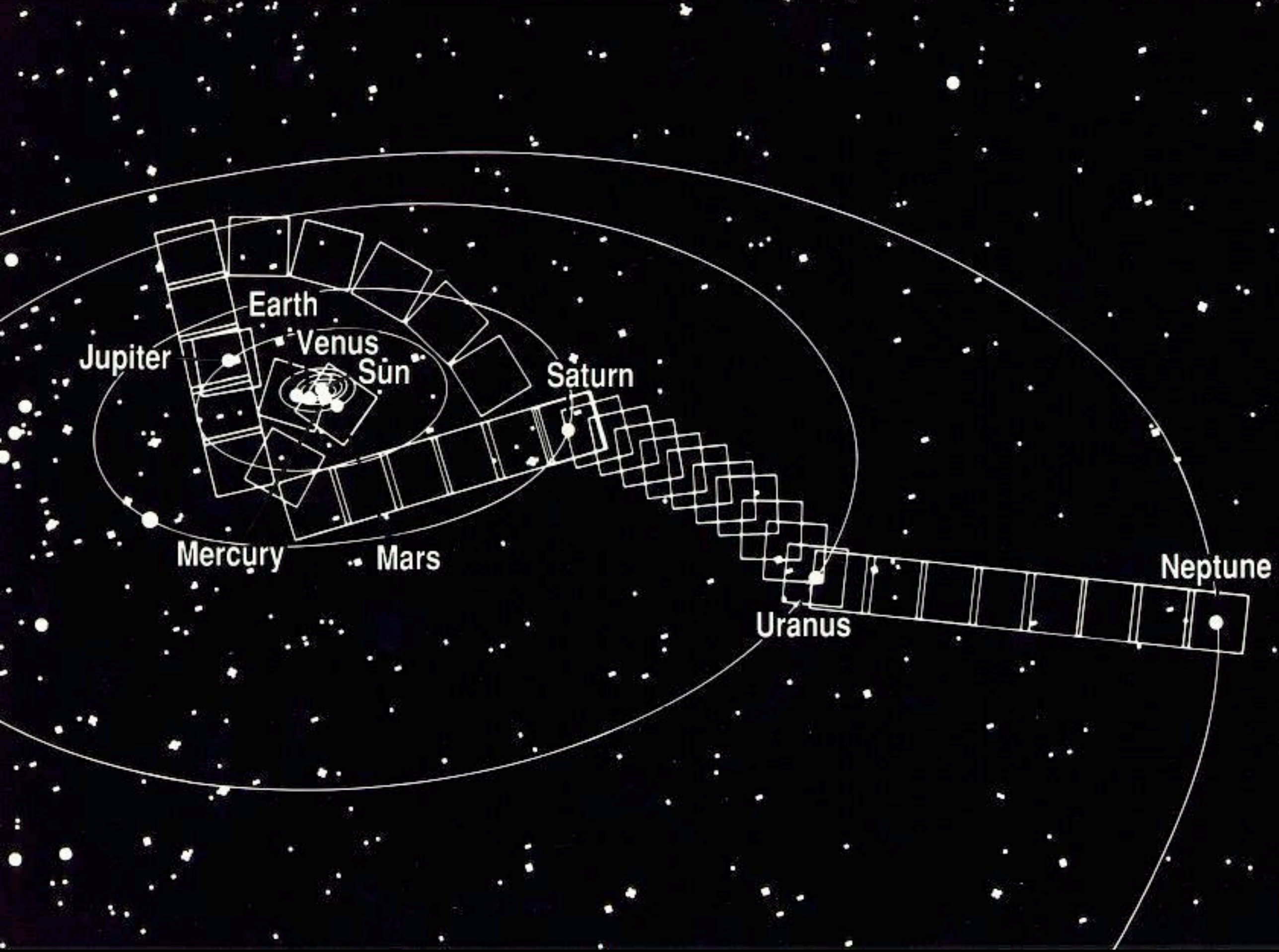
3 - jupiter
3 - saturn
10 - uranus
6 - neptune

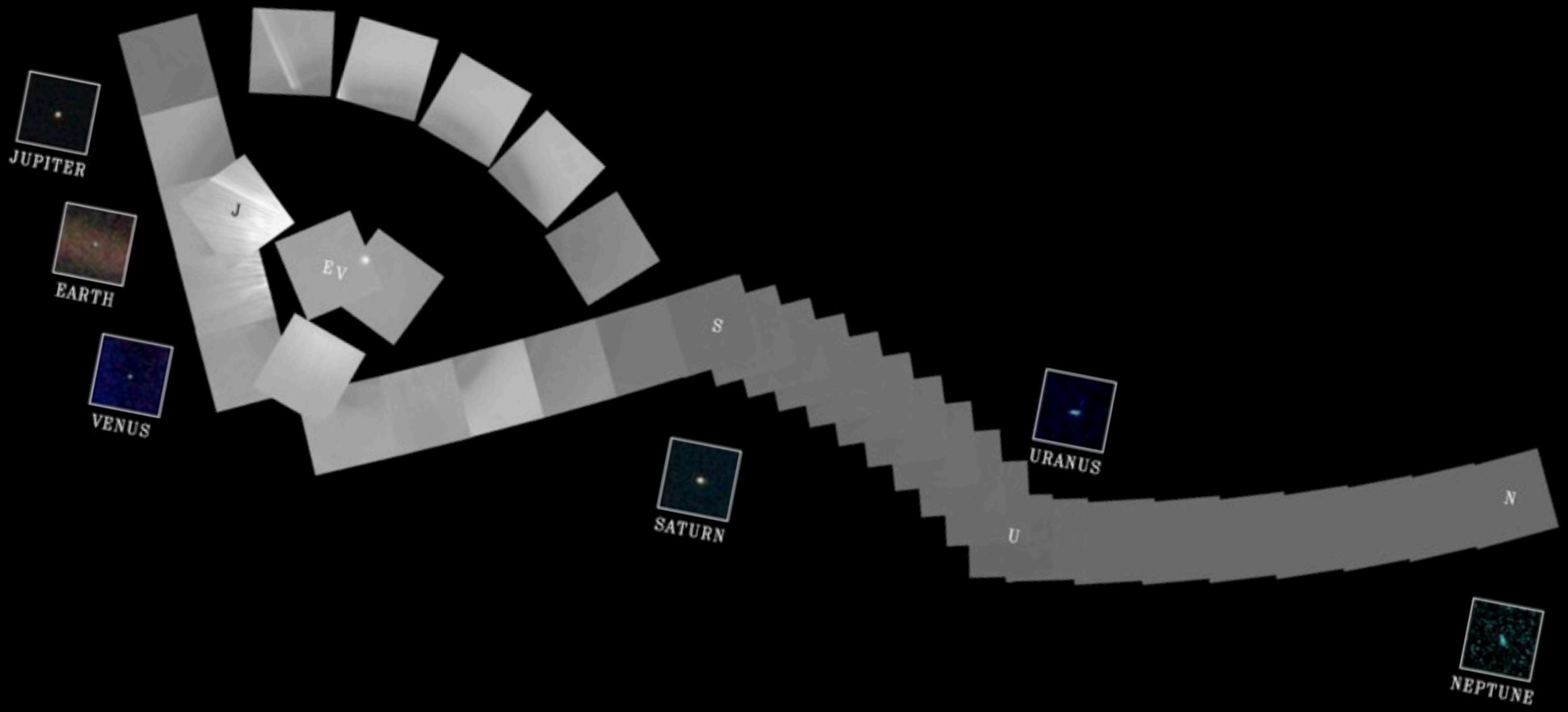
volcanic activity on io

discovery:



storms on neptune


Earth
Venus
Jupiter
Sun
Saturn
Mercury
Mars
Uranus
Neptune


JUPITER
J
EARTH
EV
VENUS
S
SATURN
URANUS
U
N
NEPTUNE

Not fare well,
But fare forward, Voyagers.
-- T. S. Eliot, The Dry Salvages

Bow Shock

Heliosheath

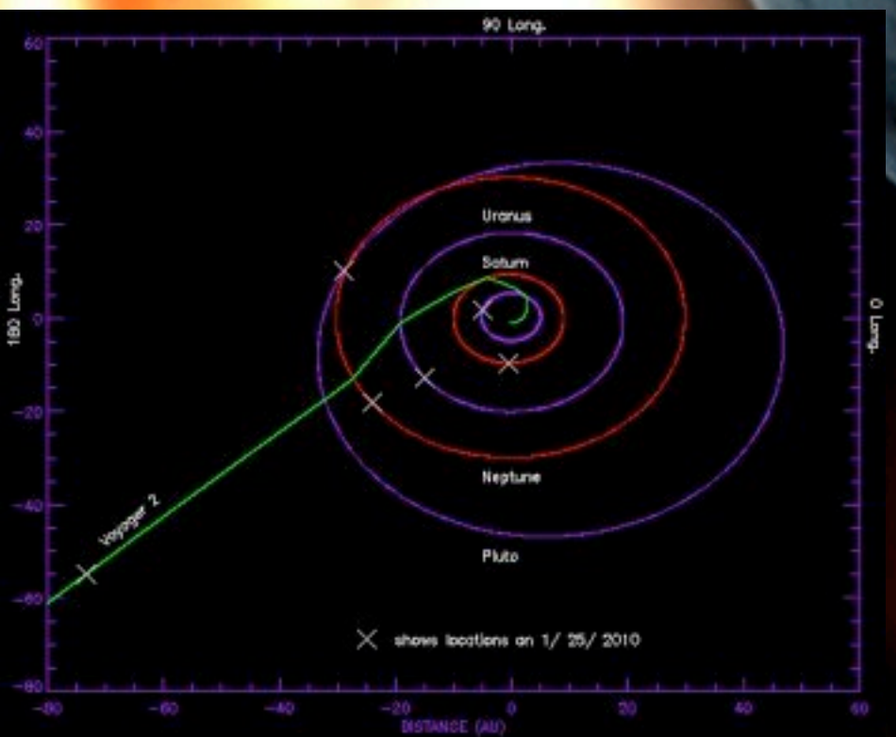
Voyager 1

Termination Shock

Voyager 2

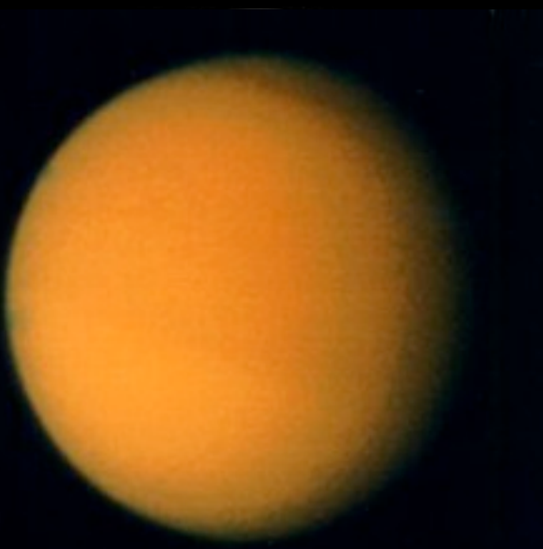
Heliopause

Heliosphere



Cassini-Huygens

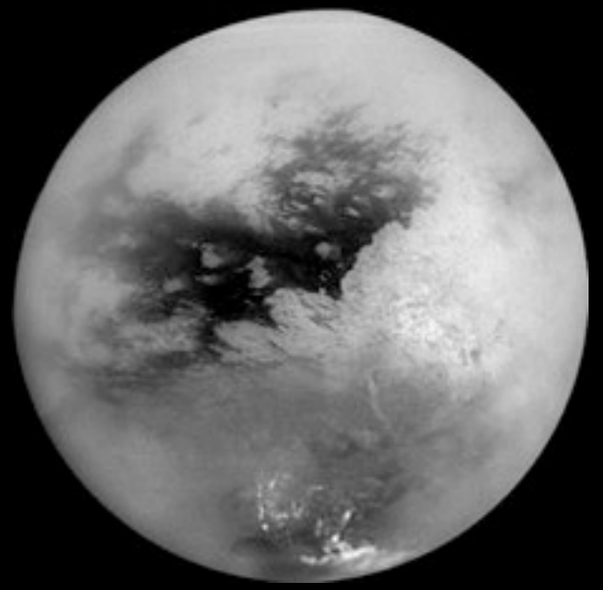
Orbiting Saturn, Landing on Titan



NASA esa asi agenzia spaziale italiana

Cassini-Huygens

Orbiting Saturn, Landing on Titan



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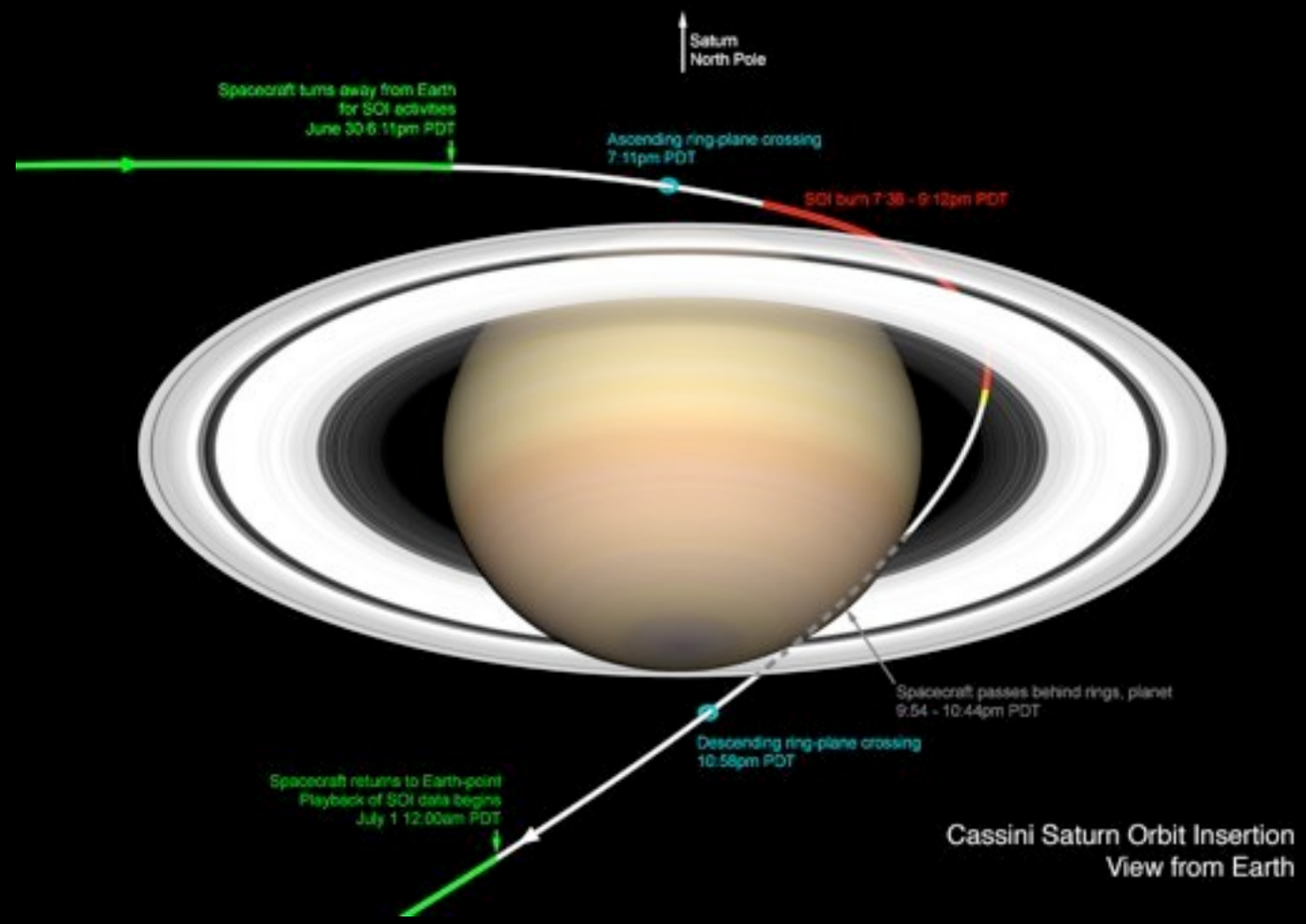
Cassini-Huygens

