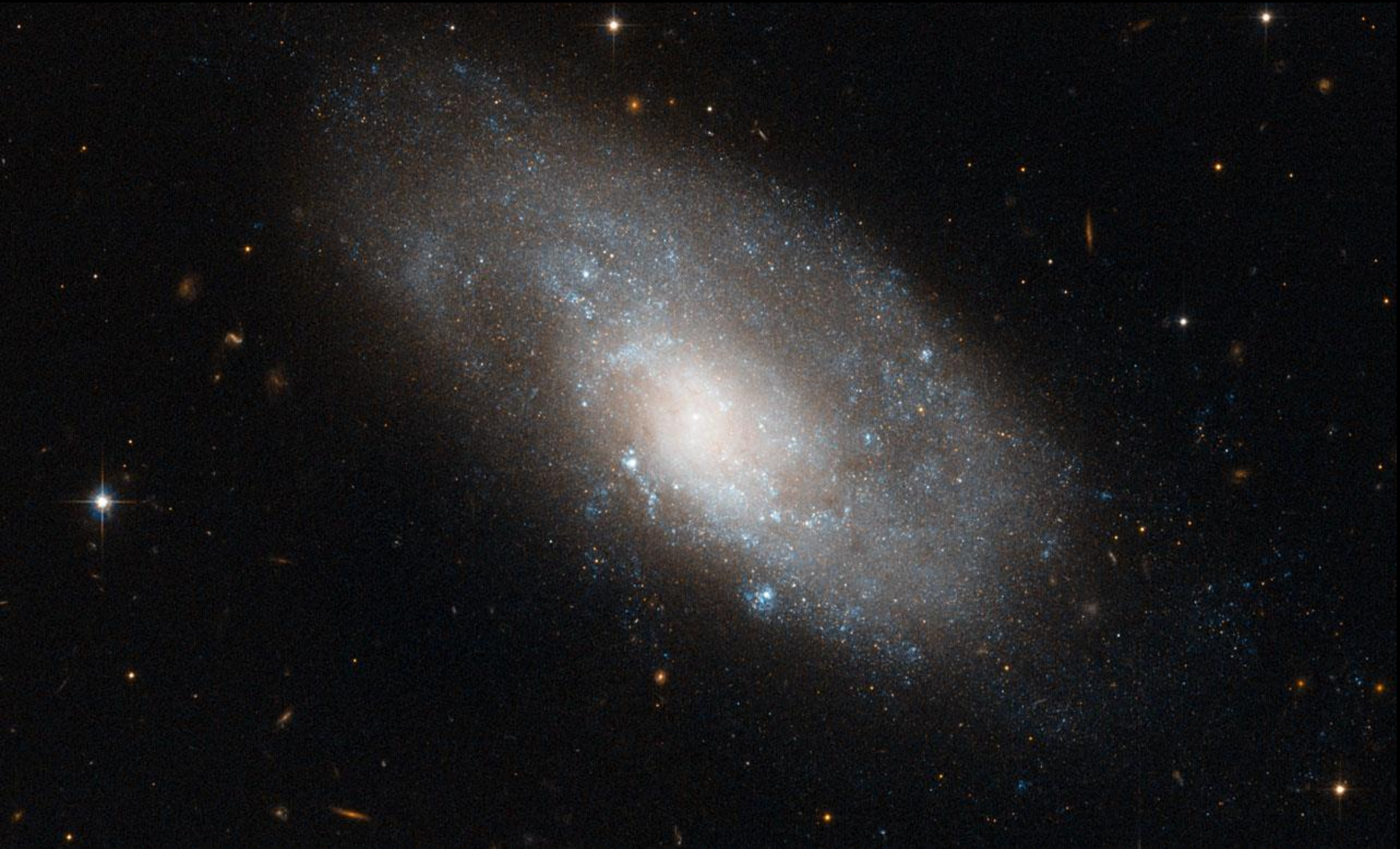
JUNO

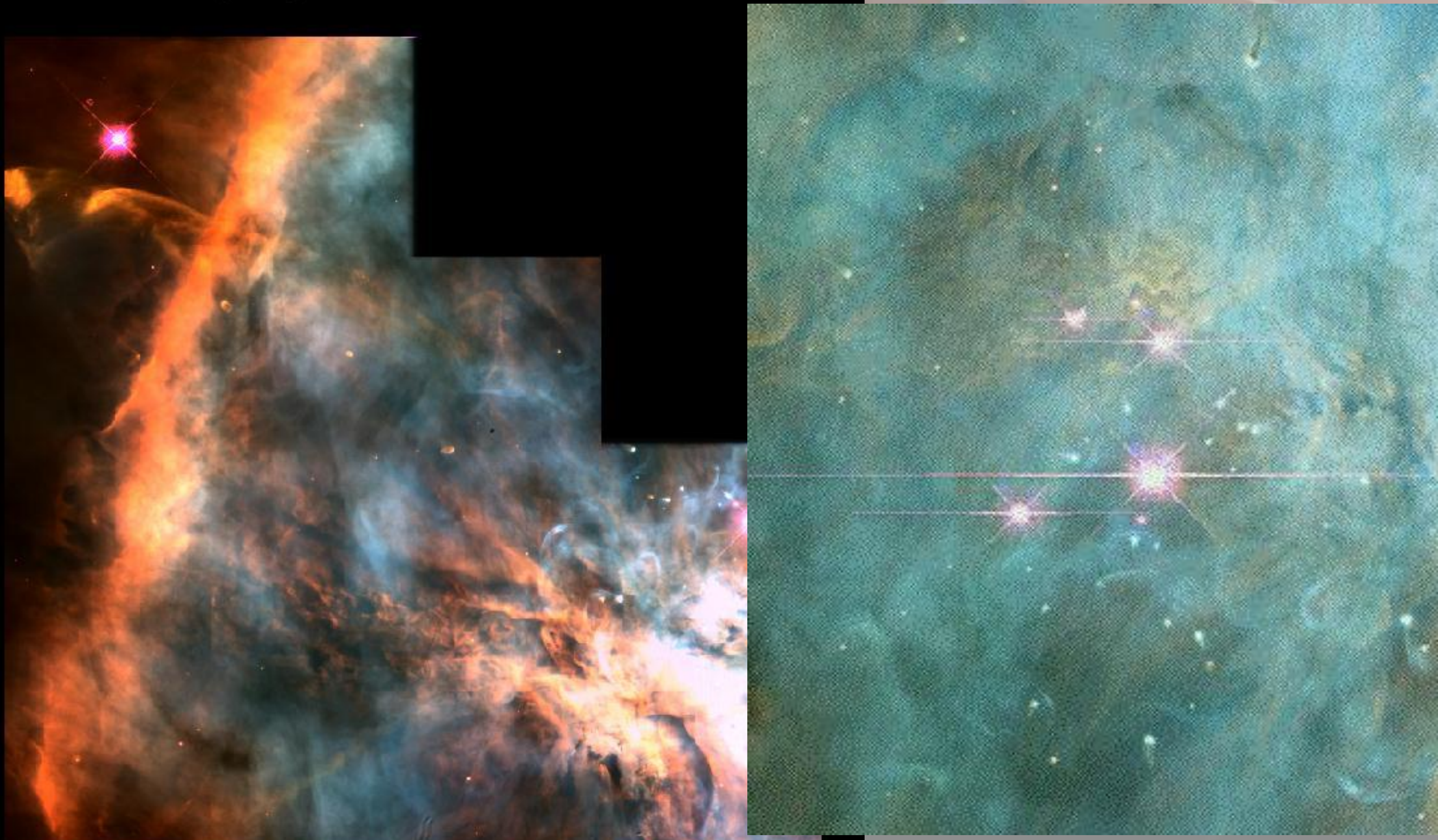
Scott Bolton – Juno Principal Investigator

In the beginning….

- Scientists believe our solar system started as a cloud of gas in our galaxy…
- This cloud was probably like other clouds that we see throughout our galaxy…
- Clouds are mostly hydrogen and helium, different from the stars or the “plasma” that makes up most of our Universe



The Orion Nebula



Hubble Space Telescope
Wide Field Planetary Camera 2

SPACE TELESCOPE SCIENCE INSTITUTE

Pillars of Creation

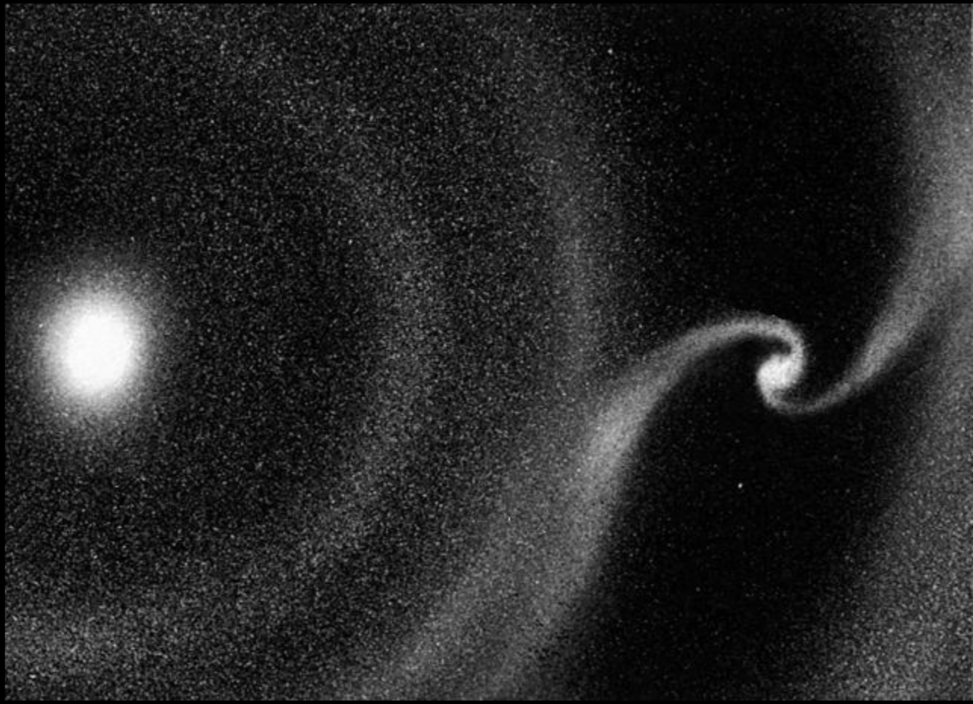
The First Step…

- Somehow the spinning cloud collapsed and our Sun was born.
- Most of the tiny bit of leftovers became Jupiter
- and the leftovers of the leftovers became the rest

The History of our Solar System

Present theories of solar system origin and evolution do not explain how Jupiter was enriched in heavy elements.

This is key to understanding how giant planets form, in our own and other planetary systems.



These heavy elements are the seeds for the Earth and life as we know it.

The Elements…

- The key to understanding where we came from and how we got here….

- Everything is made up of atoms…

- There are different kinds, and the comparison of our composition with that of the sun, the planets, and the universe is a major clue

Periodic Table of Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VII	VII	VII	IB	IB	IIIA	IVA	VA	VIA	VIIA	0
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 +Ac	104 Rf	105 Ha	106 106	107 107	108 108	109 109	110 110								

* Lanthanide Series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
+ Actinide Series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Legend - click to find out more...

H - gas

Li - solid

Br - liquid

Tc - synthetic

Non-Metals

Transition Metals

Rare Earth Metals

Halogens

Alkali Metals

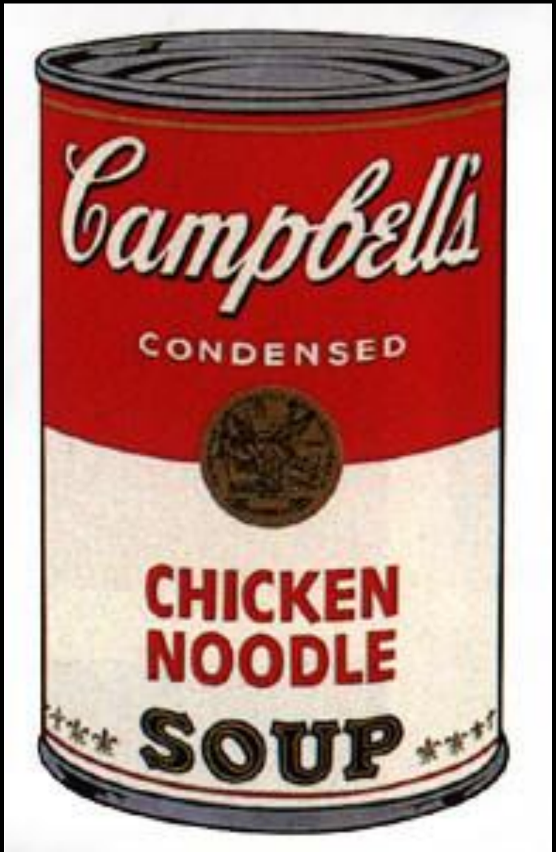
Alkali Earth Metals

Other Metals

Inert Elements

Consider the solar system as a soup…

we need to figure out the recipe…



Why Jupiter is so Important

- It’s the largest planet.
- Probably formed first.
- Is very much like the Sun in composition.
- We lost Earth’s history, but not Jupiter’s.

