Today's Topics

Monday, September 21, 2020 (Week 5, lecture 14) – Chapter 7.

A. Space Probes

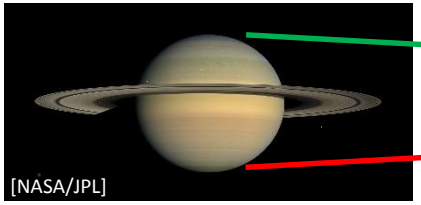
B. Structure of the Solar System

C. Density

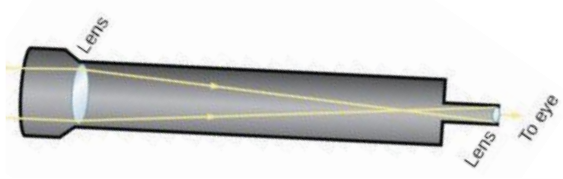
Angular Resolution and Size

Angular resolution (or resolving power) $\boldsymbol{\theta_{min}}$

The minimum angle that a telescope can see, i.e. it's the "angular pixel" size.



θ_{object}



celestial object

telescope

Imaging Detail

What ultimately matters is the number of angular pixels that you can get for your image:

$$number\ of\ angular\ \ pixels = \frac{\theta_{object}}{\theta_{min}}$$

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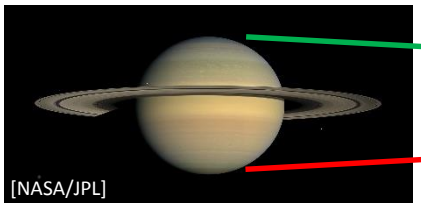

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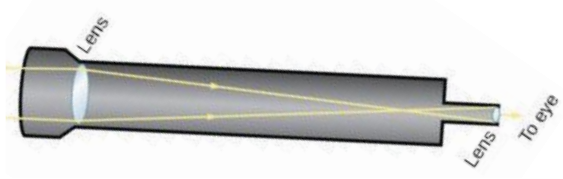


celestial object

telescope

Imaging Detail

What ultimately matters is the number of angular pixels that you can get for your image:

$$number\ of\ angular\ \ pixels = \frac{\theta_{object}}{\theta_{min}}$$

Telescopes maximize the number of pixels by minimizing θ_{min}.

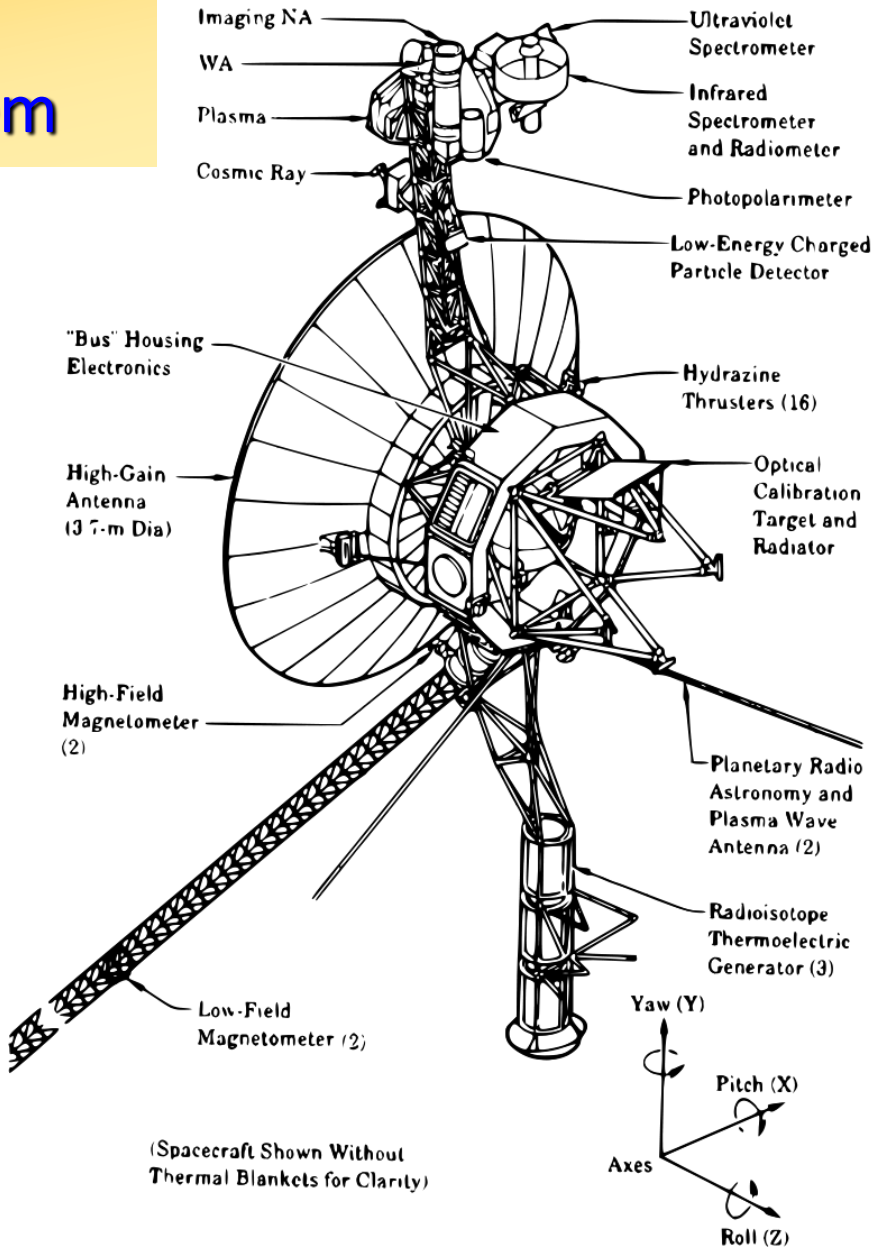
Space probes maximize the number of pixels by maximizing θ_{object}.