Orbiting Saturn, Landing on Titan

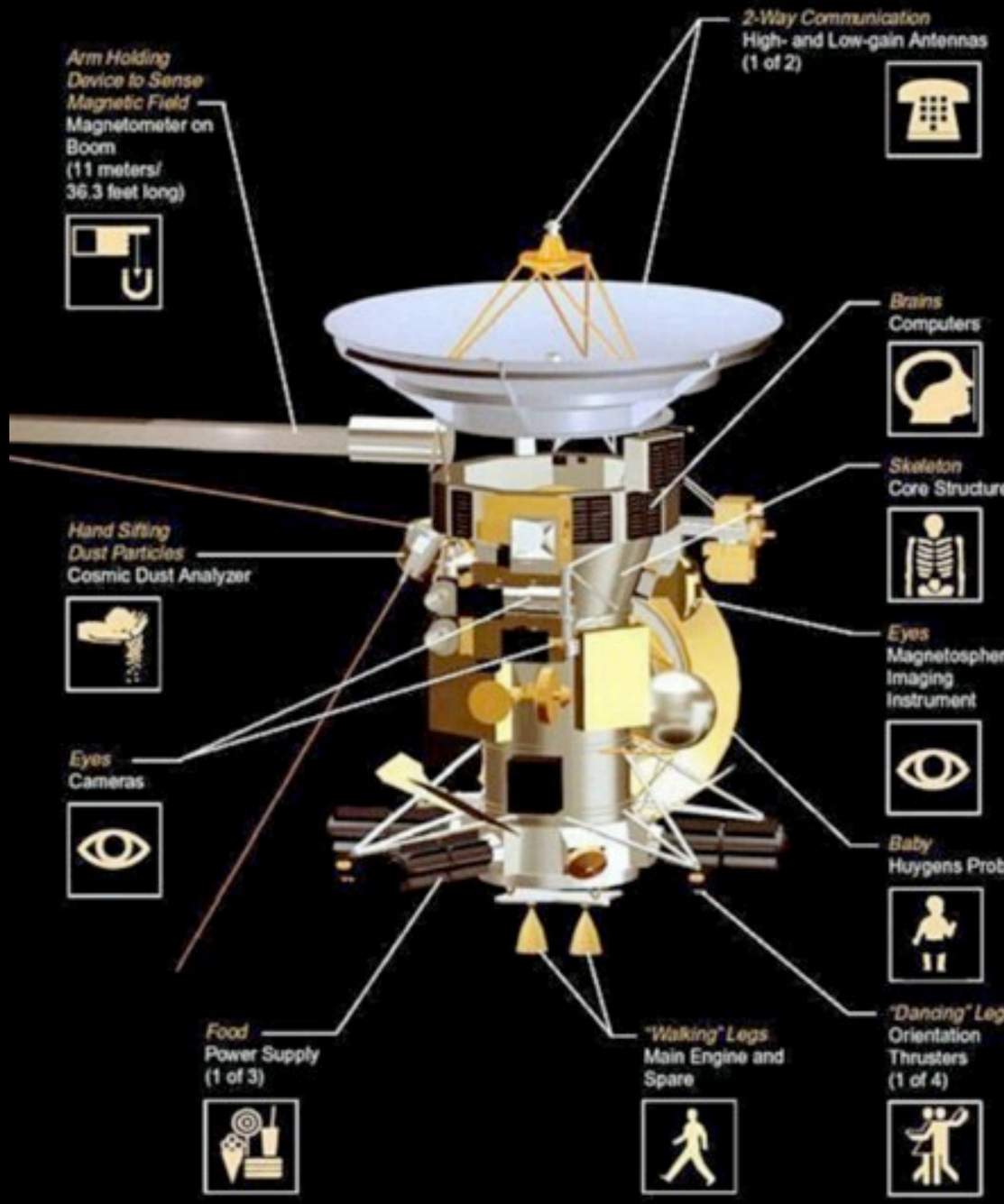
gravity assist to get there



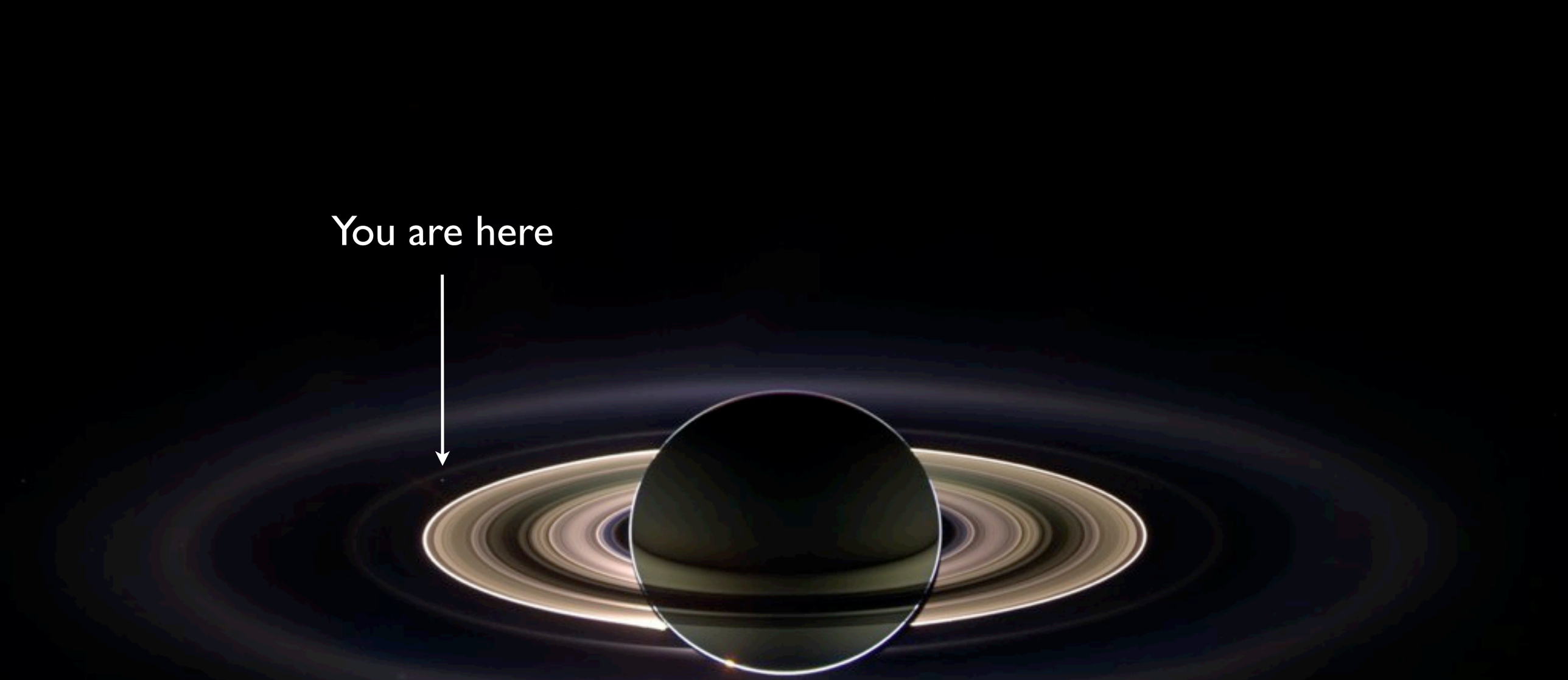
maneuvering to stay there

Cassini

Orbiting Saturn



You are here



Phoebe

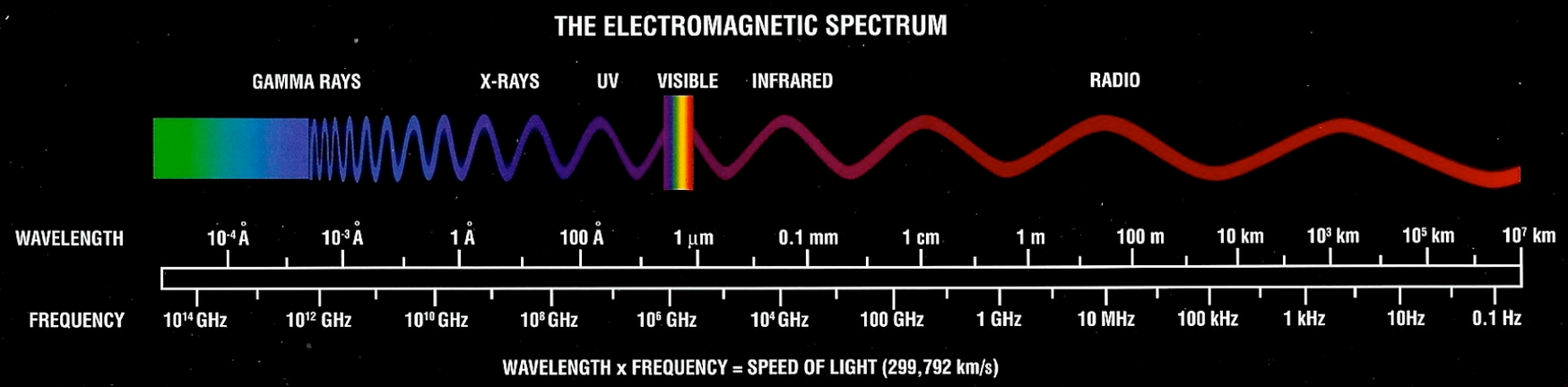
Voyager II
4 Sept 1981

2.2 million km away

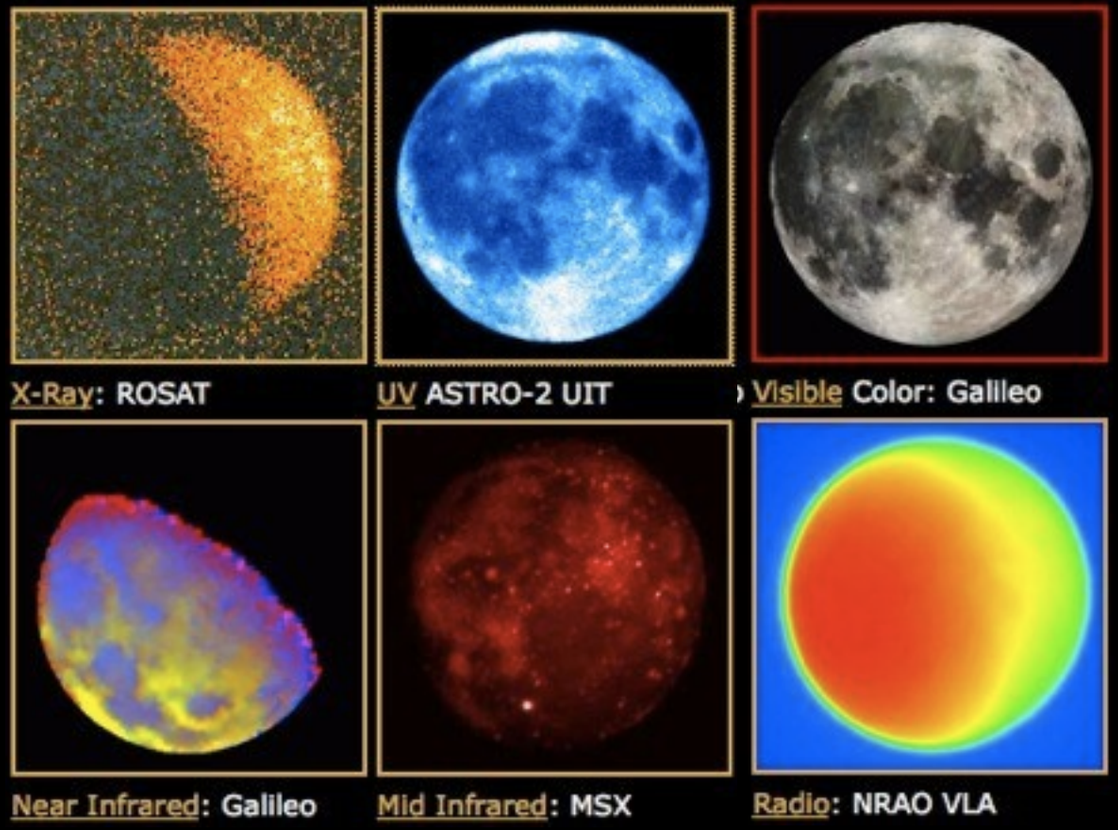
Cassini
11 June 2004

2000 km away

Multi-Wavelength Observations

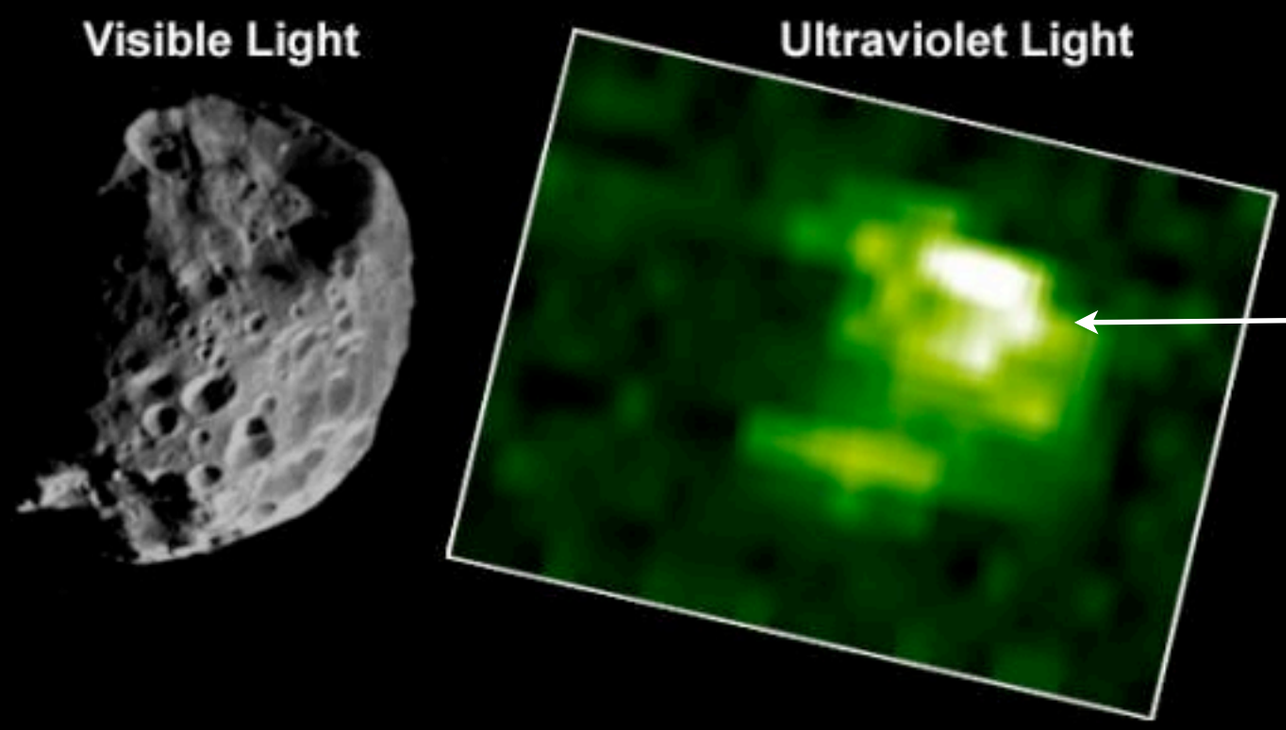


shorter wavelength



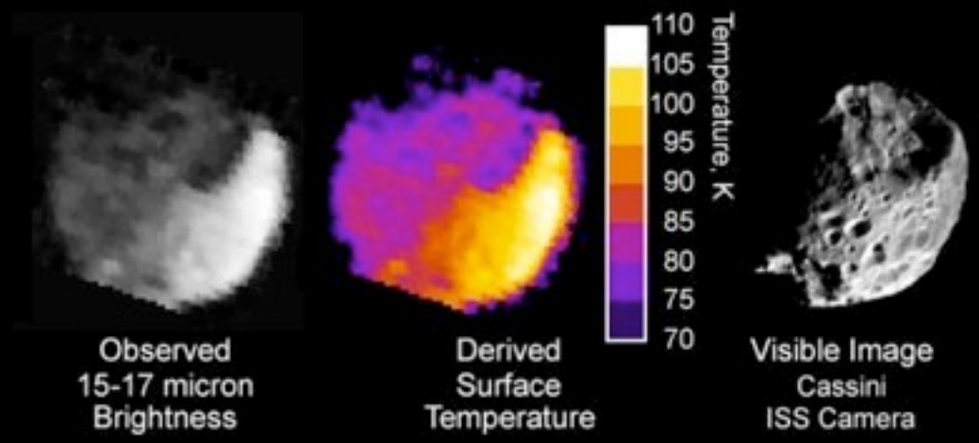
longer wavelength

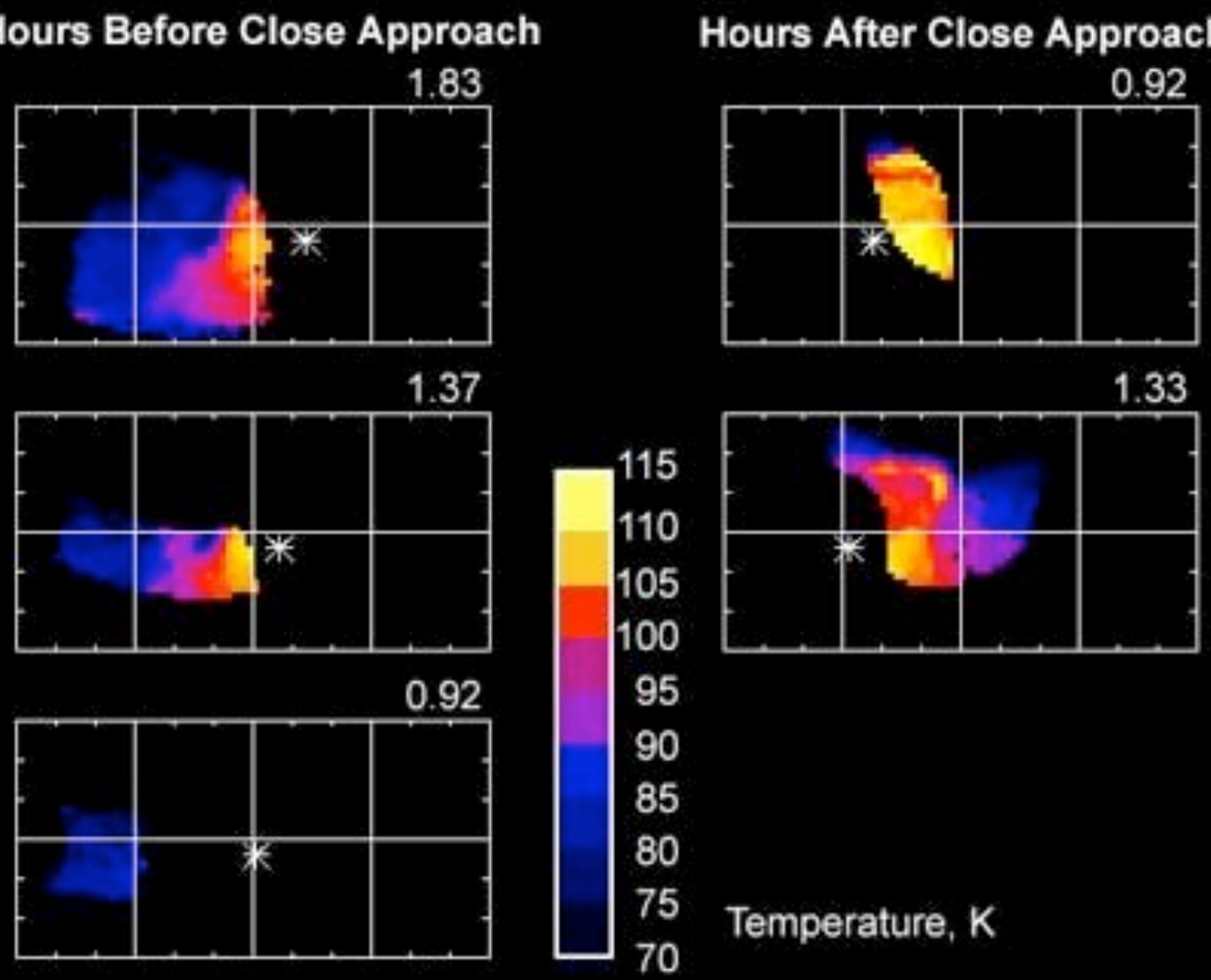
a view from the ultraviolet



Ultraviolet (UV) image displays brightness variations.