Juno’s Measurements Related to Origin

Gravity Science

Does Jupiter have a core of heavy elements?

What initiated the formation of Jupiter? When?

What were the conditions in the proto-planetary nebula?

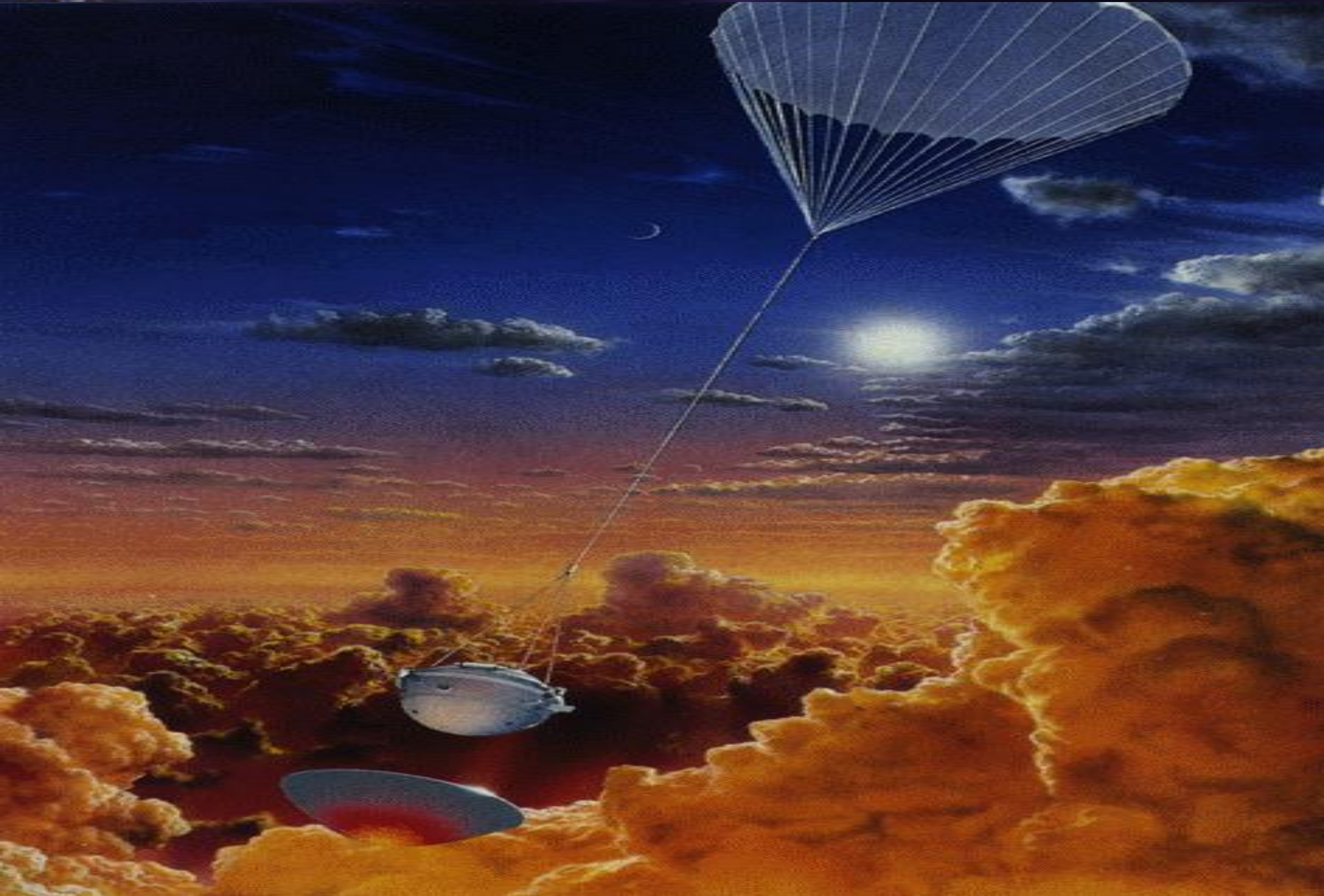
Water Abundance

How does the enrichment of Oxygen compare with the other heavy elements?

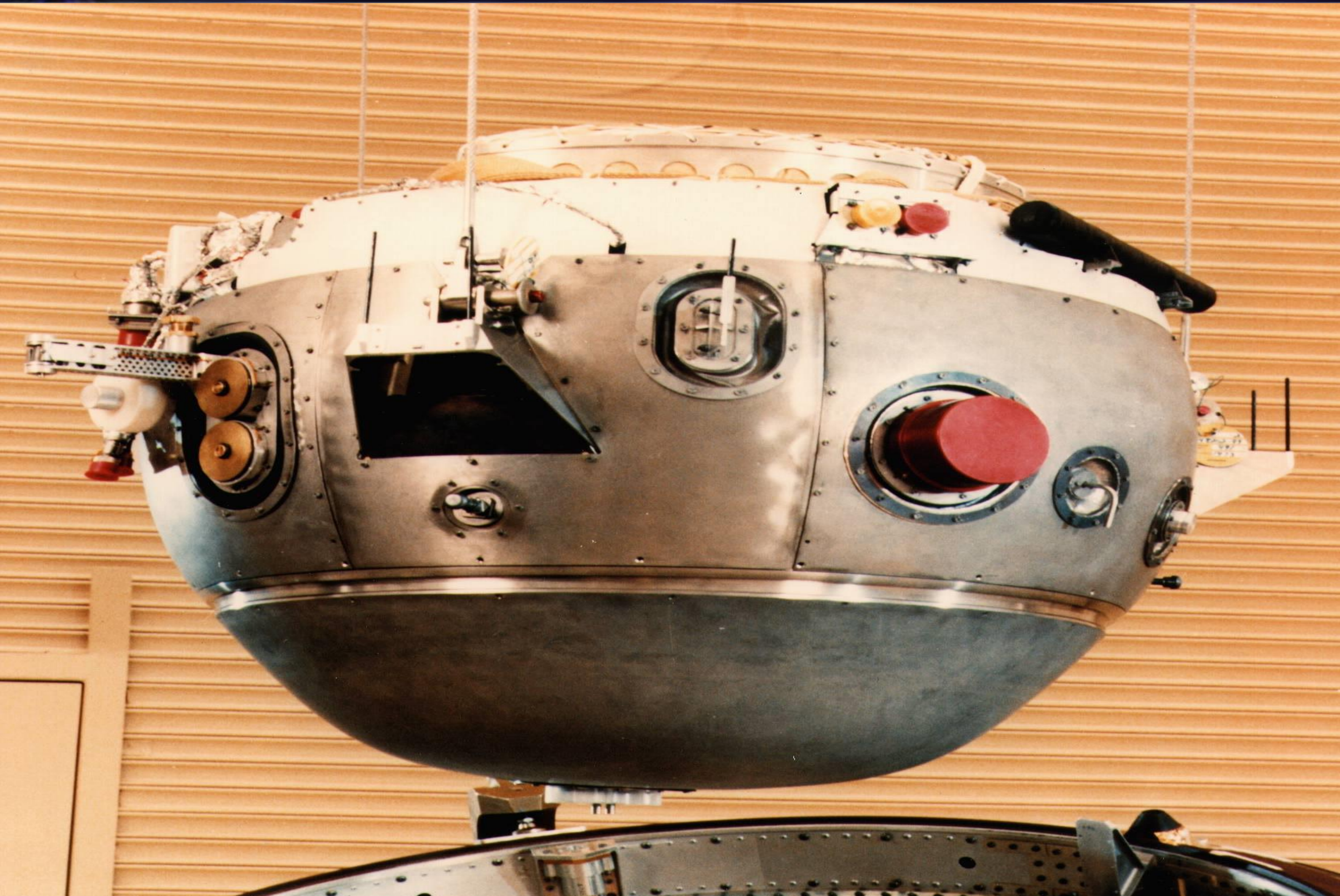
How did the planets get their heavy elements?

How did Earth’s get its oceans and volatiles?