→ i.e. They get closer to the celestial object.

Space Probes

for exploring the Solar System

Voyager Spacecraft: basic structure



[Wikipedia: NASA derivative work: Camilo Sanchez (talk)]

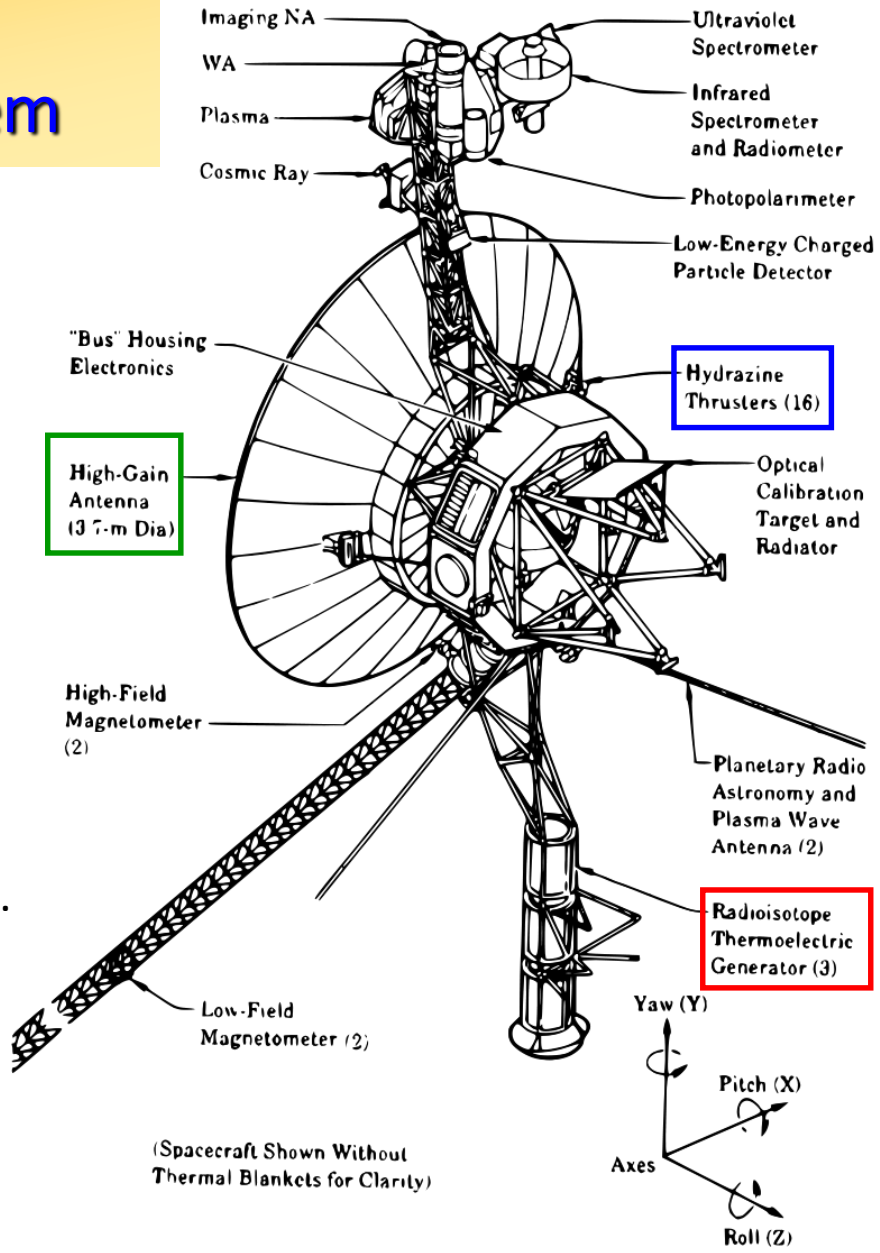
Space Probes

for exploring the Solar System

Basic Structure of an Interplanetary Space Probe

- ❑ Communications antenna / dish
  - → receive commands.
  - → transmit data.
- ❑ Computer
  - → Control all spacecraft parts.
- ❑ Power source
  - → Plutonium (thermoelectric), solar cells.
- ❑ Thrusters
  - → Rockets for motion control.
- ❑ Science sensors
  - → cameras, magnetometers, particle detectors, etc .

Voyager Spacecraft: basic structure

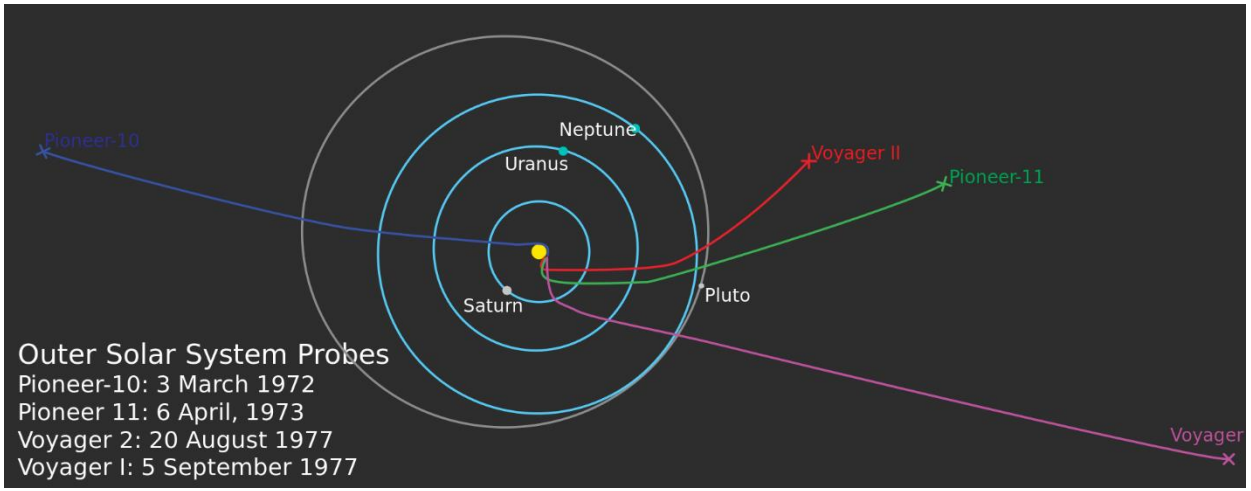


[Wikipedia: NASA derivative work: Camilo Sanchez (talk)]

Voyager 1 & Voyager 2

Explored the gas giant planets:

- Jupiter
- Saturn
- Uranus (V2)
- Neptune (V2)



Main Instruments

Cameras, magnetometers, IR & UV spectrometers, low-energy particle detector, cosmic ray detector, etc.