UV spectra confirm presence of water frost on surface.

a view from the infrared - temperature





day night variation

made of loose dust and ice particles

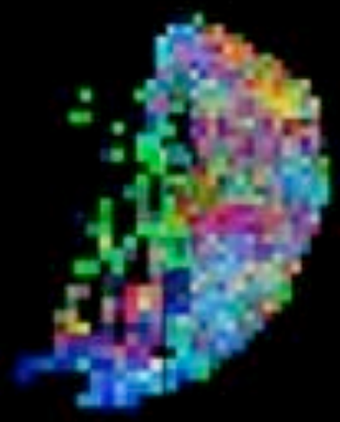
a view from the infrared - mineral distribution

Phoebe
Imaging
Mosaic

Infrared
Reflectance

Carbon Dioxide
Locations

Unidentified
Material



Ferrous Iron

Unidentified
Material

Water Ice

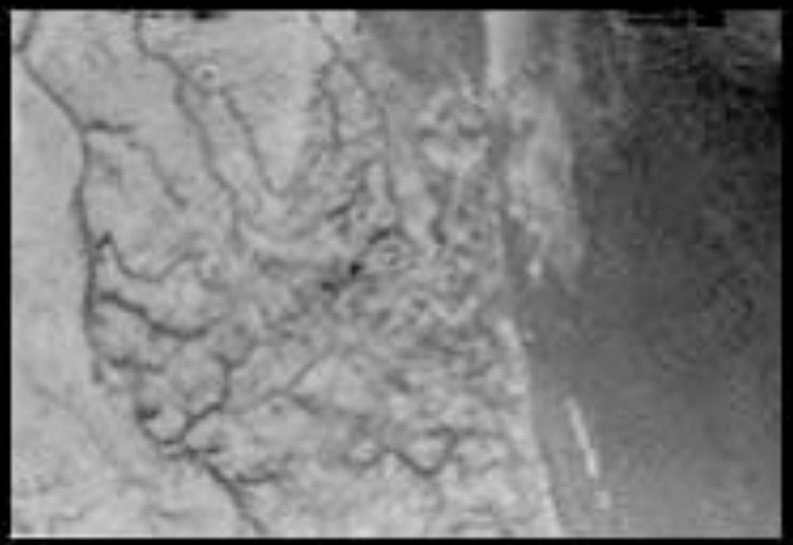
originated in the kuiper belt

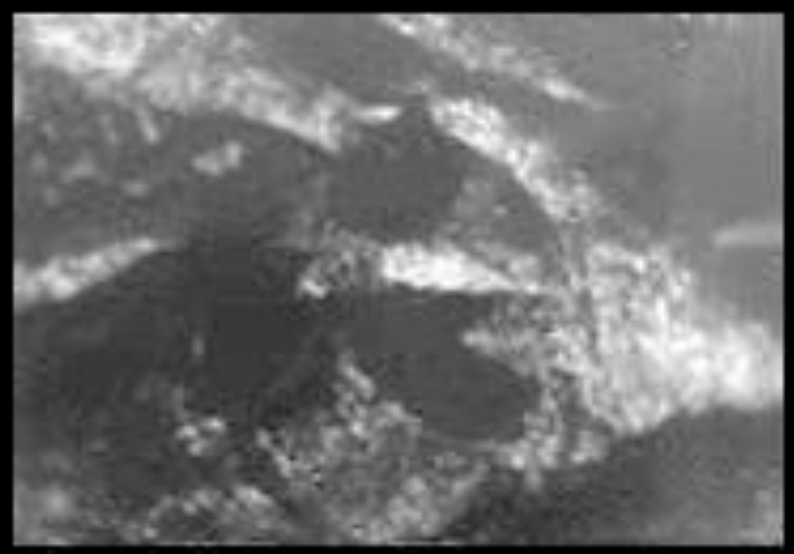
Huygens

Landing on Titan

- Imager
- Measure winds using radio
- Analyze the atmosphere
- Measure titan's surface