Galileo probe descent

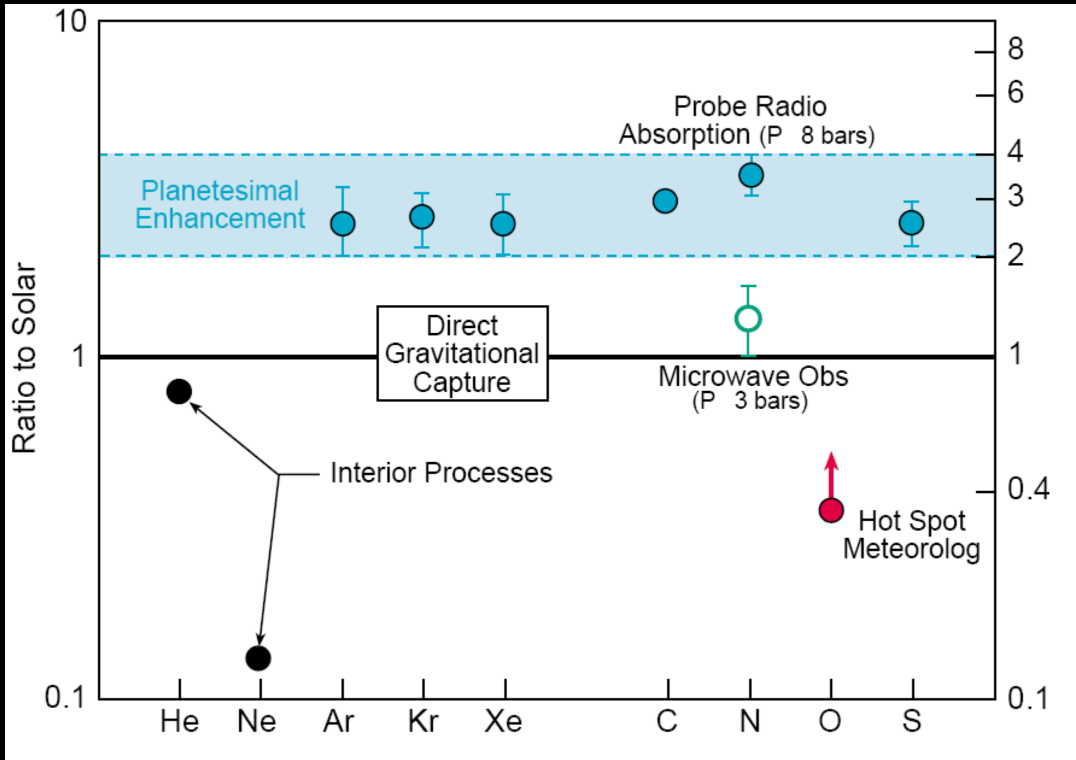


Galileo Probe Close Up



Galileo Probe Results

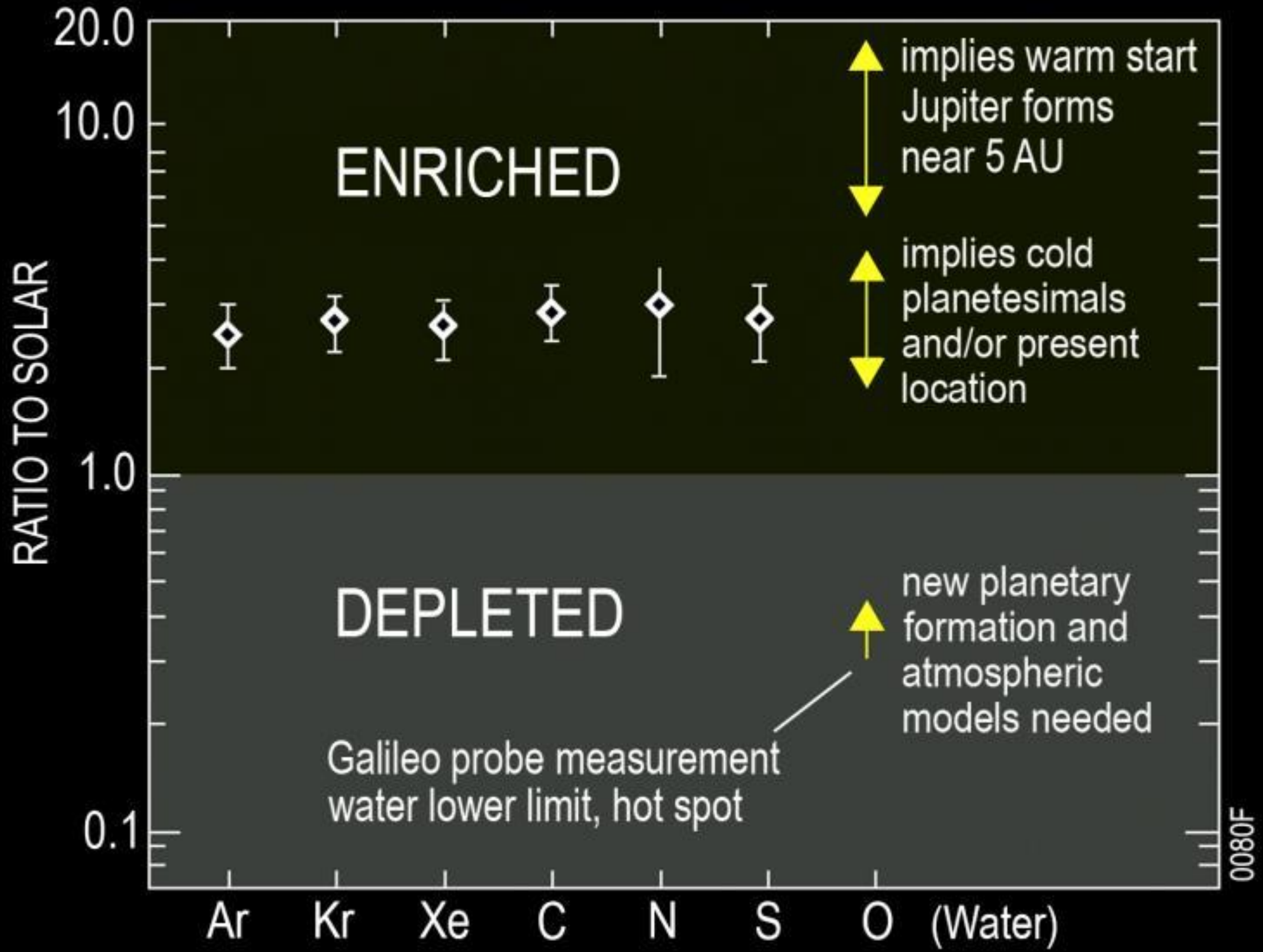
- Galileo results show similar enrichment in key elements, independent of volatility
- Results imply Jupiter formed colder and/or further out than 5 AU
- Solid material that enriched Jupiter was most abundant solid material in early solar system



Ratio of Jovian to Solar Abundances

Water → Oxygen

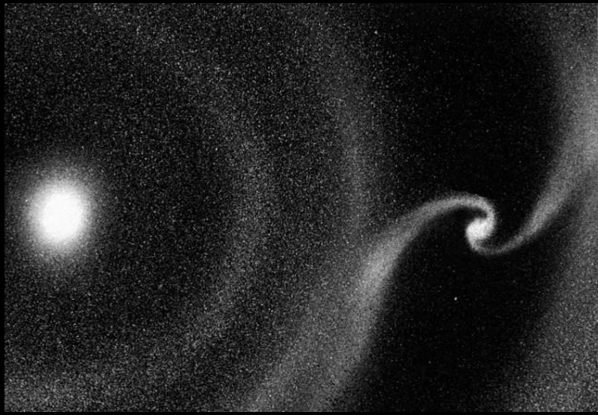
Water is key to understanding the formation of Jupiter.



Juno’s Science Objectives

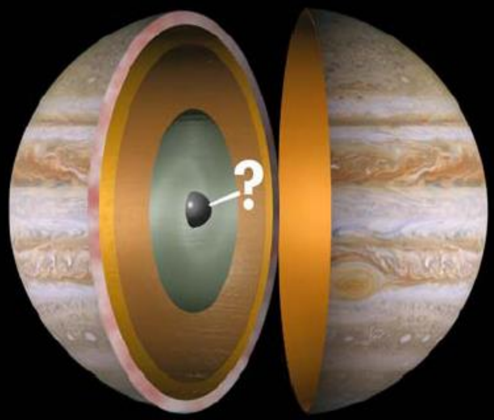
Origin

Determine O/H ratio (water abundance) and constrain core mass to decide among alternative theories of origin.



Interior

Understand Jupiter's interior structure and dynamical properties by mapping its gravitational and magnetic fields

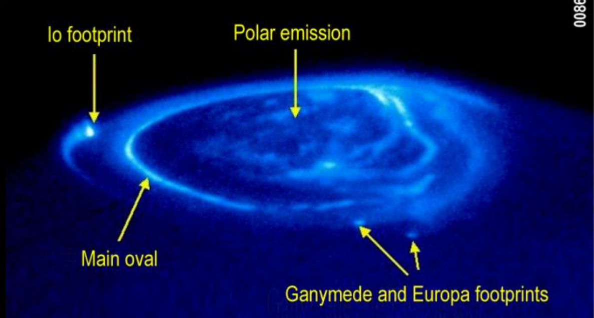


Atmosphere

Map variations in atmospheric composition, temperature, cloud opacity and dynamics to depths greater than 100 bars at all latitudes.

Magnetosphere

Characterize and explore the three-dimensional structure of Jupiter's polar magnetosphere and auroras.



Juno Mission Overview

Salient Features:

- First solar-powered mission to Jupiter
- Eight science instruments to conduct gravity, magnetic and atmospheric investigations, plus a camera for education and public outreach
- Spinning, polar orbiter spacecraft launched on August 5, 2011
  - 5-year cruise to Jupiter, arriving July 4 2016
  - 16 months of science operations at Jupiter, ending with de-orbit into Jupiter in February 2018
- Elliptical 14-day orbit swings below radiation belts to minimize radiation exposure
- 2nd mission in NASA's New Frontiers Program

Science Objective: Improve our understanding of giant planet formation and evolution by studying Jupiter's origin, interior structure, atmospheric composition and dynamics, and magnetosphere

Juno Mission Design

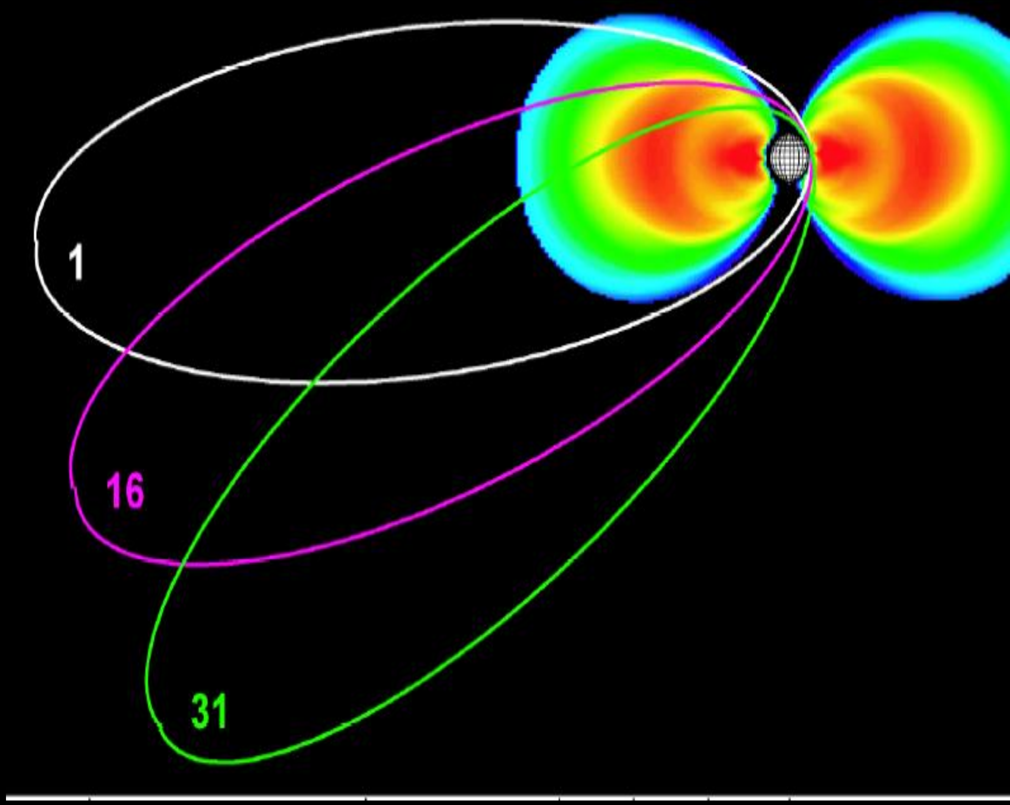
32 polar orbits around Jupiter

Each orbit is 14 days long

Closest Juno gets to Jupiter is 5000 km

Spacecraft spins 2 rpm

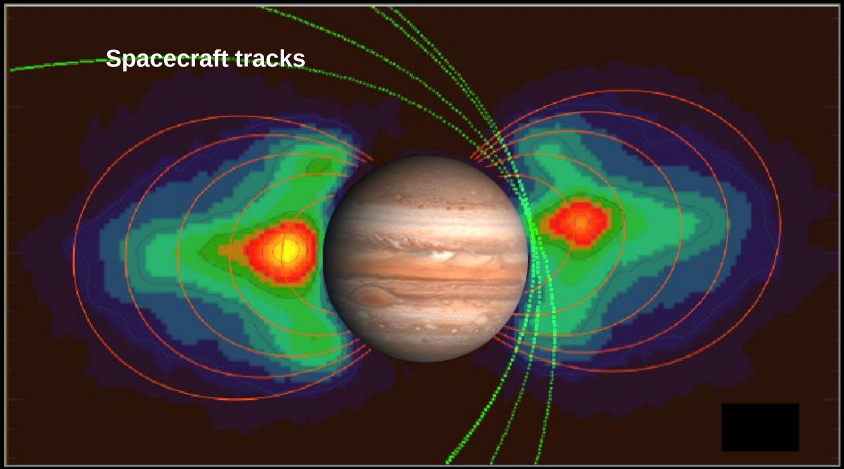
Solar-powered



The Juno/DSN-GAVRT Connection

Education and Science

- Students contribute to Juno science
  - Modeling the radiation environment
  - Providing context for Microwave Radiometer data
- Juno science lessons (in and out of the classroom)
- Juno scientists participate in GAVRT teacher training
- Juno scientists in the (GAVRT) classroom
- Future plans (Junocam)



GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L04104, doi:10.1029/2004GL021986, 2005

A revised model of Jupiter's inner electron belts: Updating the Divine radiation model