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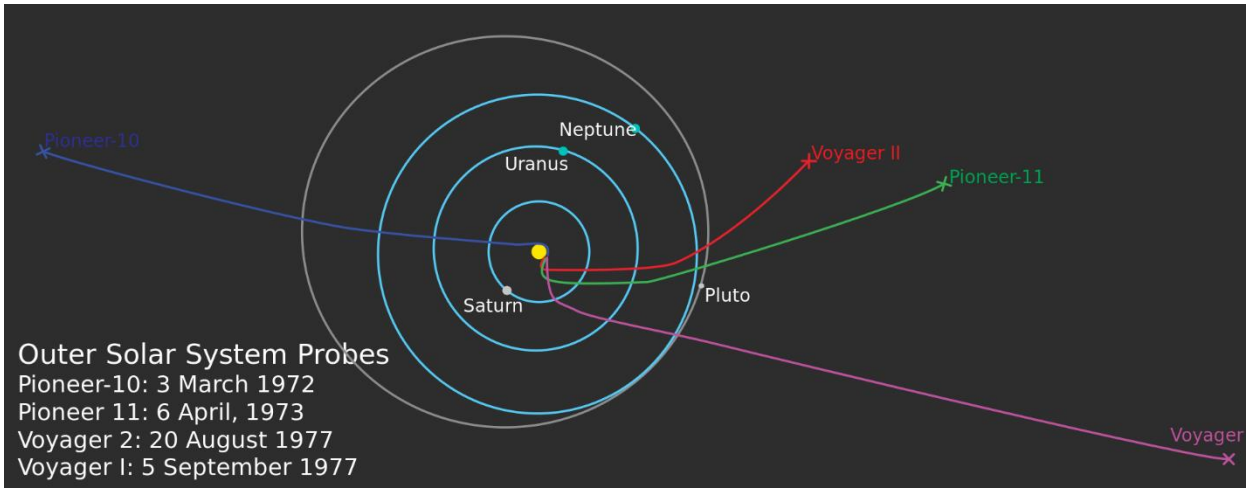


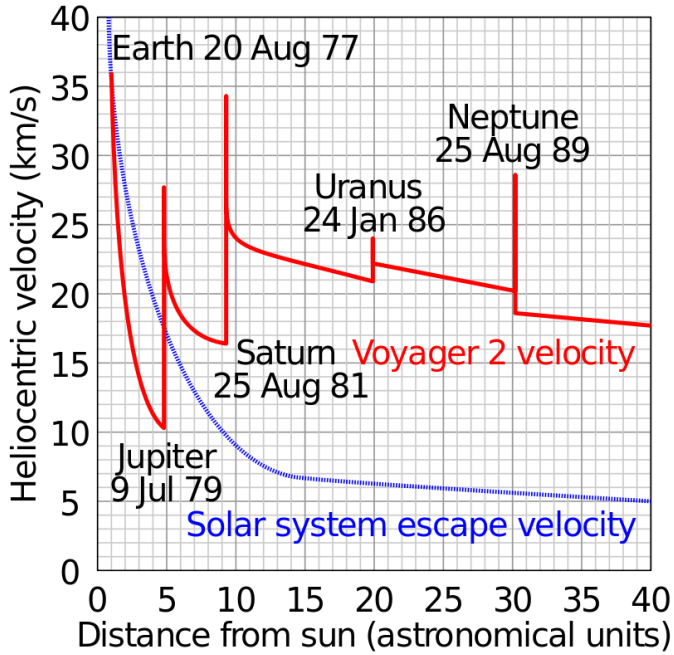
[By 7Train at the English Wikipedia, CC BY-SA 3.0]

Main Instruments

Cameras, magnetometers, IR & UV spectrometers, low-energy particle detector, cosmic ray detector, etc.