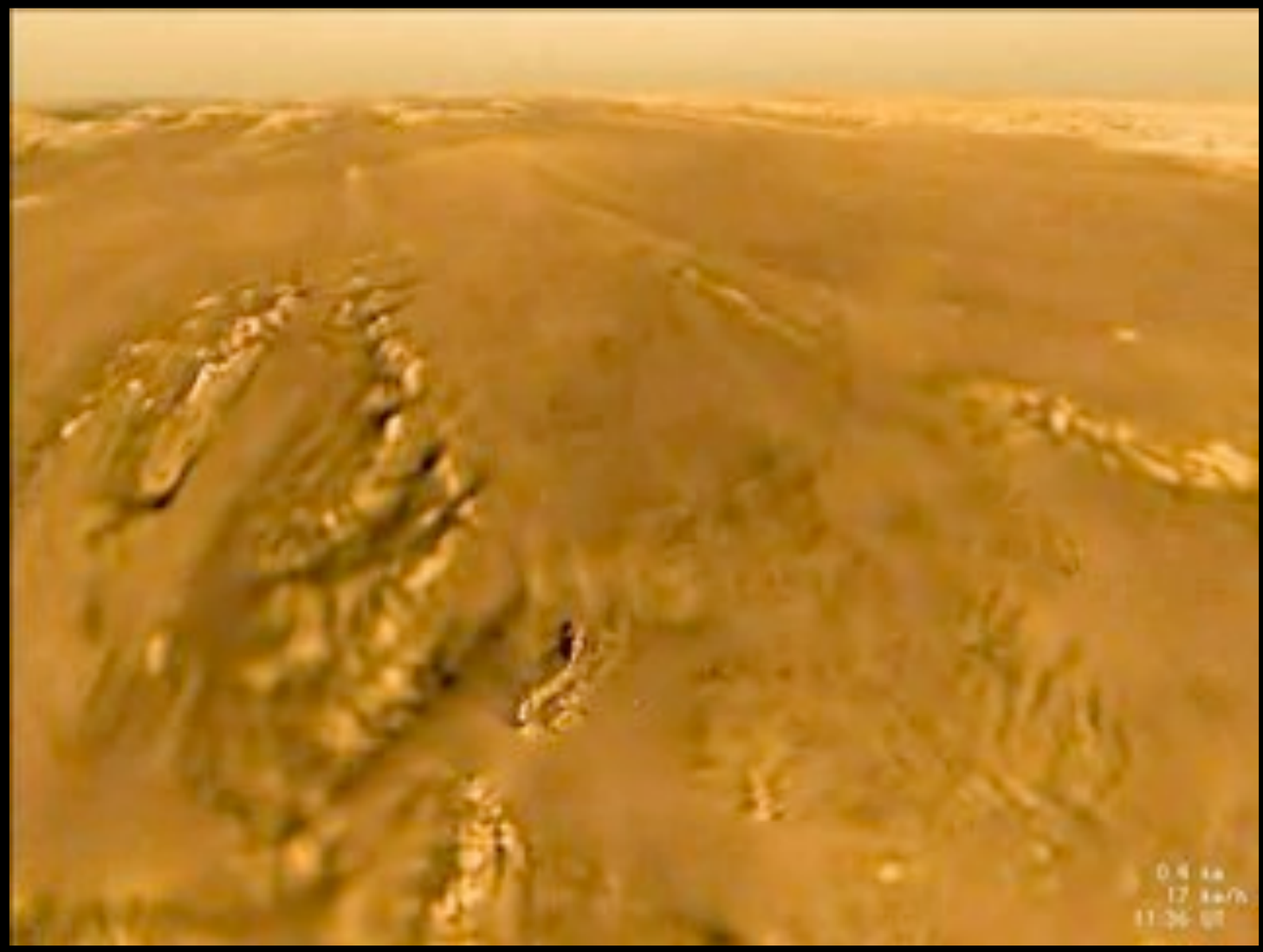
descent unto Titan





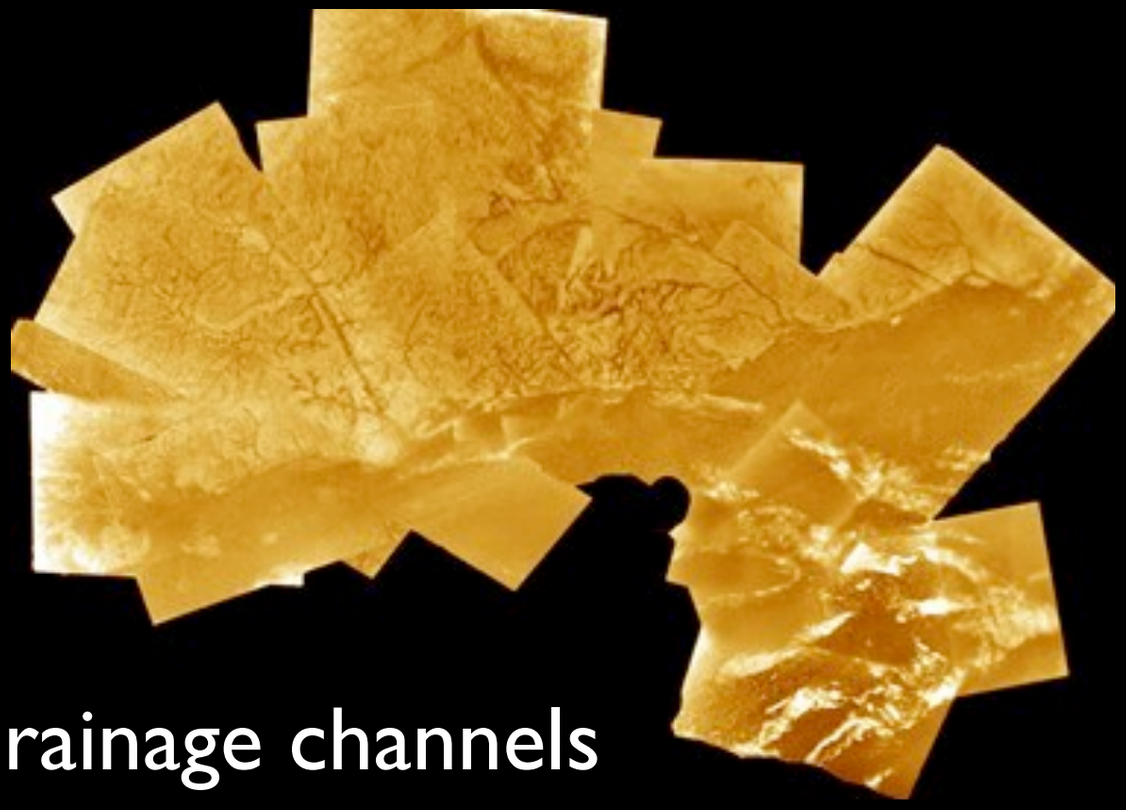
Jan. 14, 2005

descent unto Titan

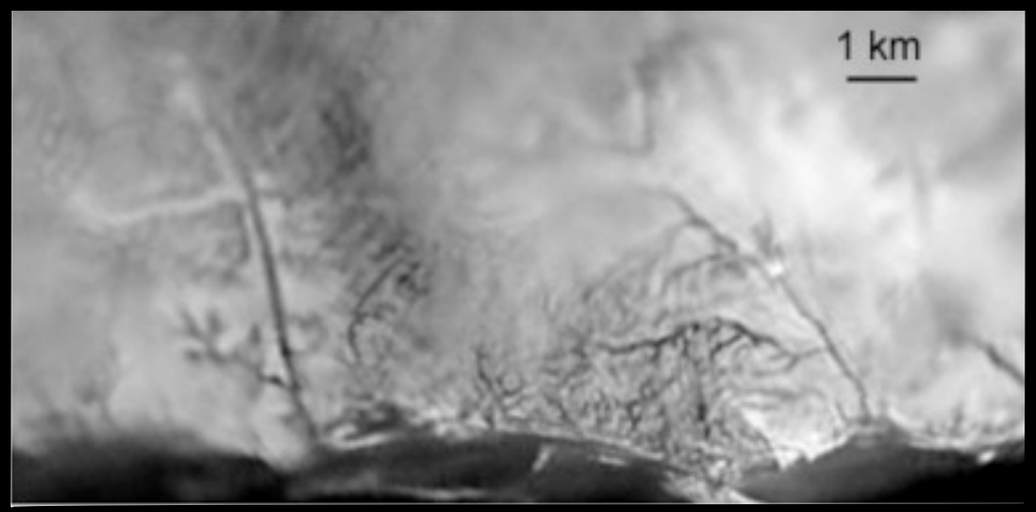


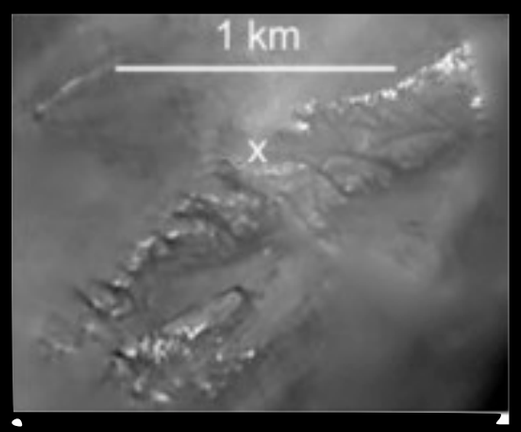
[Movie with images and sounds from the
Huygens probe landing on Titan]

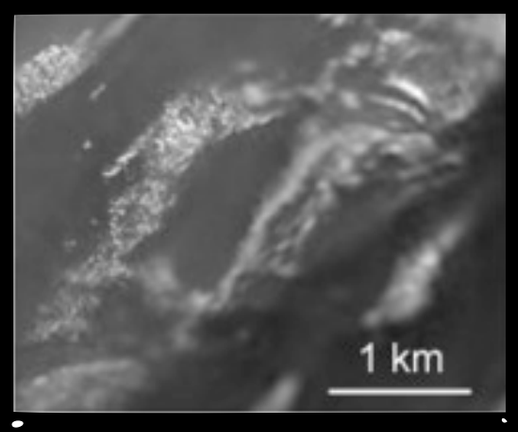
wind - from the furthest sounds in the Solar System



drainage channels







hydrocarbon rain & flows

Mars Exploration Rovers

Roving the Red Planet

Opportunity

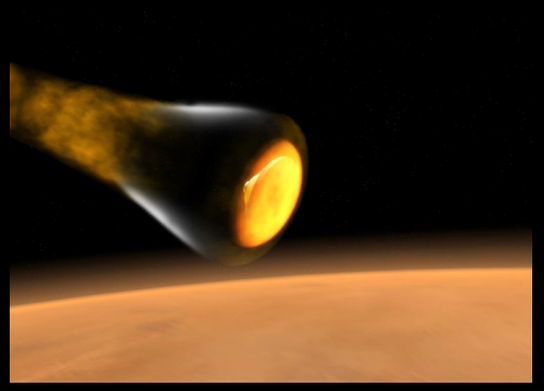
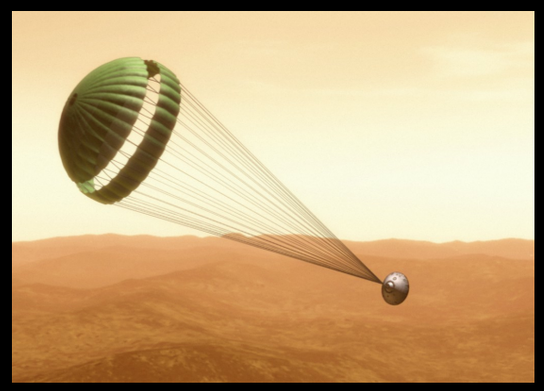
Spirit