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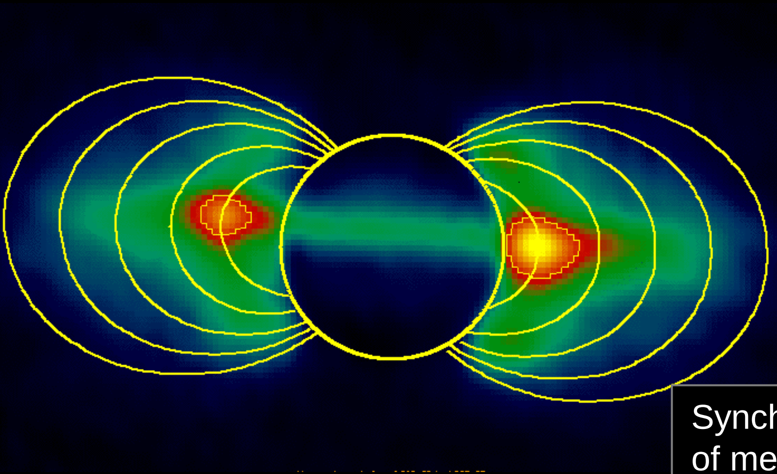
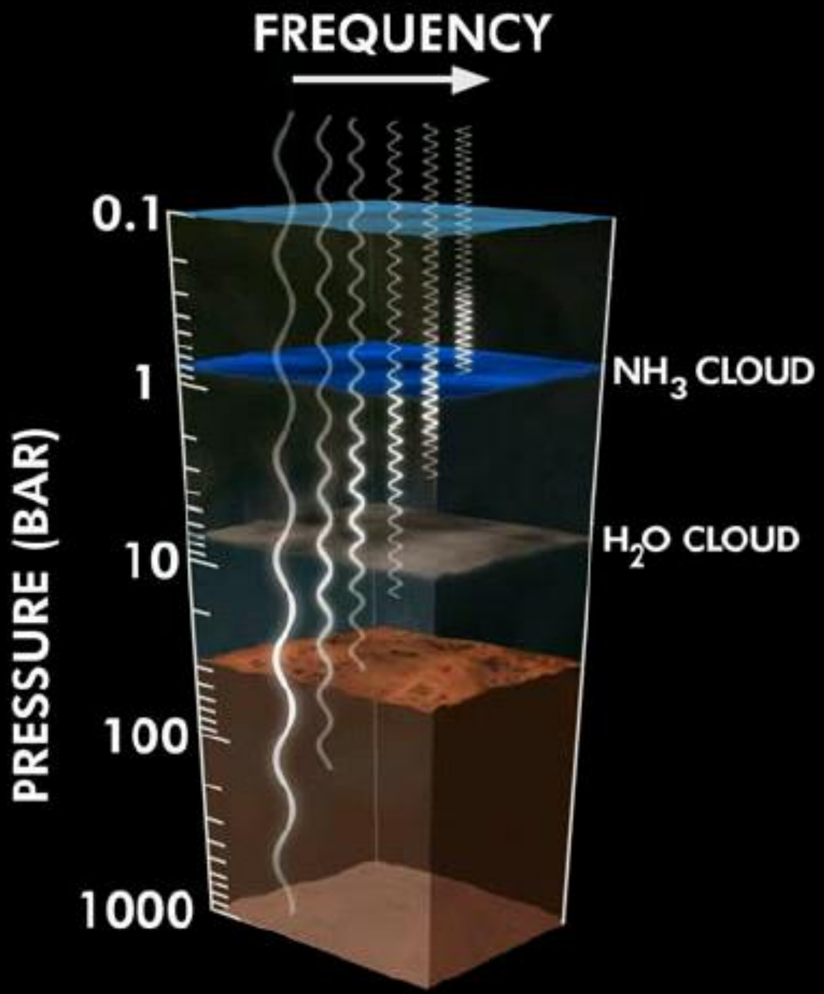
Received 17 December 2004; revised 3 January 2005; accepted 1 February 2005; published 26 February 2005.

Sensing the Deep Atmosphere

Juno's Microwave Radiometer measures thermal radiation from the atmosphere to as deep as 1000 atmospheres pressure (~500-600km below the visible cloud tops).

Determines water and ammonia abundances in the atmosphere all over the planet

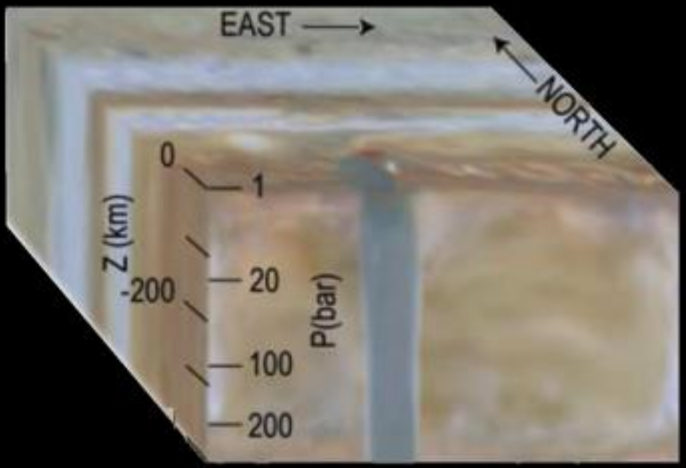




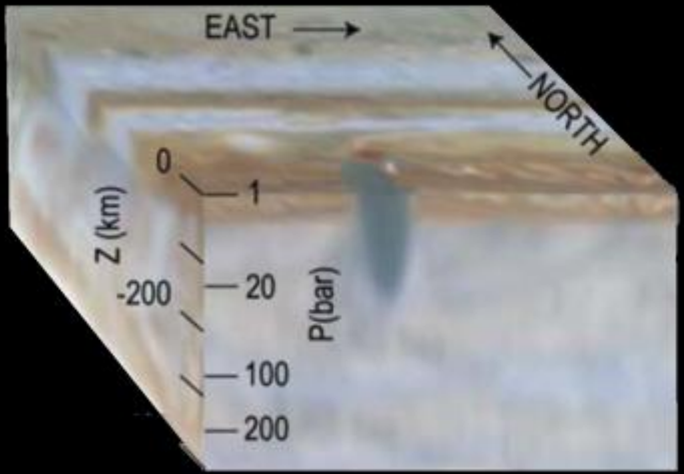
Synchrotron radio emission from the radiation belts makes this kind of measurement impossible from far away on Earth

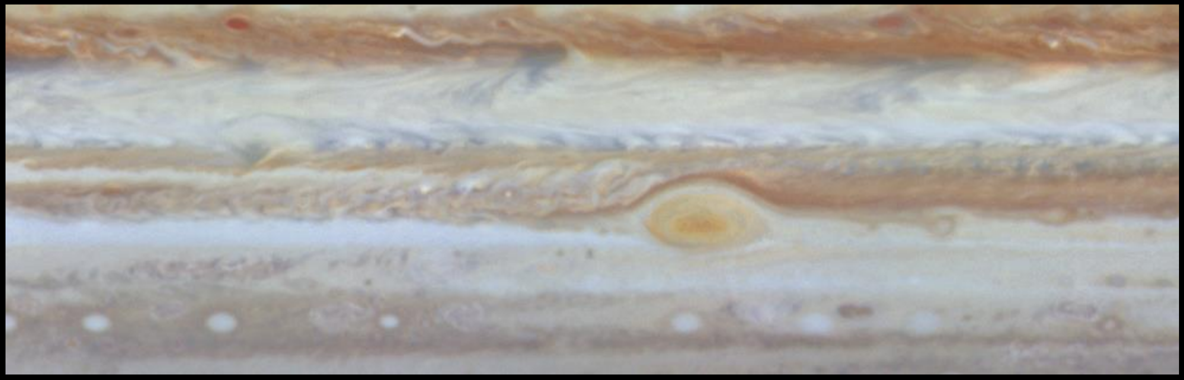
Atmospheric Dynamics

Radiometry investigates atmospheric structure

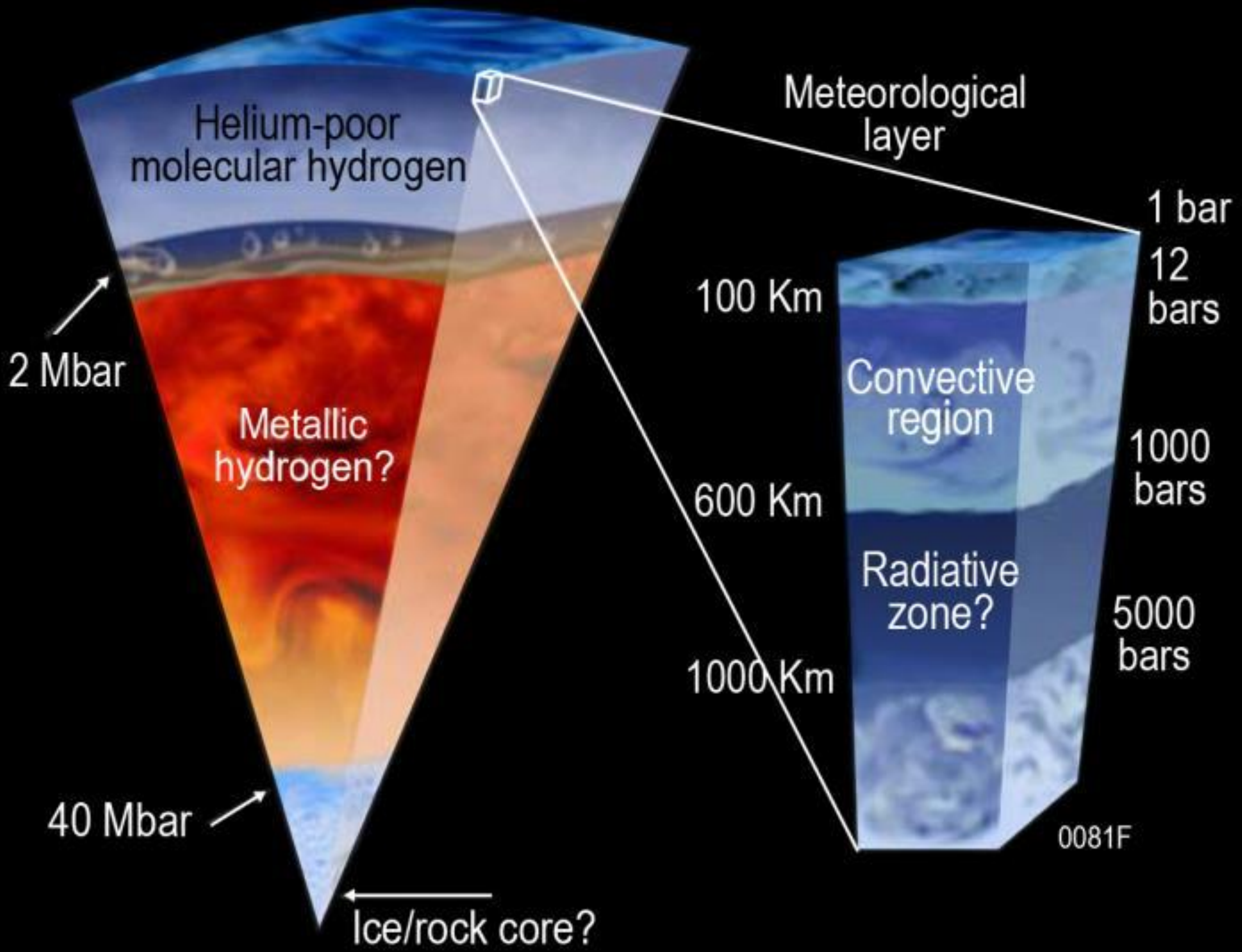


Gravity investigates differential rotation

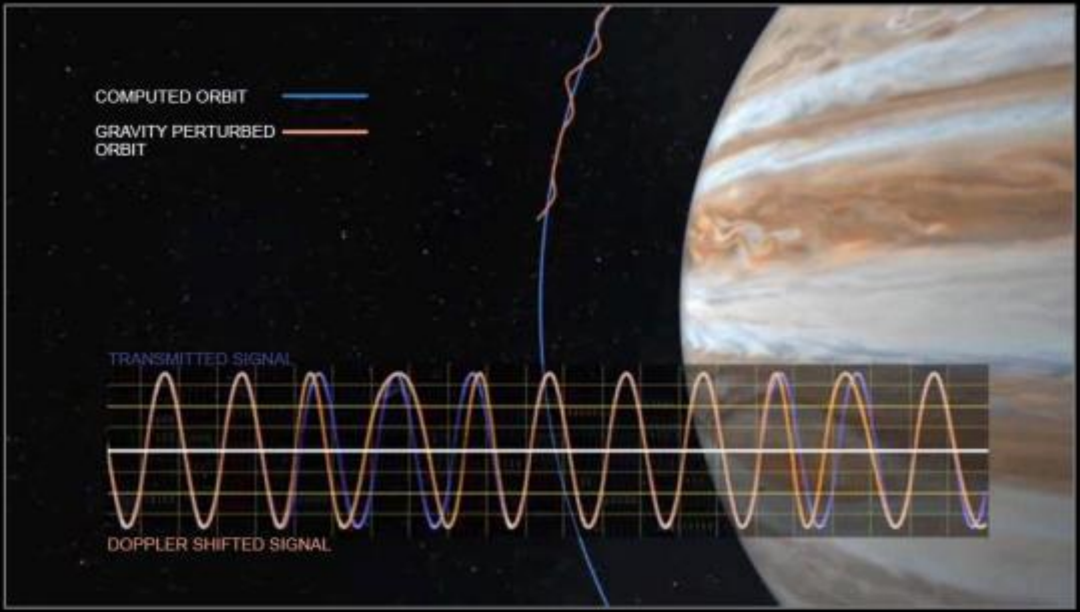




Probing Deep and Globally



Mapping Jupiter's Gravity



Tracking changes in Juno's velocity reveals Jupiter's gravity (and how the planet is arranged on the inside).