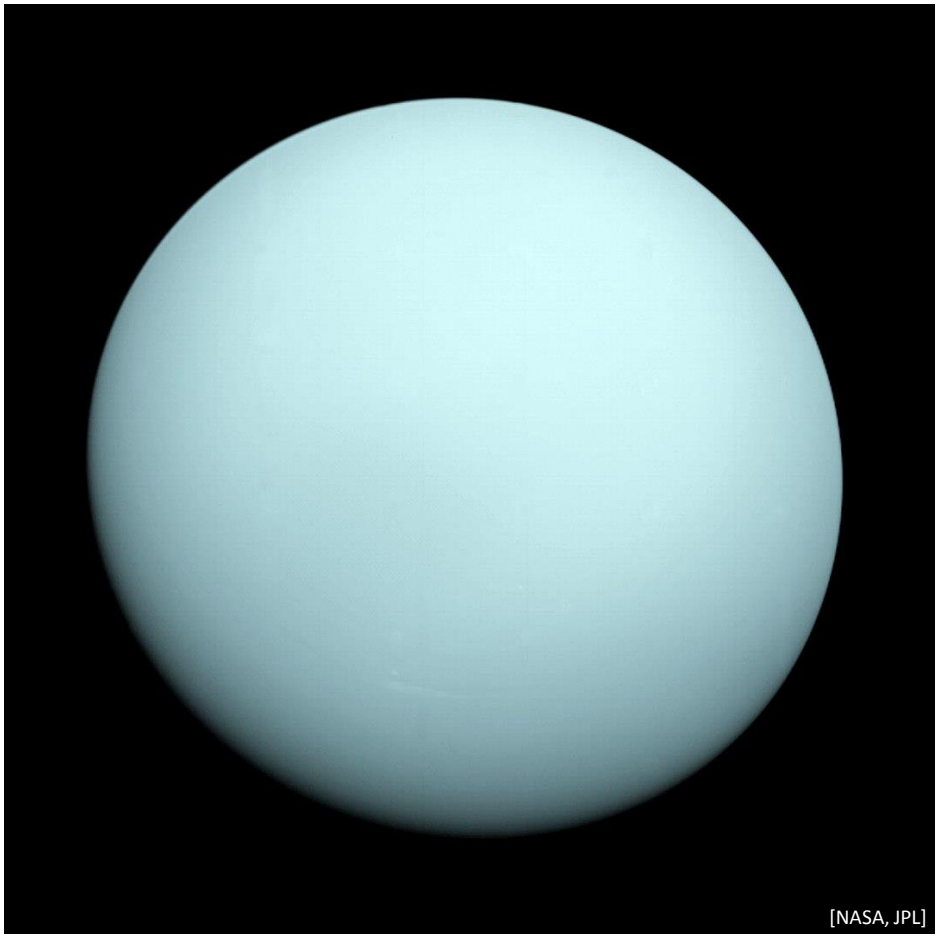
Key facts

- USA, launched in 1977, cost ~ $ 850 million USD.
- Voyager 1 was the first probe to leave the Solar System and enter interstellar space (2012).
- Used gravity assist from planets to increase speed.

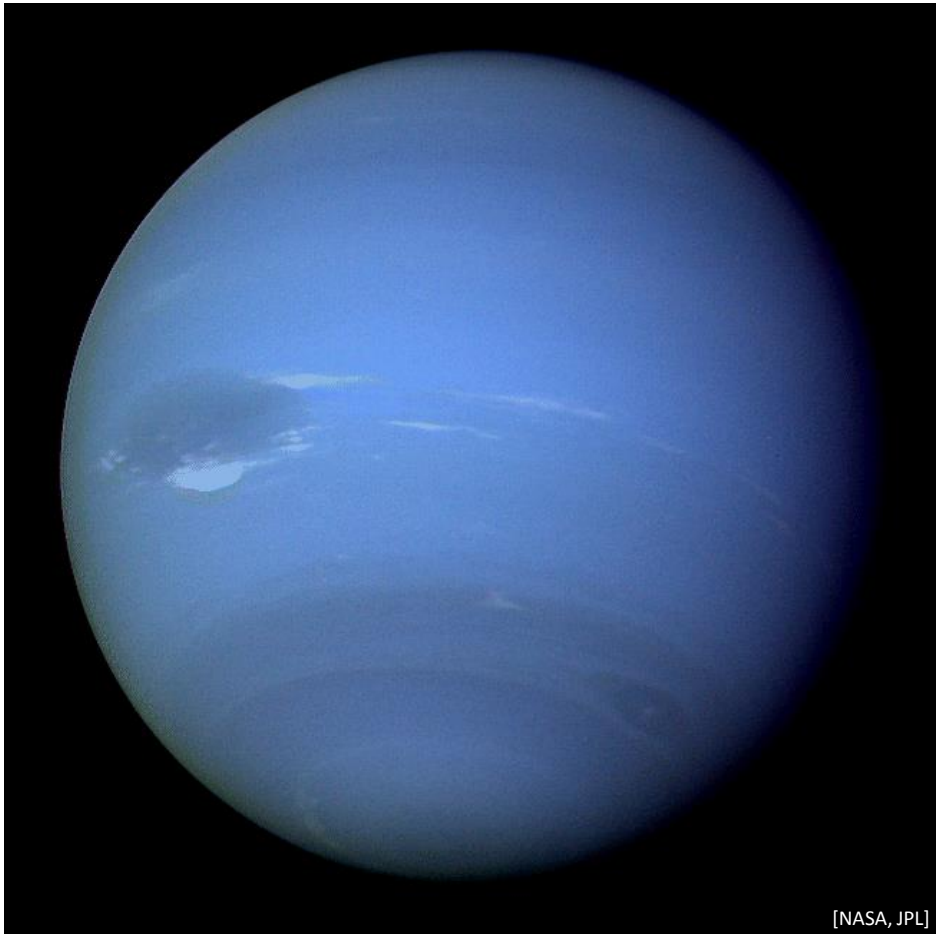


[By Cmglee - Own work, CC BY-SA 3.0]

Voyager 2: Uranus & Neptune



Uranus -- photo by Voyager 2 (1986)

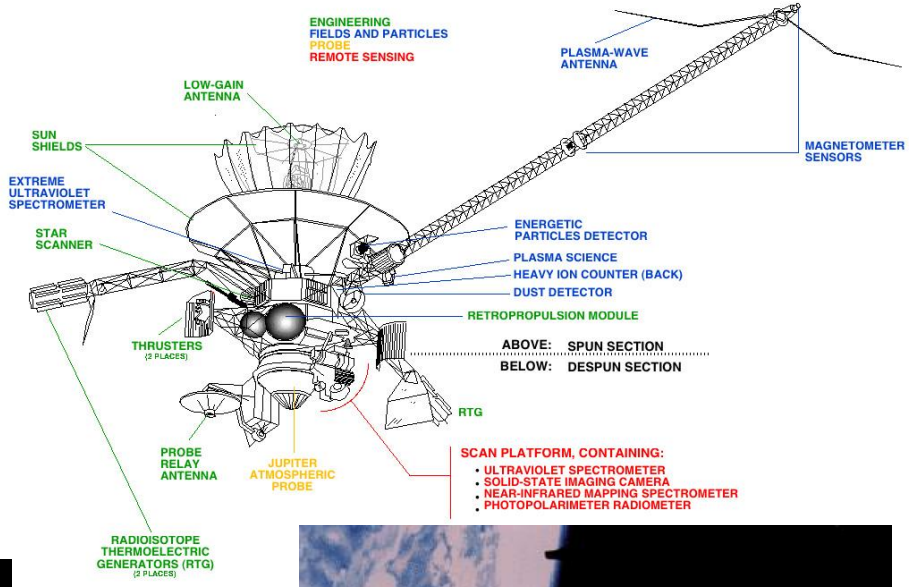


Neptune -- photo by Voyager 2 (1989)