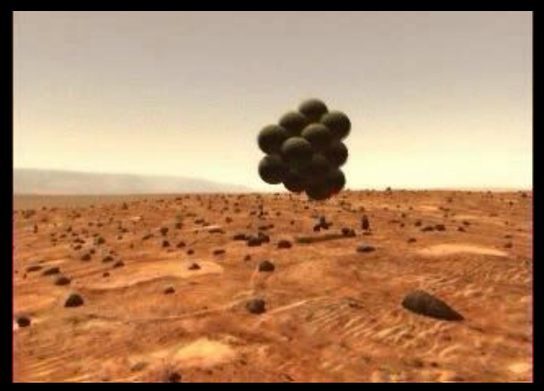
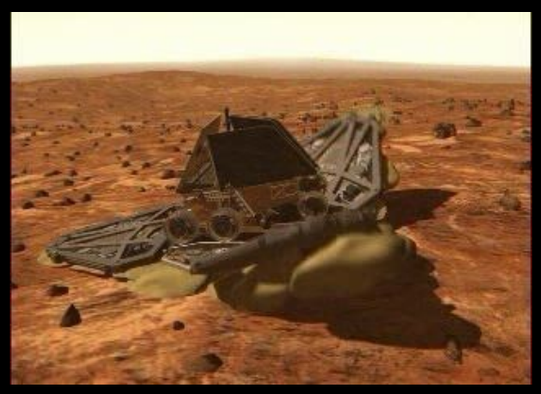
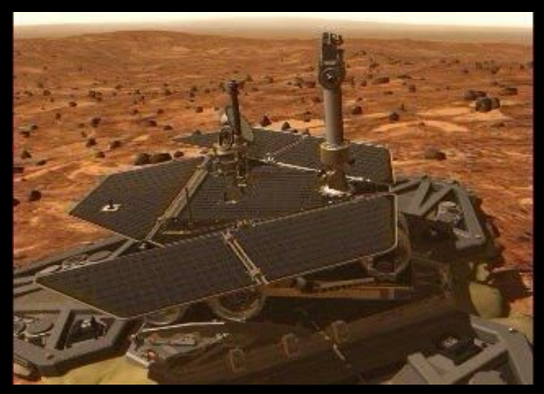
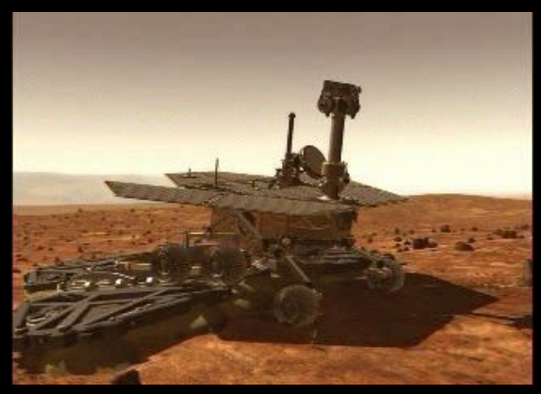
R.I.P.
2004-2010