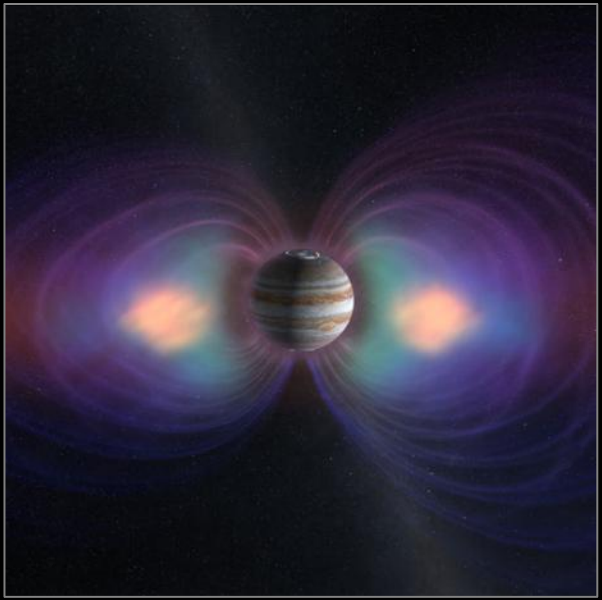
Precise Doppler measurements of spacecraft motion reveal the gravity field.

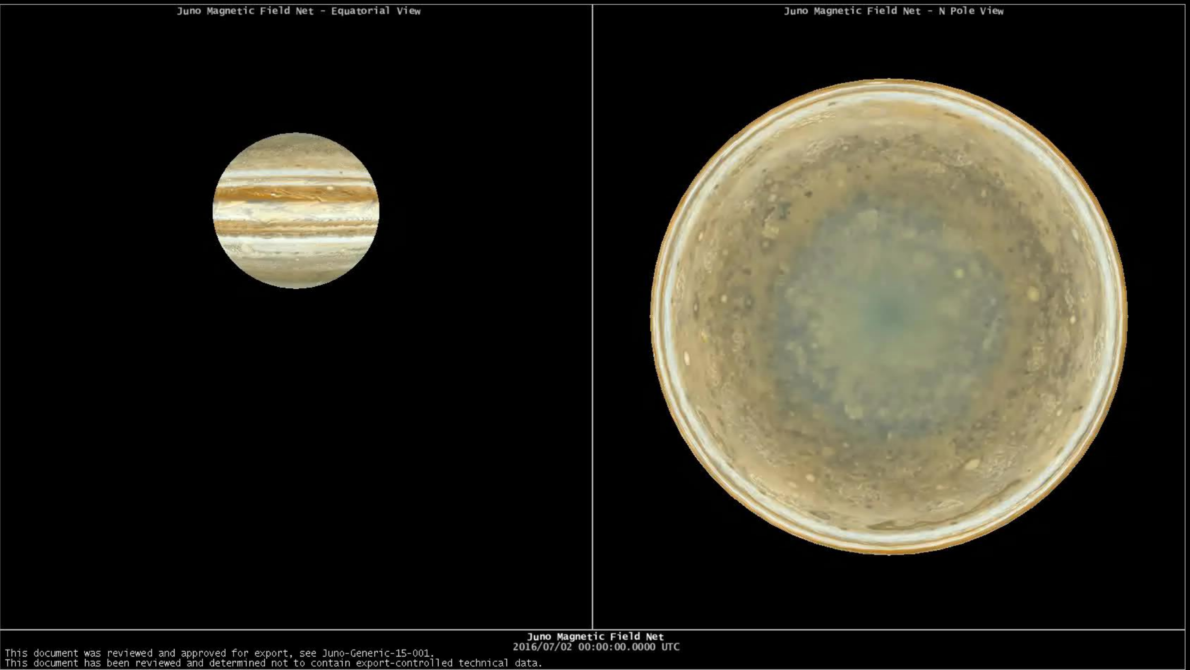
Tides provide further clues.

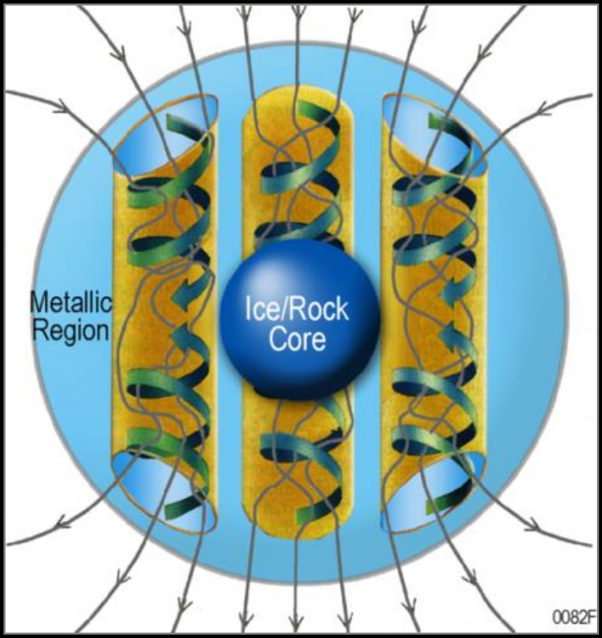
Mapping Jupiter’s Magnetic Field

Jupiter’s magnetic field lets us probe deep inside the planet.

Juno’s polar orbit provides complete mapping of planet’s powerful magnetic field.



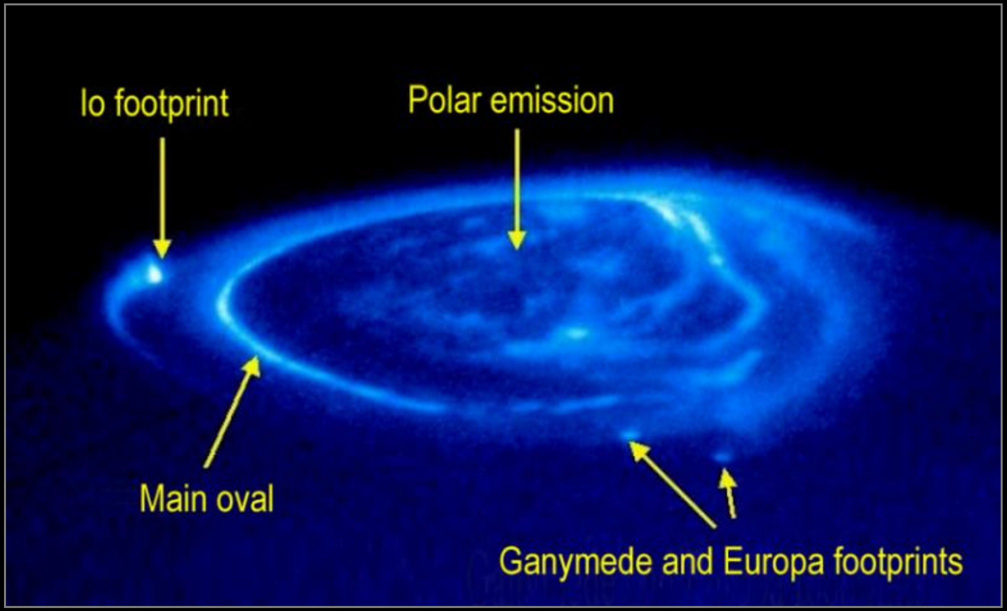


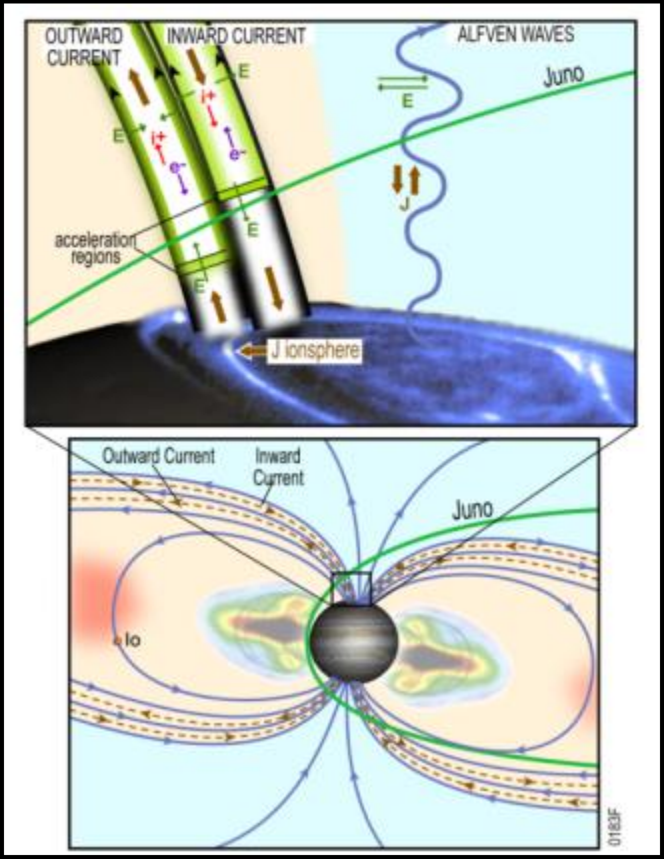


Exploring the Polar Magnetosphere

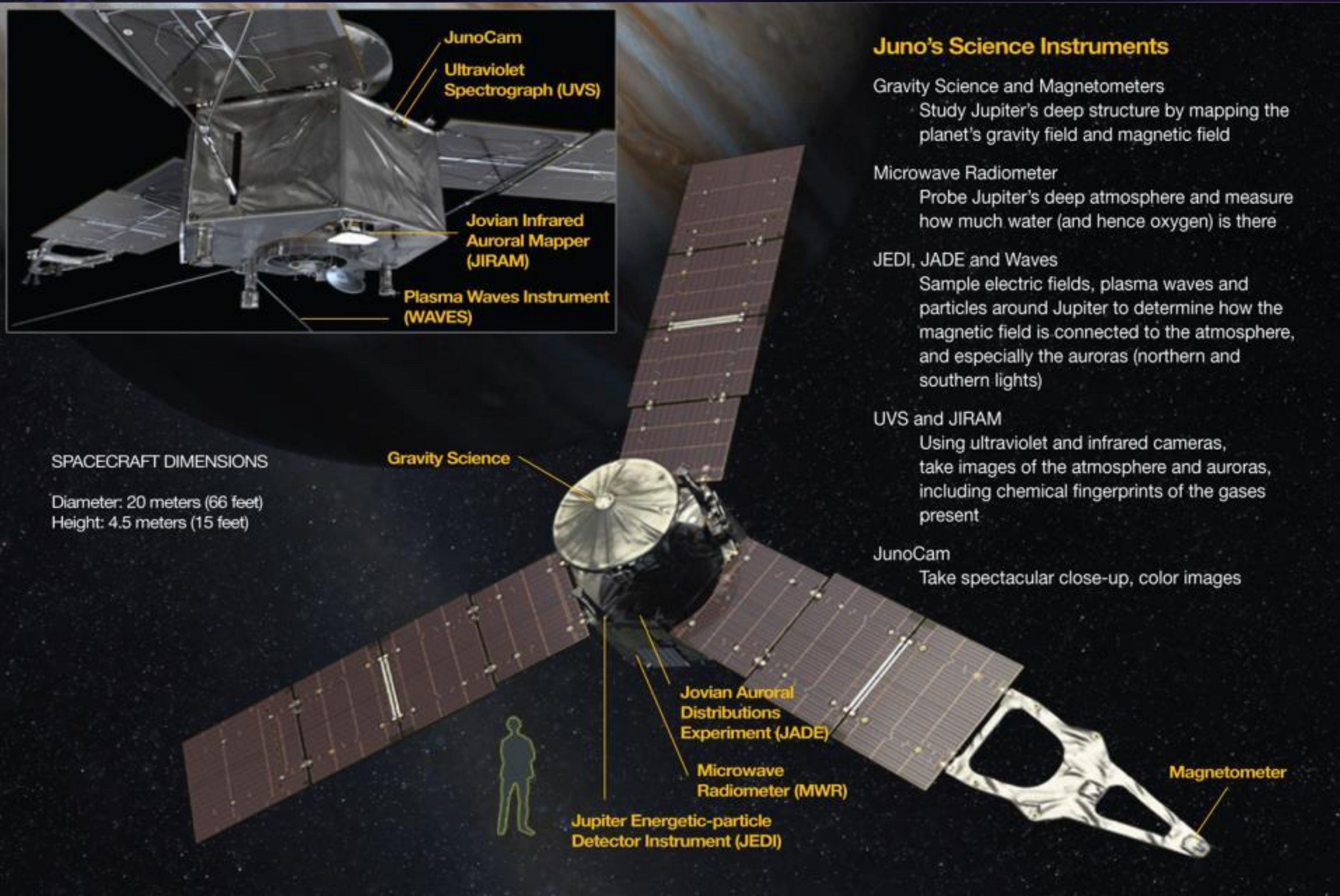
Jupiter's magnetosphere near the planet's poles is a completely unexplored region!