Galileo Probe: Jupiter

Key Facts

- Launched 1989 (NASA + UK, FR, CA, SW).
- Arrived at Jupiter in 1995.
- 34 orbits & atmospheric probe.
- Studied Jupiter and main moons:
  → Io, Ganymede, Callisto, and Europa.
- Mission end in 2003 (atmospheric entry).

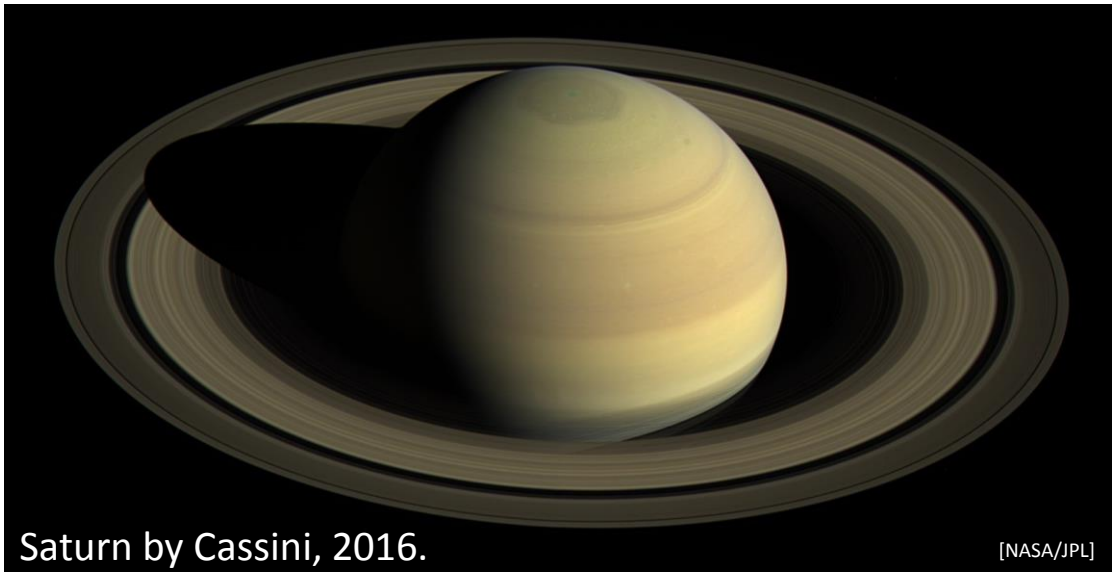



Europa by Galileo spacecraft [NASA/JPL]

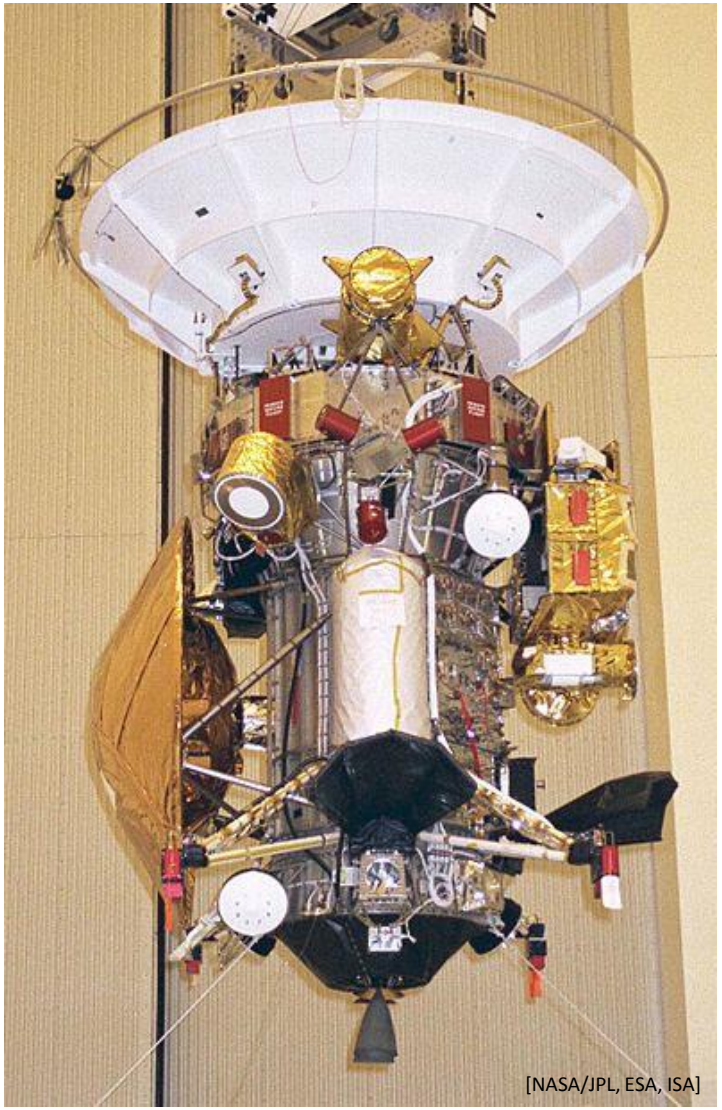
Cassini-Huygens Probe: Saturn

Key Facts

- Launched in 1997, NASA + ESA, ISA.
- Arrived at Saturn in 2004.
- Studied Saturn, rings, and moons.
  → Lander probe on Titan (largest moon).
- Mission end in 2017 (atmospheric entry).