getting there in one piece

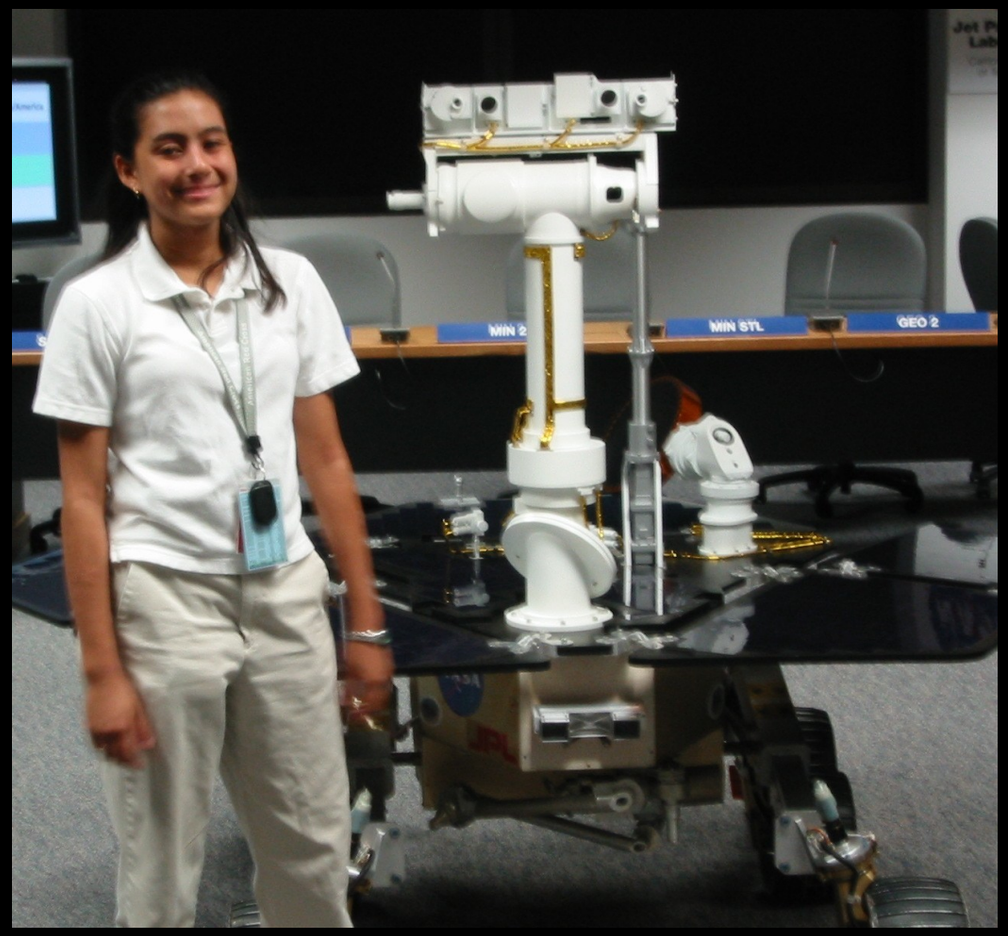


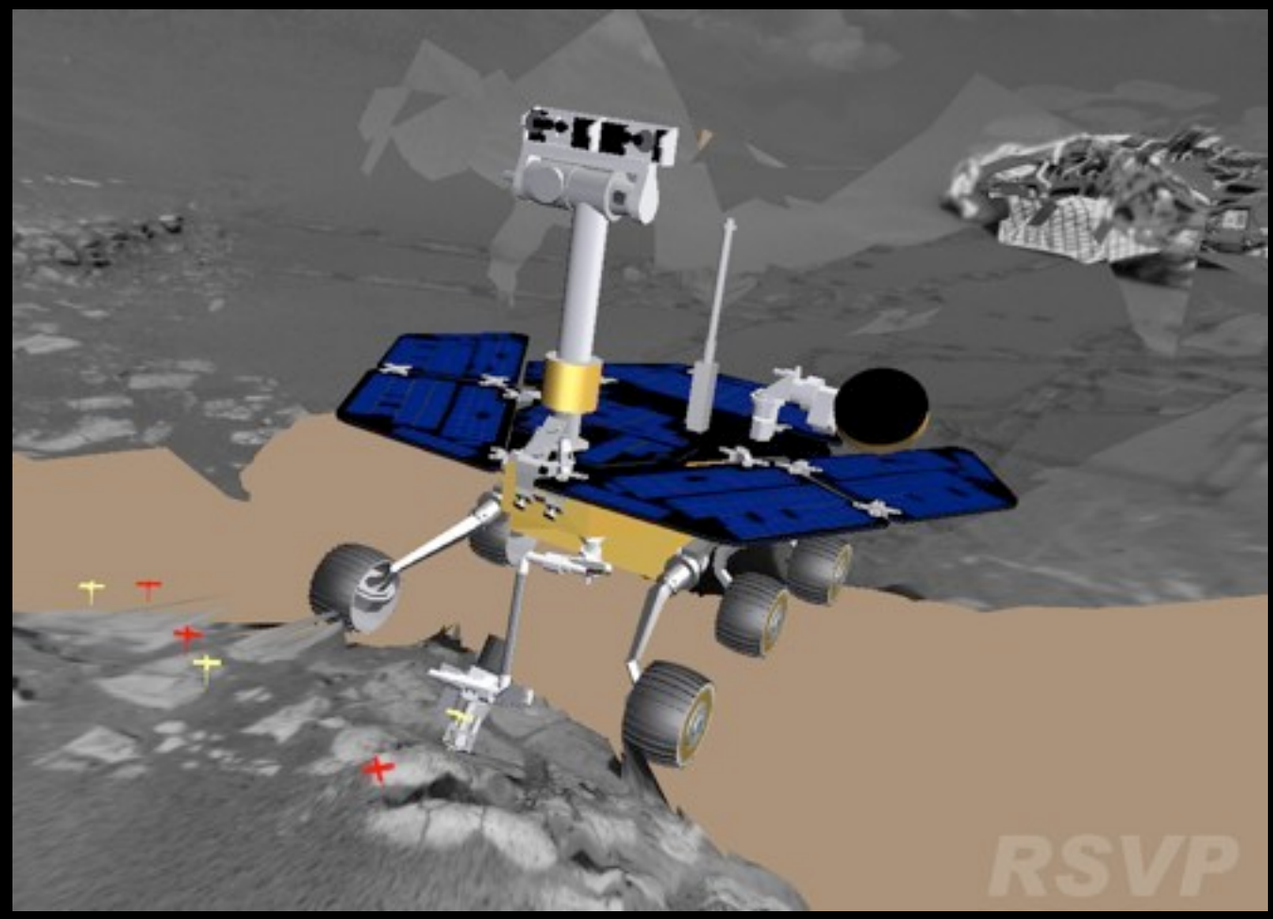



can update and set science goals daily





use current data to plan next moves

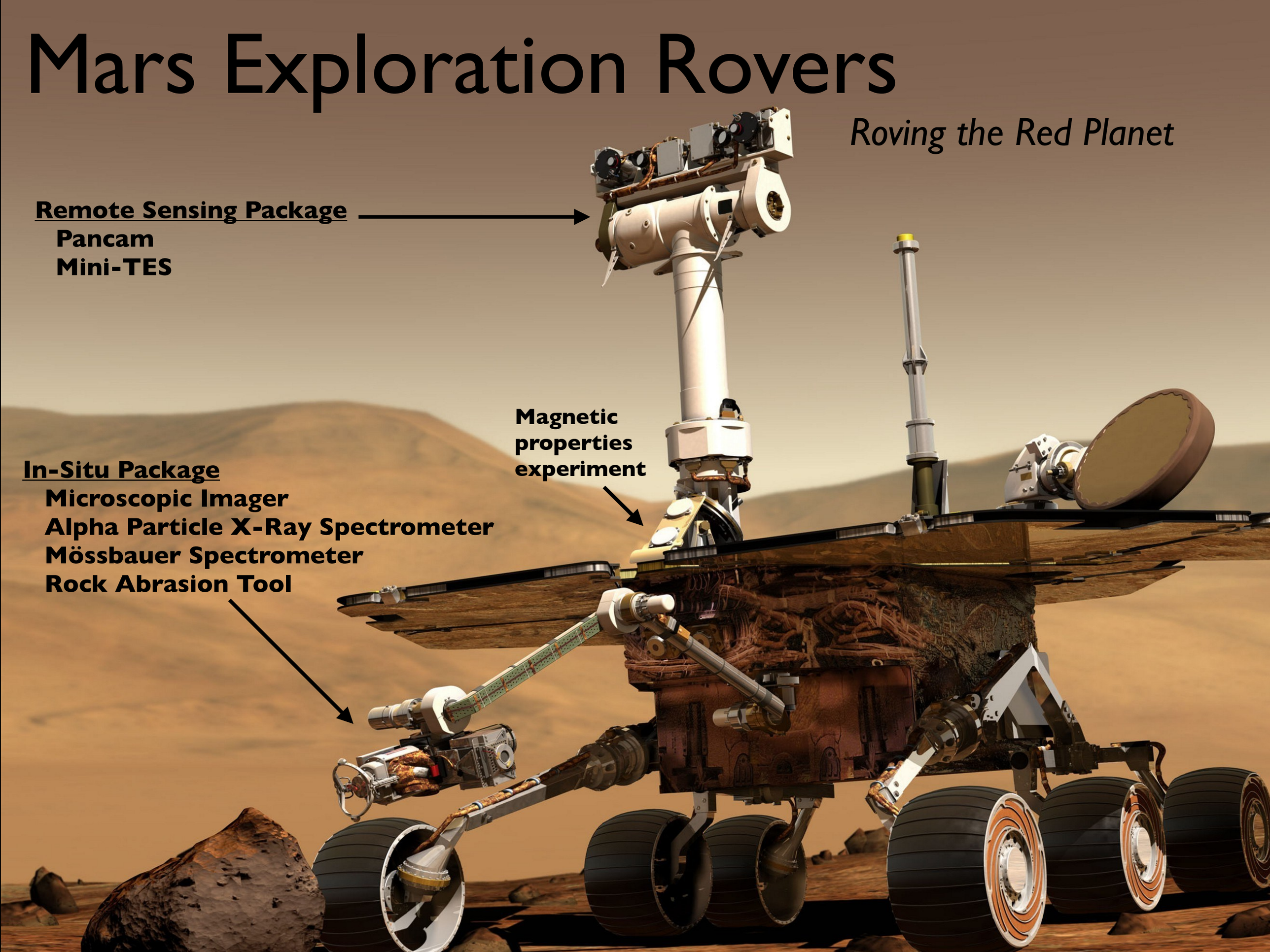
Mars Exploration Rovers

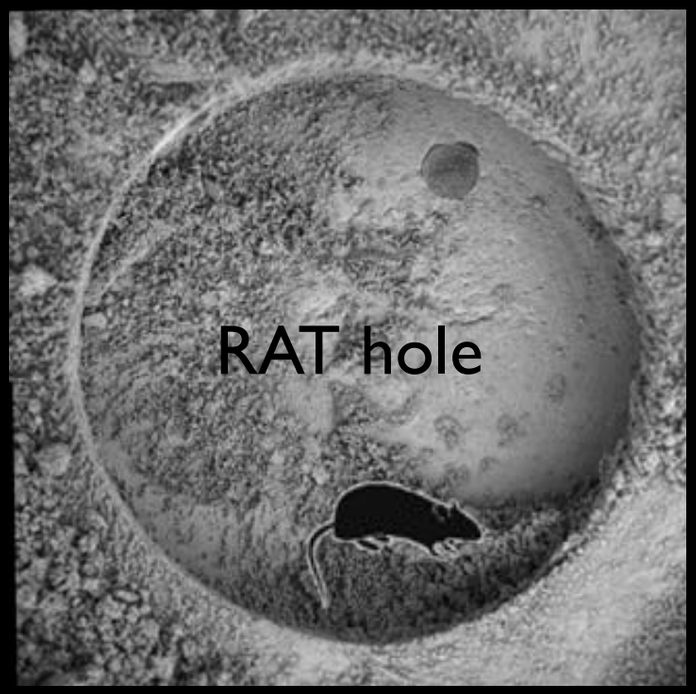
Roving the Red Planet

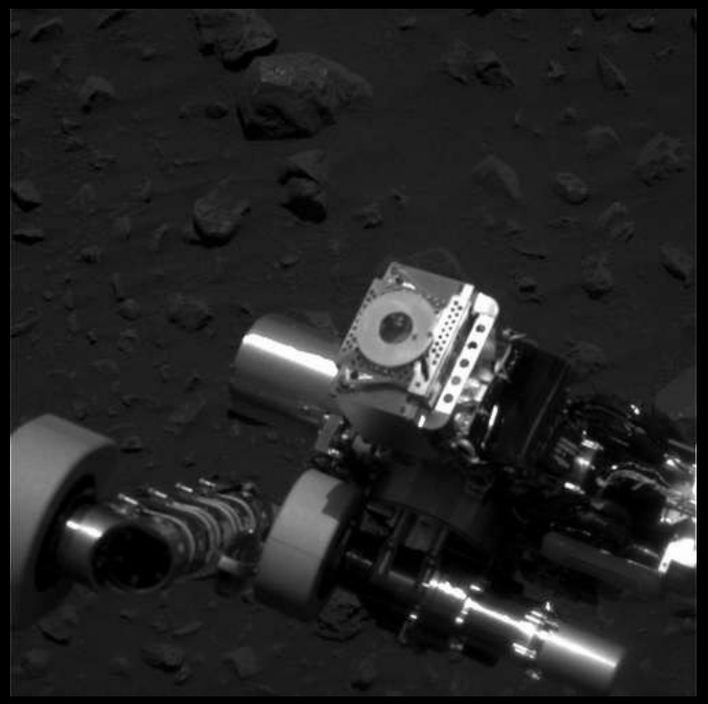
Remote Sensing Package
- **Pancam**
- **Mini-TES**

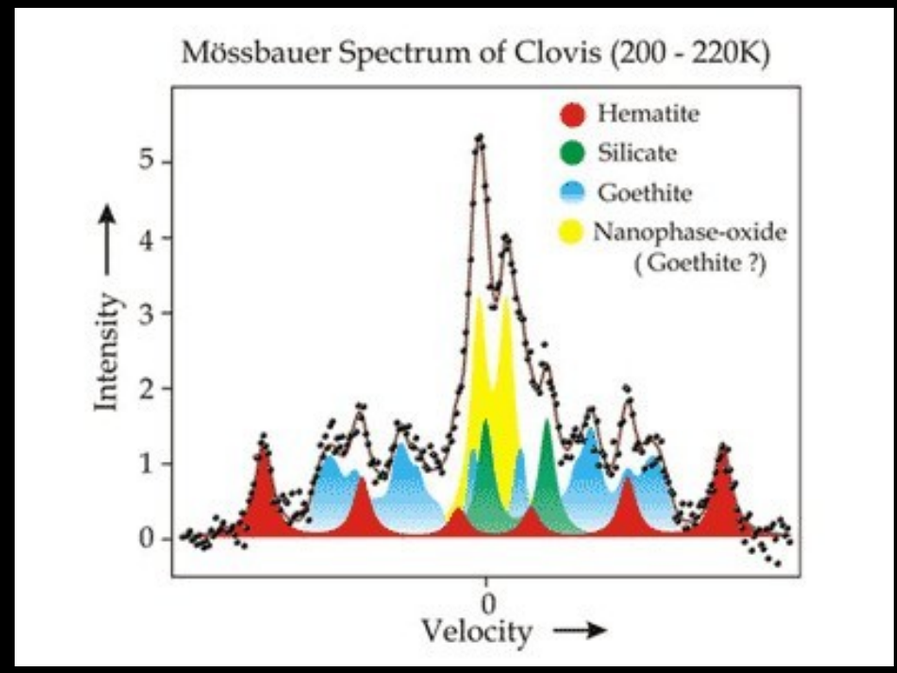
Magnetic properties experiment

In-Situ Package
- **Microscopic Imager**
- **Alpha Particle X-Ray Spectrometer**
- **Mössbauer Spectrometer**
- **Rock Abrasion Tool**




RAT hole

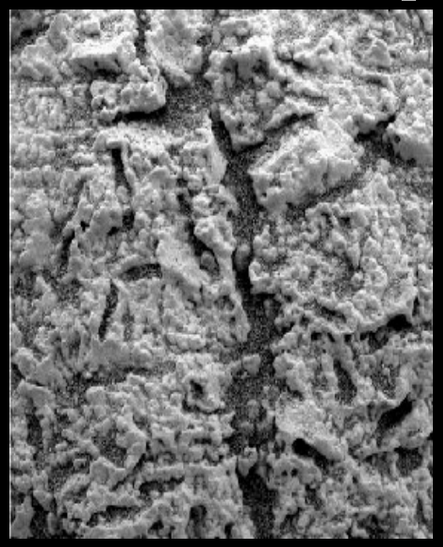



Mössbauer Spectrum of Clovis (200 - 220K)
Hematite
Silicate
Goethite
Nanophase-oxide
(Goethite ?)
Intensity
5
4
3
2
1
0
0
Velocity

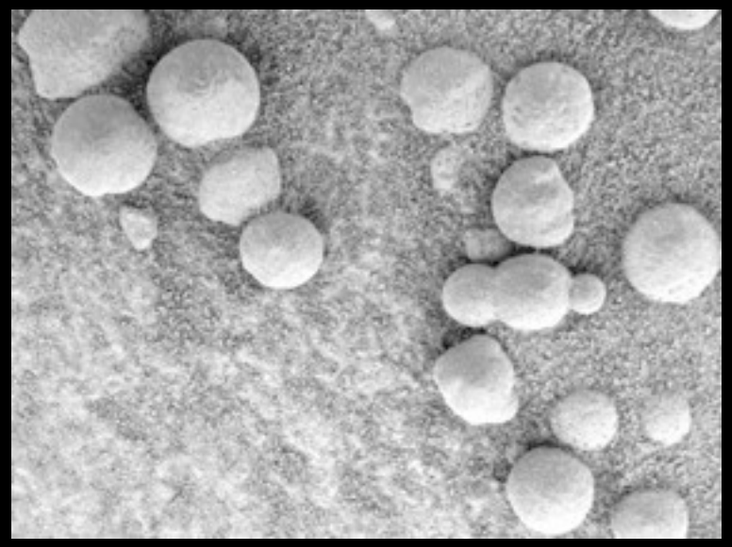
water?

water?