Juno's investigation will provide new insights about how the planet's enormous magnetic force field generates the aurora.





Spacecraft & Payload



Juno's Science 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

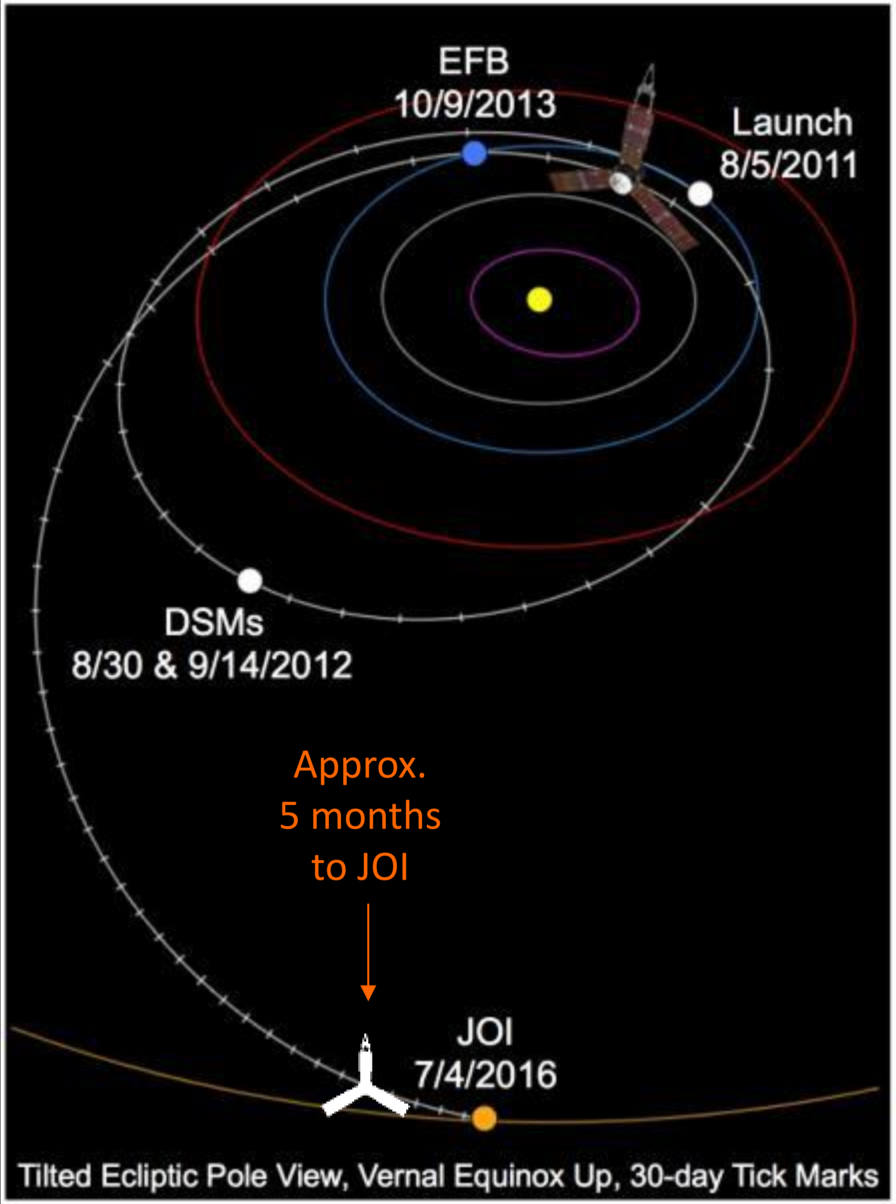
JunoCam
: Take spectacular close-up, color images

Video – Cruise/EFB

Juno's Flight Plan, or Trajectory

A well designed trajectory

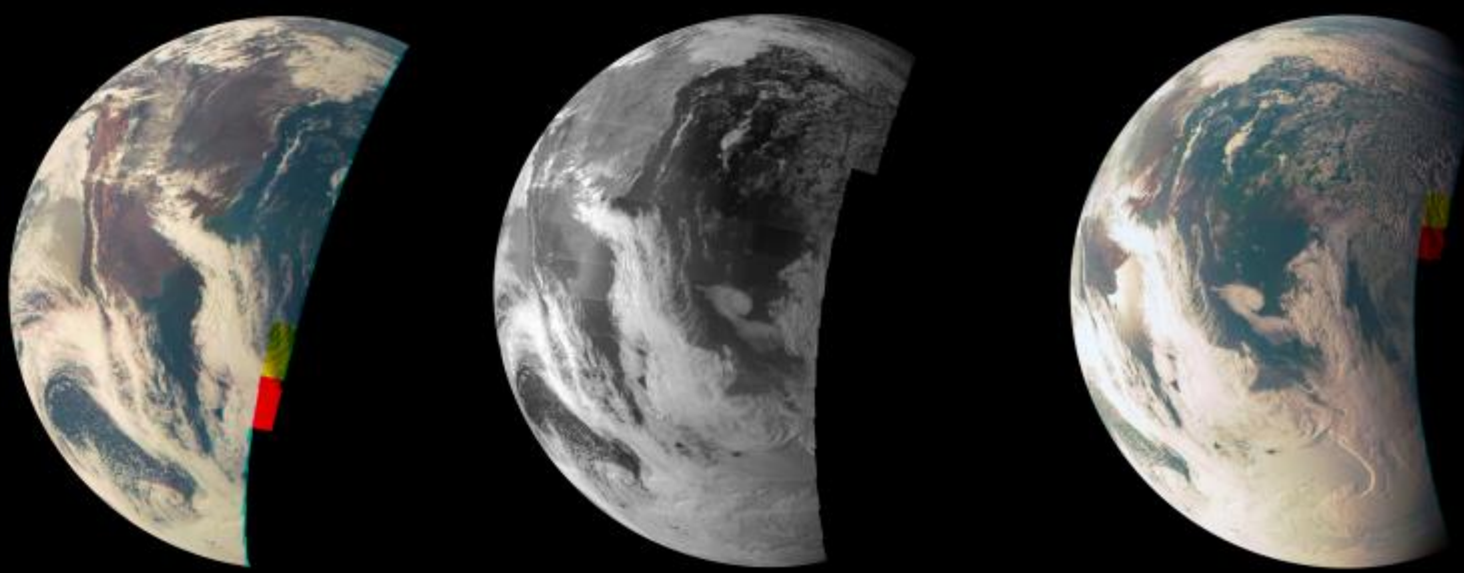
- DSMs (Deep Space Maneuvers aka main engine firings)
  - Early characterization of engine performance
  - Reduces risk at JOI
- Earth Flyby
  - Provides gravity assist
  - Allows early "science pass" of planetary body
- 5 Year Cruise
  - Team gains significant operations experience
  - Allows time to prepare for rapid 14 day science orbit cadence and limited 16 month mission