Saturn by Cassini, 2016. [NASA/JPL]



[NASA/JPL, ESA, ISA]

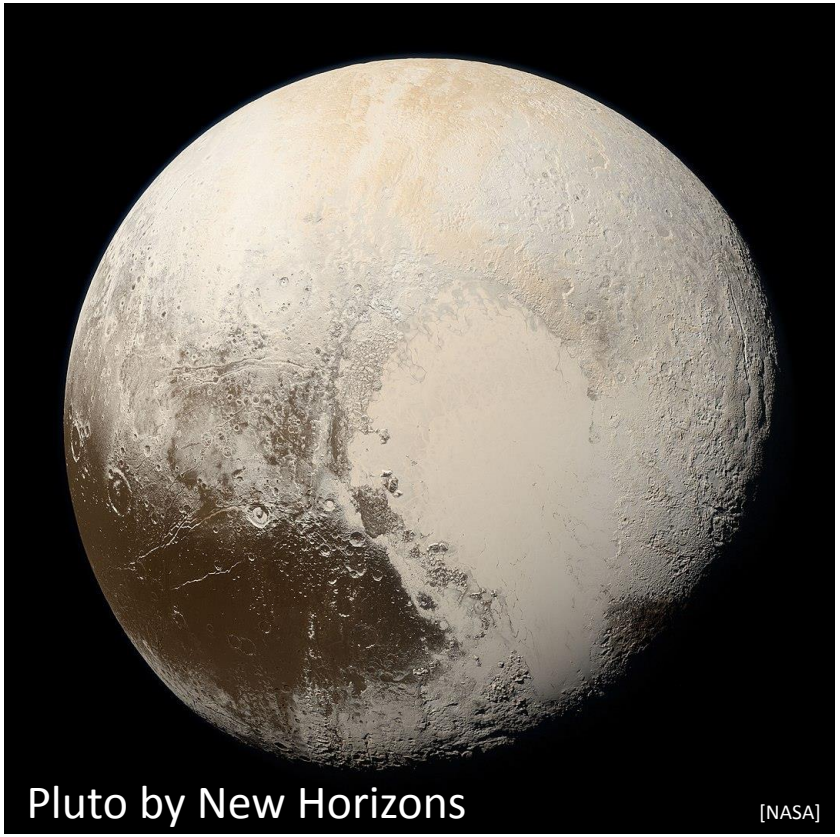
New Horizons: Pluto

Key Facts

- Launched in 2006, NASA + Johns Hopkins APL.
- Fly-by of Pluto in 2015.
- Studied Pluto and five moons.
- Studying Kuiper Belt objects, e.g. Ultima-Thule.
- Mission is on-going.

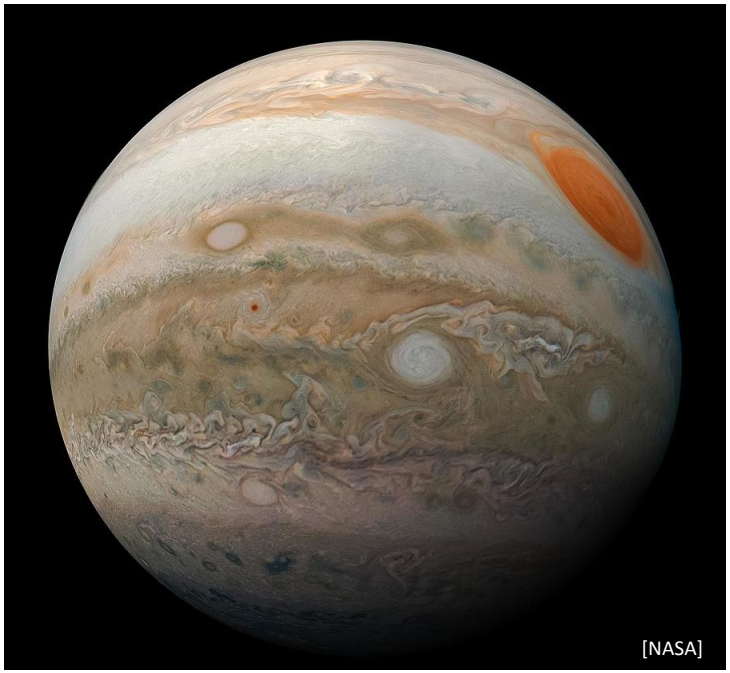
[NASA]


[NASA]



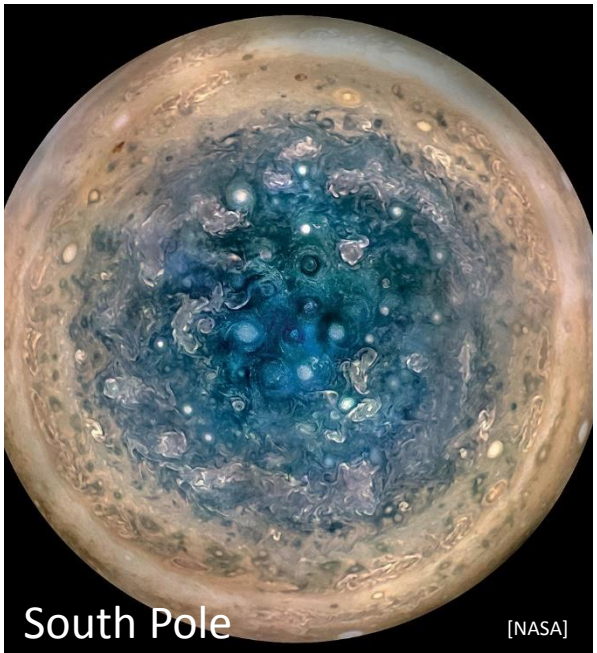
[NASA]