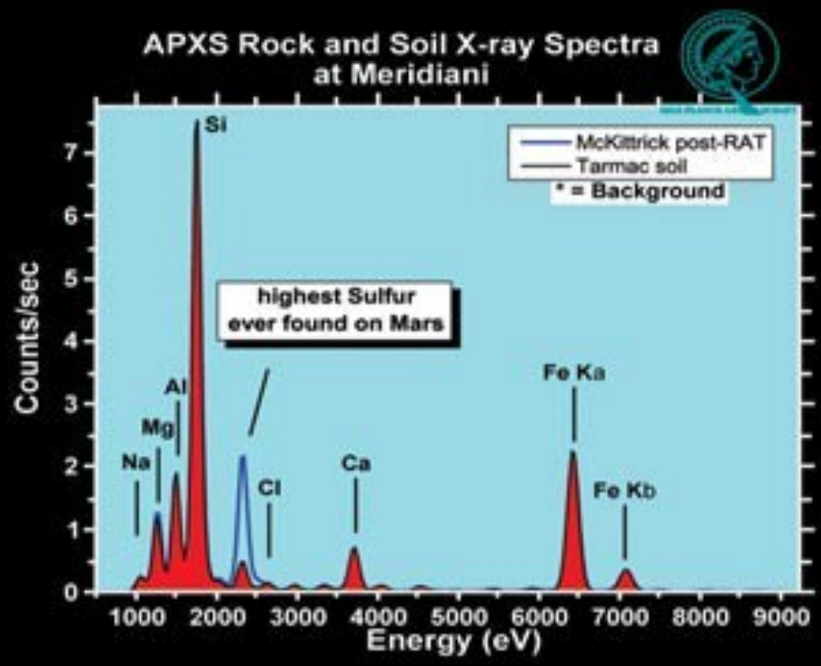
dissolved crystals



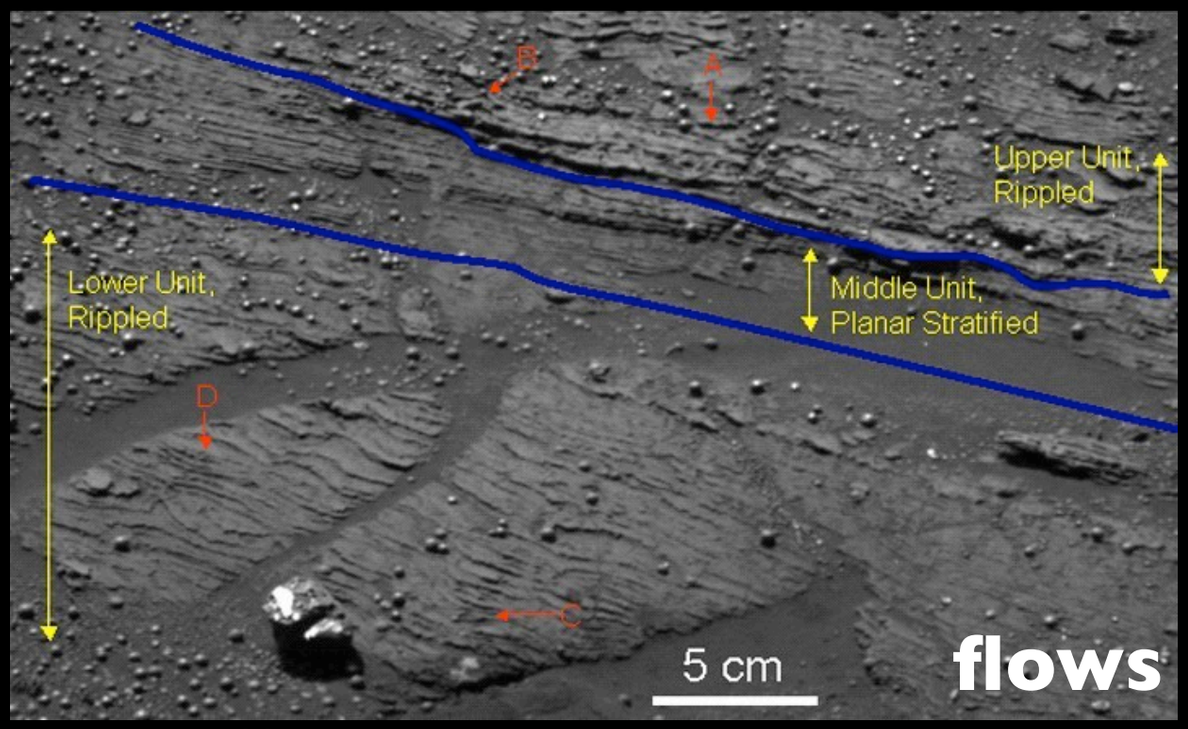
voids



blueberries

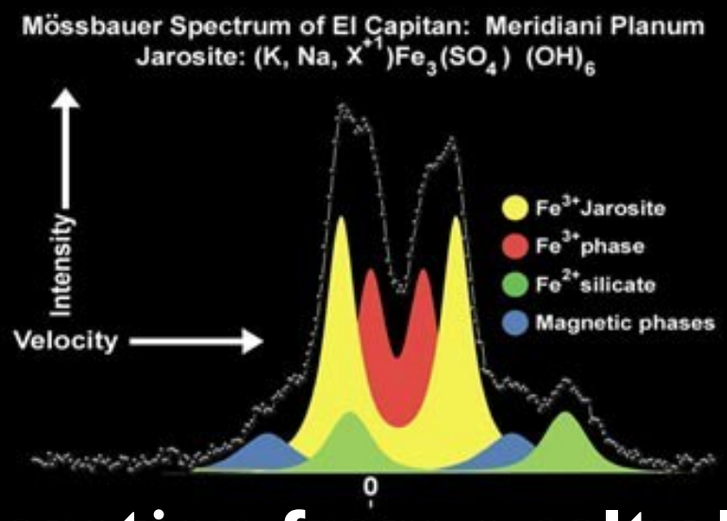


sulphates and standing water

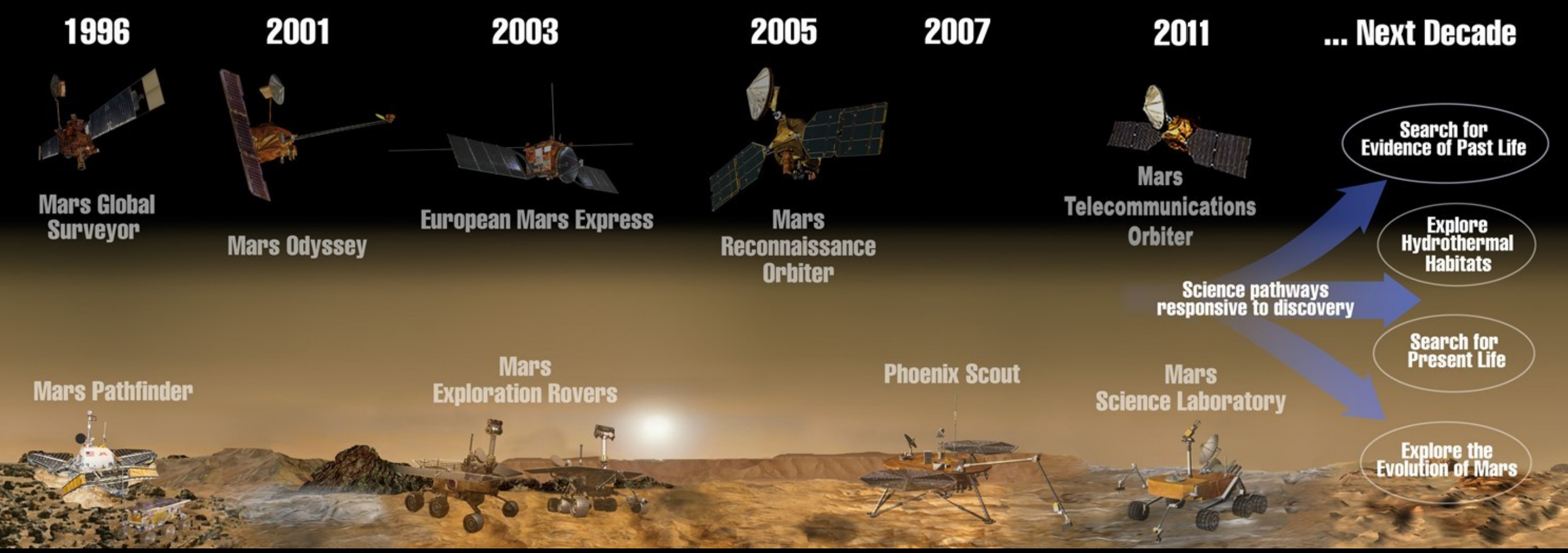


flows

different, rippled layers



evaporation from a salty brine



coming soon...

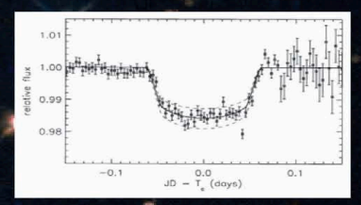
sample return

beyond the solar system

extrasolar planets

PLANETQUEST

KEPLER *the Search for Extra-solar Planets*



transiting exoplanets

the learning continues...