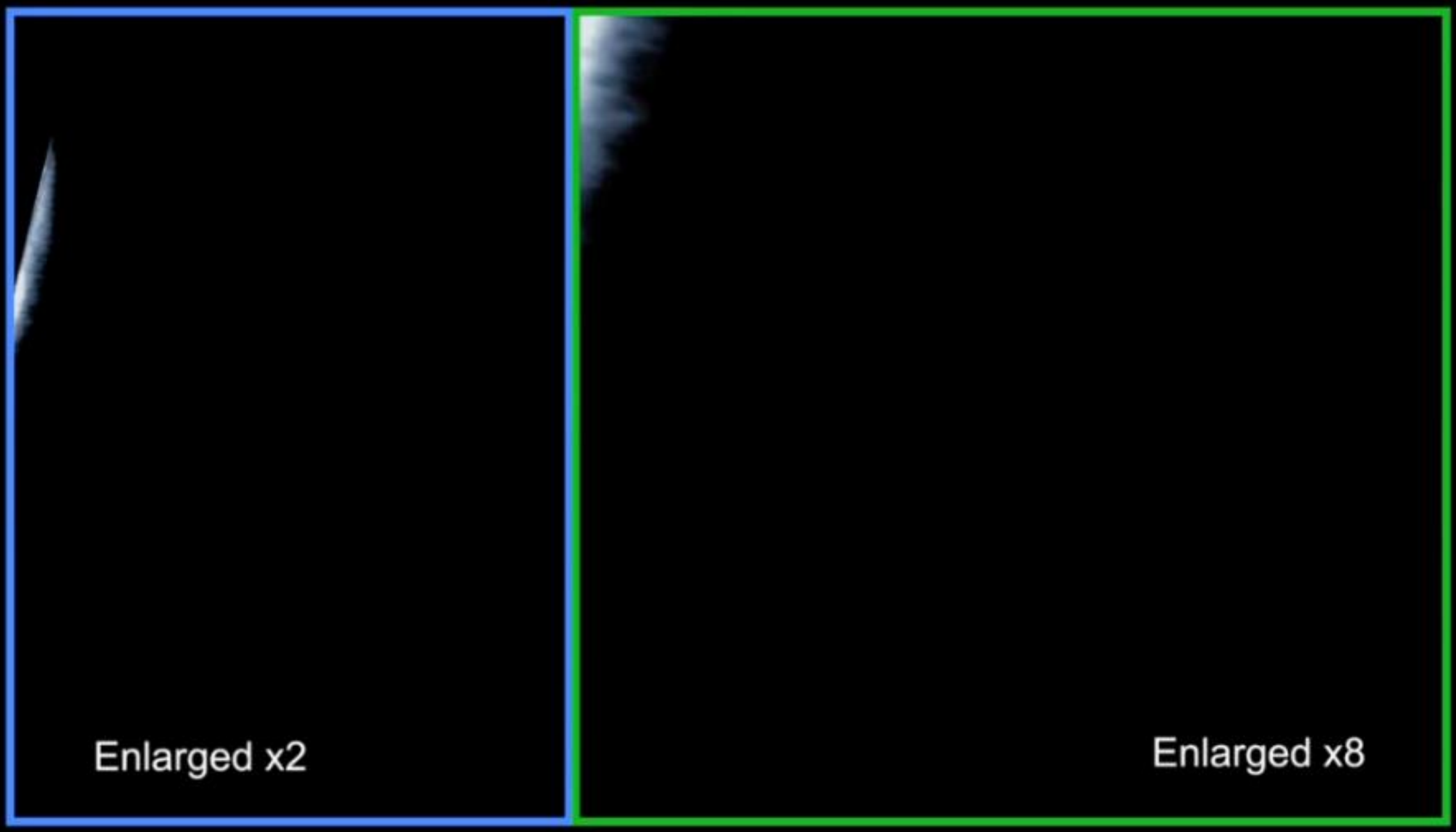
Bill Nye Explains the Earth Flyby

Earth Flyby

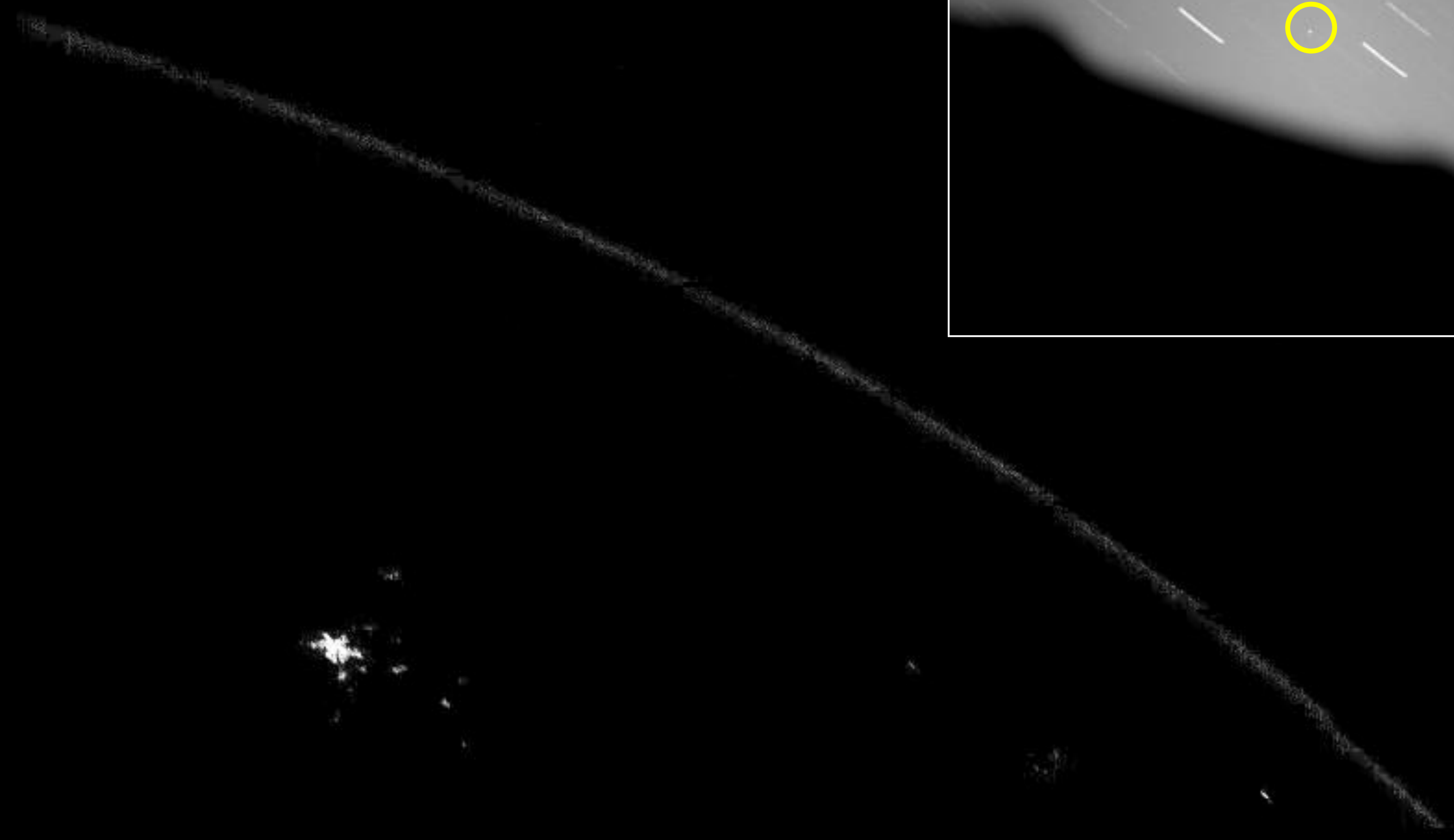
- Successful Earth flyby completed on Oct. 9, 2013
- Multiple spacecraft instruments took data as a practice run for Jupiter
- Juno left the encounter with the necessary velocity and heading to reach Jupiter on July 4th, 2016

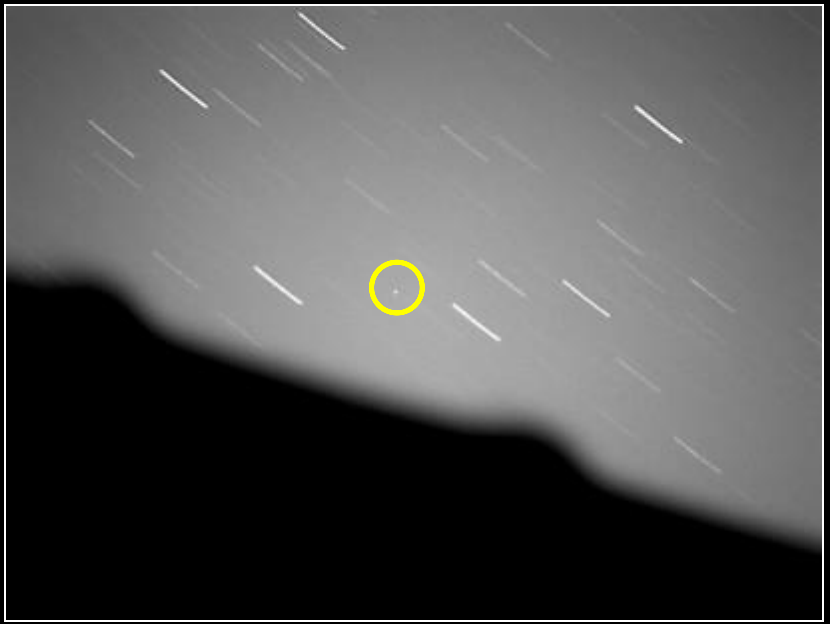


EFB – Earth/Moon Video



Earth Flyby – From Space and Ground

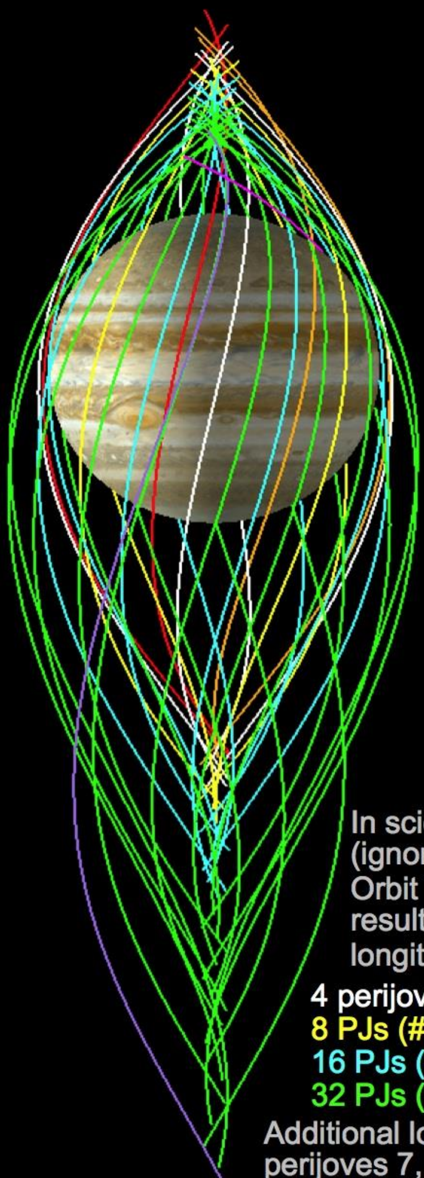




Earth Flyby – Hi Juno Video

Video – JOI/Orbit

Longitude Map after 32 (+1) Orbits

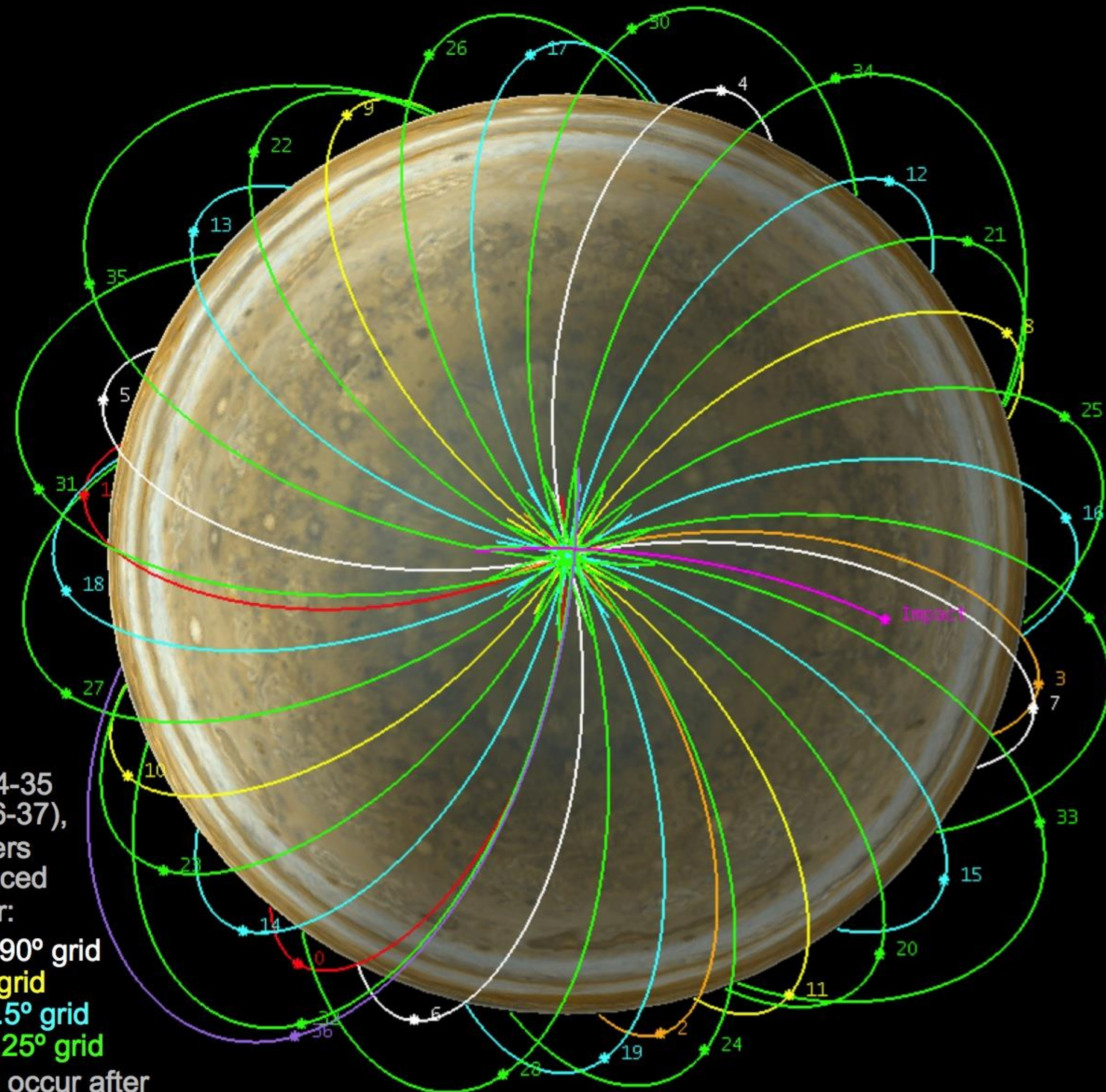


0 (JOI)
1 (PJ1)
2 (PRM)
3 (PJ3)
4 (MWR)
5 (GRAV)
6 (MWR)
7 (MWR)
8 (MWR Tilt)
9 (MWR)
10 (GRAV)
11 (GRAV)
12 (GRAV)
13 (GRAV)
14 (MWR Tilt)
15 (GRAV)
16 (GRAV)
17 (GRAV)
18 (GRAV)
19 (GRAV)
20 (GRAV)
21 (GRAV)
22 (GRAV)
23 (MWR Tilt)
24 (GRAV)
25 (GRAV)
26 (GRAV)
27 (GRAV)
28 (GRAV)
29 (GRAV)
30 (GRAV)
31 (GRAV)
32 (GRAV)
33 (GRAV)
34 (GRAV)
35 (GRAV)
36 (Extra)
37 (Impact)

In science orbits # 4-35 (ignoring # 0-3 & 36-37), Orbit Trim Maneuvers result in evenly spaced longitude grids after:

4 perijoves (# 4-7) ⟹ 90° grid
8 PJs (# 4-11) ⟹ 45° grid
16 PJs (# 4-19) ⟹ 22.5° grid
32 PJs (# 4-35) ⟹ 11.25° grid