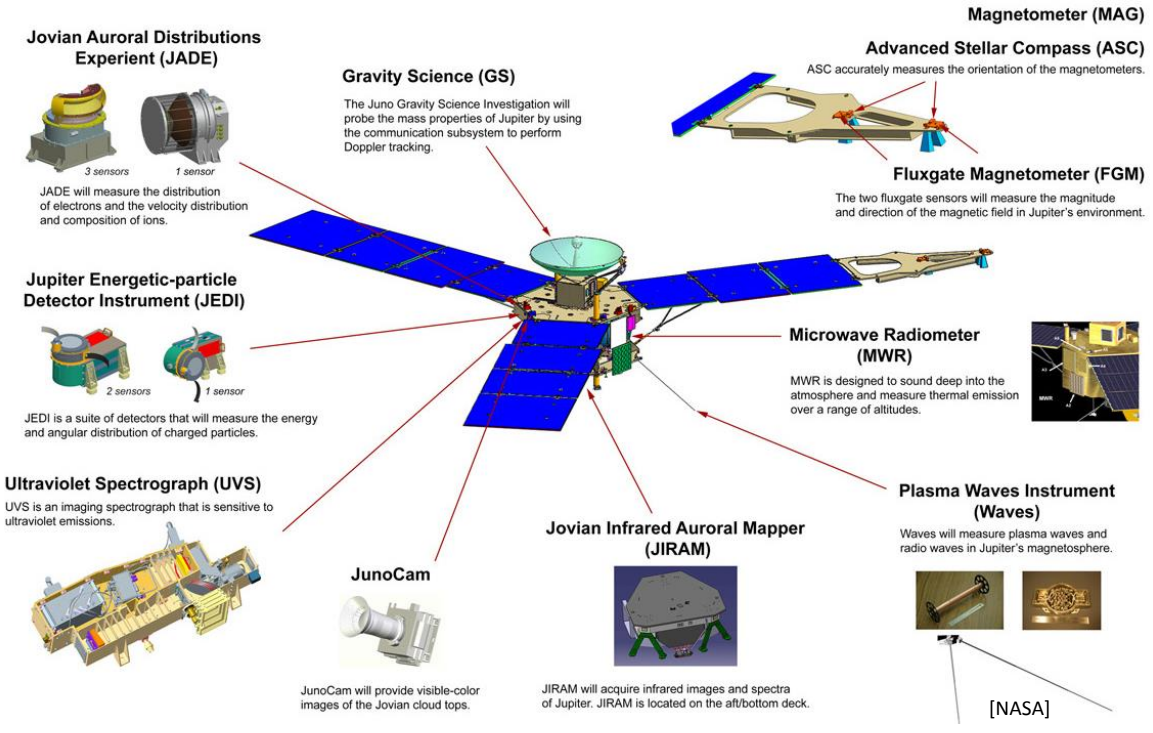
Juno: Jupiter again



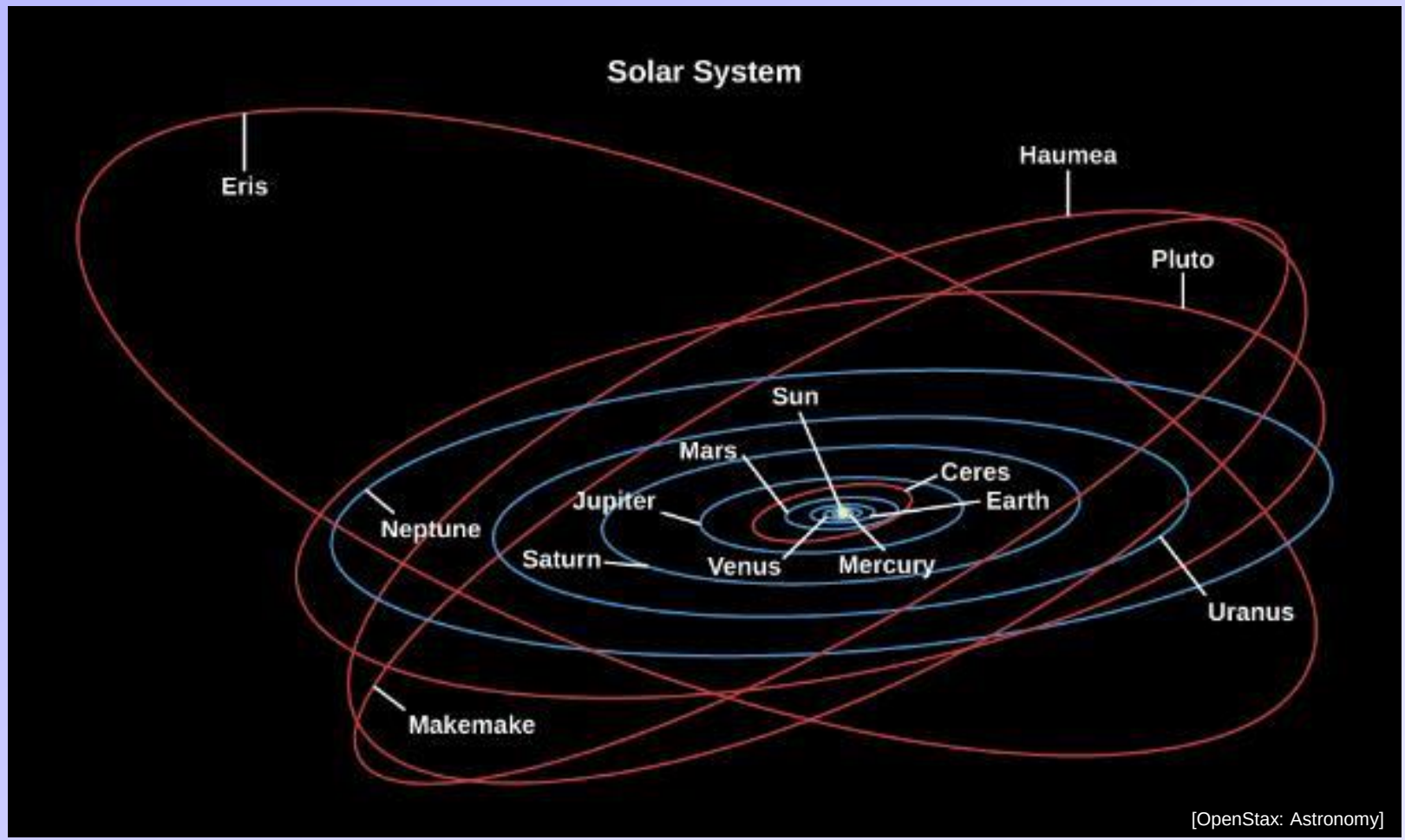
Key Facts

- Launched in 2011, NASA/JPL.
- Arrival at Jupiter in 2016.
- Studying **polar** regions, precision **gravity** map, precision **magnetic** map, frame dragging test (general relativity), chemical composition, atmosphere.
- Mission is on-going (end: 2021).





Structure of Solar System



- Planets orbit in the **same plane** (more or less), but outer dwarf planets do not.
- **Orbit direction is the same** for all planets, and matches Sun's rotation direction.
- Inner planets: rocky; outer planets: "gaseous" … icy/less rocky.

Density of Planets

Name	Distance from Sun (AU)[2]	Revolution Period (y)	Diameter (km)	Mass (10^{23} kg)	Density (g/cm^3)[3]
Mercury	0.39	0.24	4,878	3.3	5.4
Venus	0.72	0.62	12,120	48.7	5.2
Earth	1.00	1.00	12,756	59.8	5.5
Mars	1.52	1.88	6,787	6.4	3.9
Jupiter	5.20	11.86	142,984	18,991	1.3
Saturn	9.54	29.46	120,536	5686	0.7
Uranus	19.18	84.07	51,118	866	1.3
Neptune	30.06	164.82	49,660	1030	1.6

[OpenStax: Astronomy]

Density of Planets

telescope measurements ↓ ? ↓

measurements or Kepler's 3rd Law

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Newton's version of Kepler's 3rd Law using moons/satellites

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[OpenStax: Astronomy]

Density of Planets

Density of water = 1 g/cm^3

note: ml = cm^3

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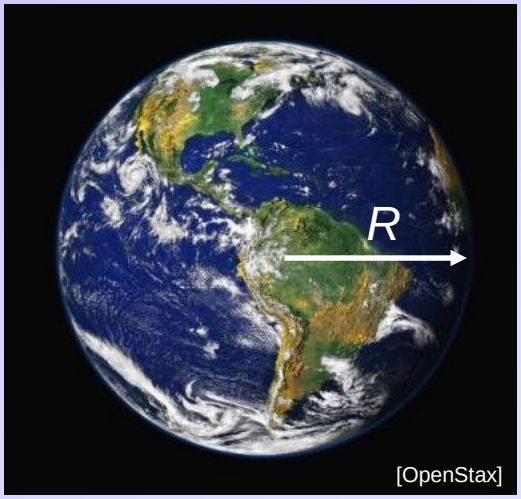
Planet Density

Q: How do you calculate density ?



Answer:

$$\text{Density} = \rho = \frac{Mass}{Volume} = \frac{Mass\ of\ Planet}{Volume\ of\ Planet}$$

$$Volume\ of\ a\ Sphere = V_{sphere} = \frac{4}{3}\pi R^3$$

with $R = radius\ of\ sphere/planet$

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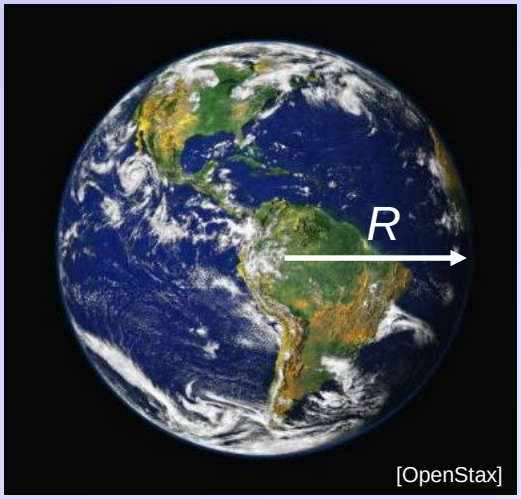

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Densities of planetary materials

water/ice H_2O = 1 g/cm^3

liquid hydrogen = 0.07 g/cm^3

liquid helium = 0.1 g/cm^3

liquid nitrogen = 0.8 g/cm^3

liquid methane = 0.4 g/cm^3

solid CO_2 = 1.6 g/cm^3

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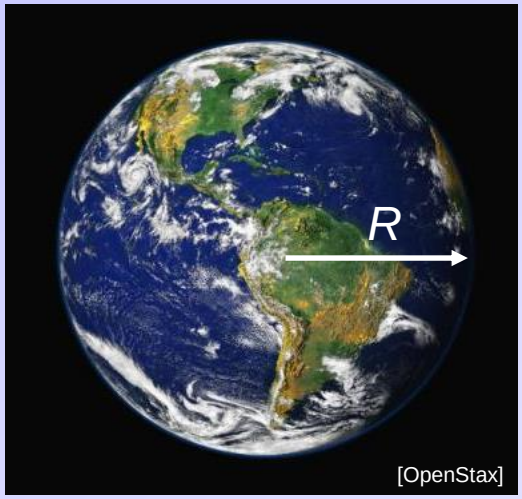

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limestone ~ 2.6 g/cm^3
granite ~ 2.7 g/cm^3
basalt ~ 3.0 g/cm^3

rock

iron ~ 9 g/cm^3
nickel ~ 9 g/cm^3
uranium ~ 19 g/cm^3
iridium ~ 22.7 g/cm^3