Additional longitude shifts occur after perijoves 7, 11, 15, 19, 23, 27, and 31



Jupiter North Pole View

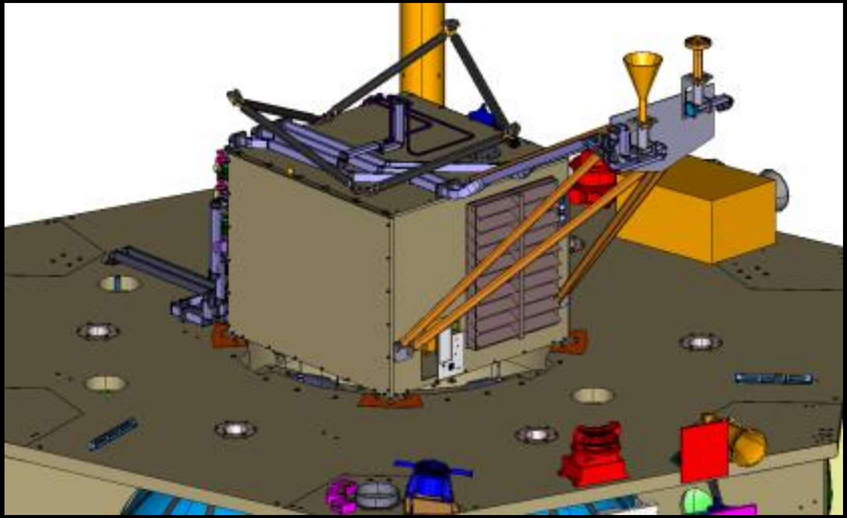
Radiation Vault Move

Moving the Titanium radiation vault (with some avionics already installed) over to the propulsion module

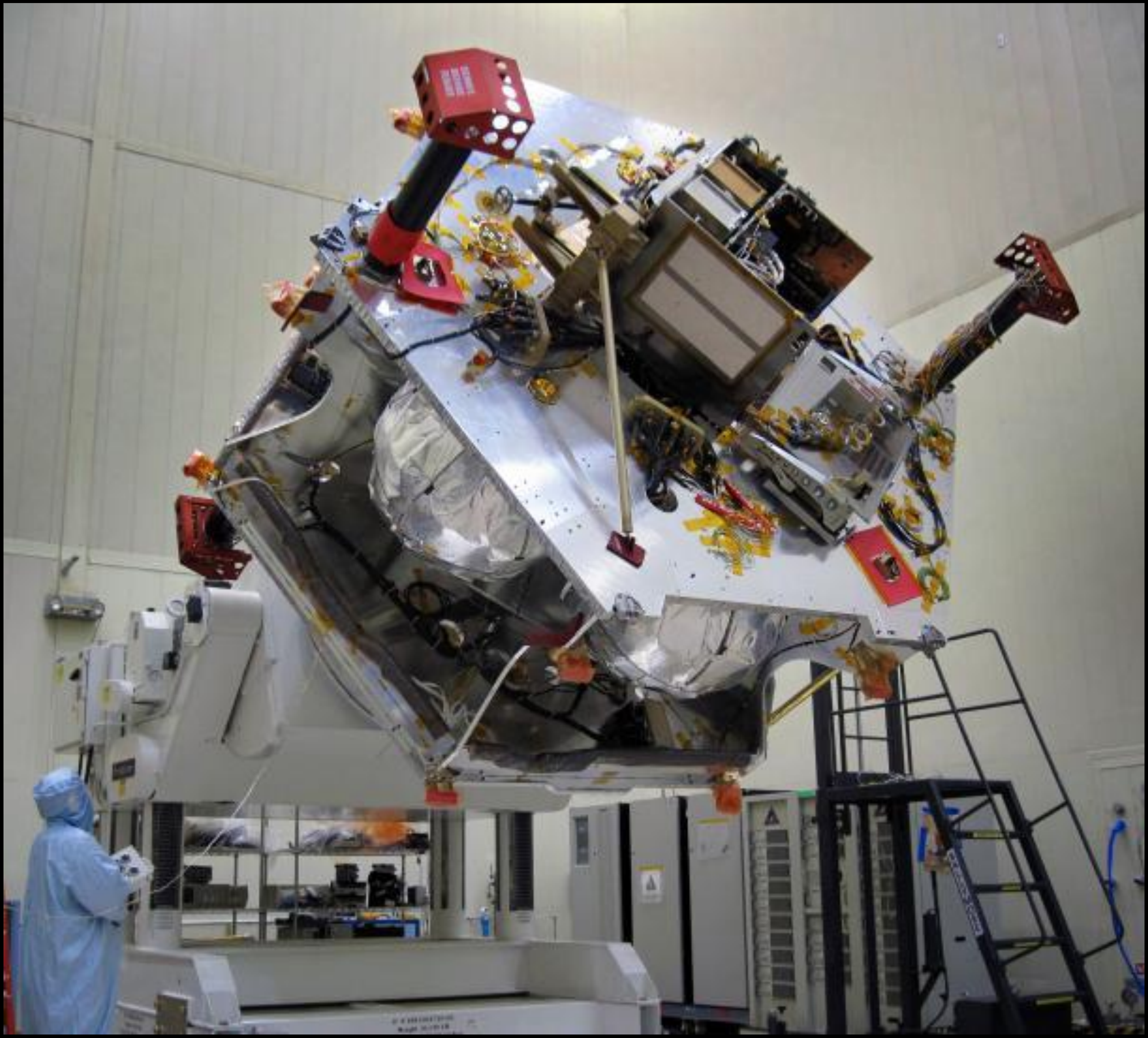
Radiation Vault

- Houses Juno's critical electronics
- Walls are solid titanium
  - 1/4" – 1/3" thick
  - Weight empty – 350 lbs or 160 kgs

- Protects electronics from Jupiter's intense radiation
- Vault reduces radiation levels by a factor of 800:1
- Allows use of electronics designs from previous NASA missions



Bus Integration at LM



Continued integration activities focusing on harness installation and test

Juno Transport to KSC via C-17

Juno being loaded into a C-17 Globemaster for transport to Kennedy Space Center (KSC)

Below – Arrival at KSC Shuttle Landing Facility

Photo credit: Stephen Clark/Spaceflight Now

Final Testing & Encapsulation

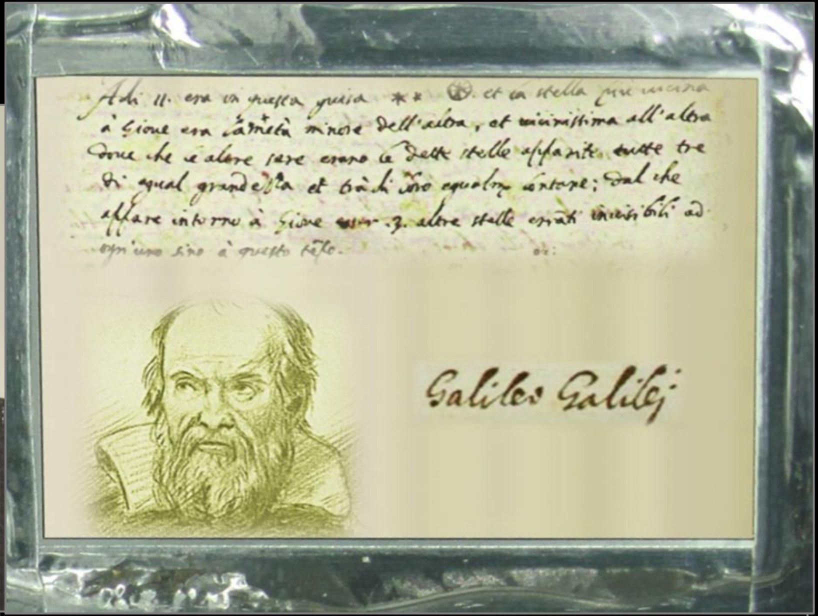
Left - Juno, fully assembled, being moved from rotation fixture to test stand for ME actuator functional test in Building 1 Highbay

Right – Juno Prior to Encapsulation in Building 9 HPF

Photo credit: NASA KSC Media

Launch!

Juno’s Special Passengers

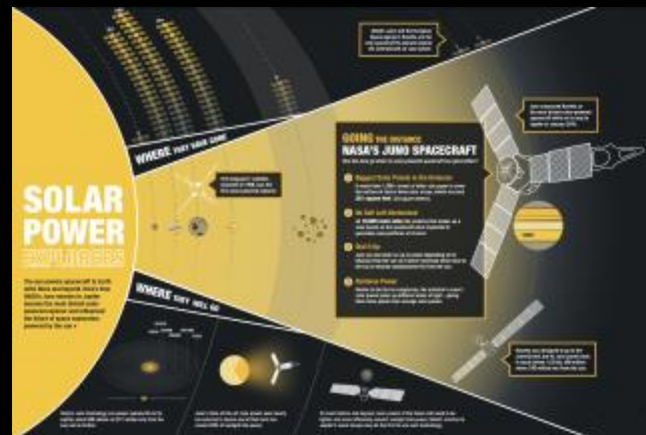


Galileo, Juno and Jupiter

“Science In A Fishbowl”

missionjuno.swri.edu
click on “Junocam”

Products

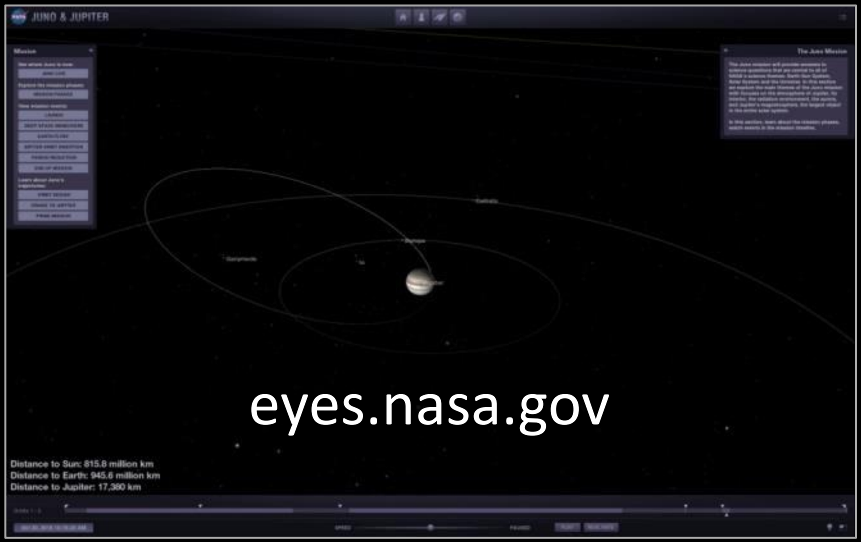


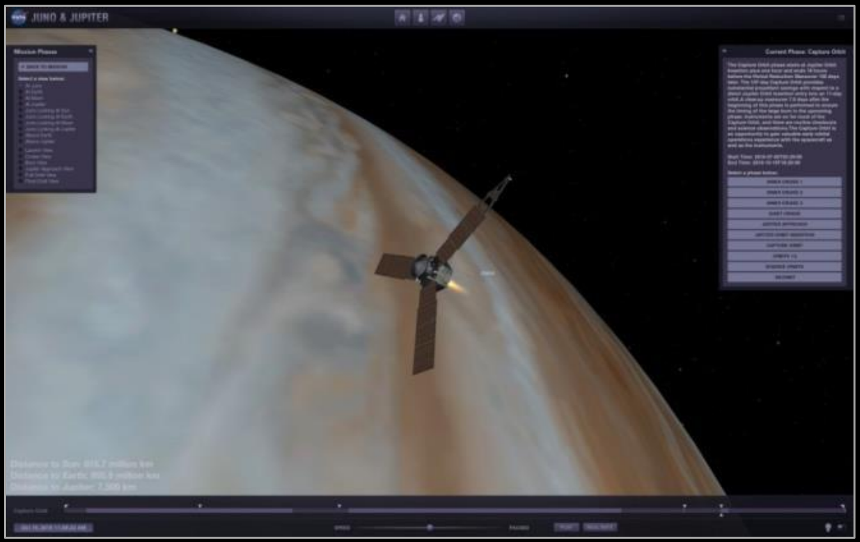
The following products will be available for Jupiter arrival:

- NASA TV live broadcast – details coming soon!
- Jupiter Lithograph, Fact Sheet, Sticker
- Jupiter Teachable Moments
- Juno Models, including DIY online
- Juno solar power infographic
- Juno overview video
- “What’s Up” Juno-themed astronomy video

Fly Along with Juno

Juno is part of NASA's 3D interactive, ***Eyes on the Solar System***…





Social Media

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twitter.com/NASAJuno
facebook.com/nasajuno
nasajunocam.tumblr.com
www.youtube.com/NASAJuno

For More Information...

<u>Juno mission website</u>:

missionjuno.swri.edu

<u>On the NASA website</u>:

www.nasa.gov/juno

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