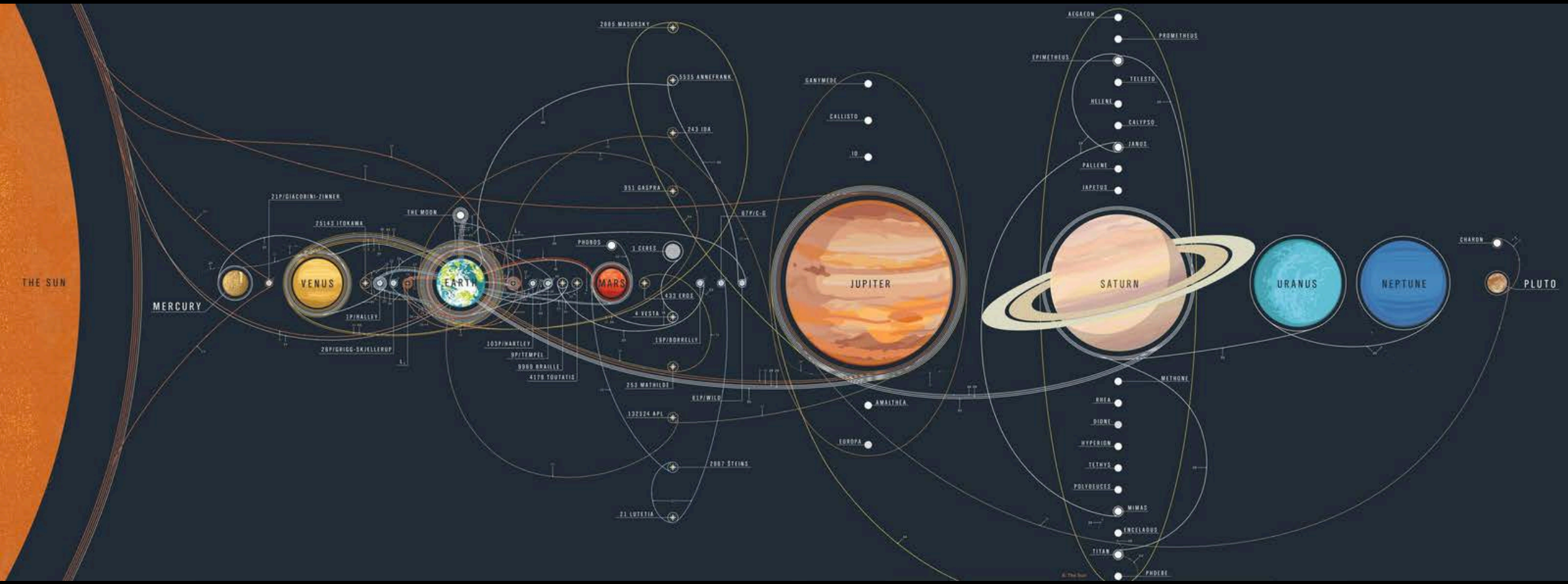
PLANETARY SCIENCE with the Hubble Space Telescope

Heidi B. Hammel
Vice President for Science at AURA

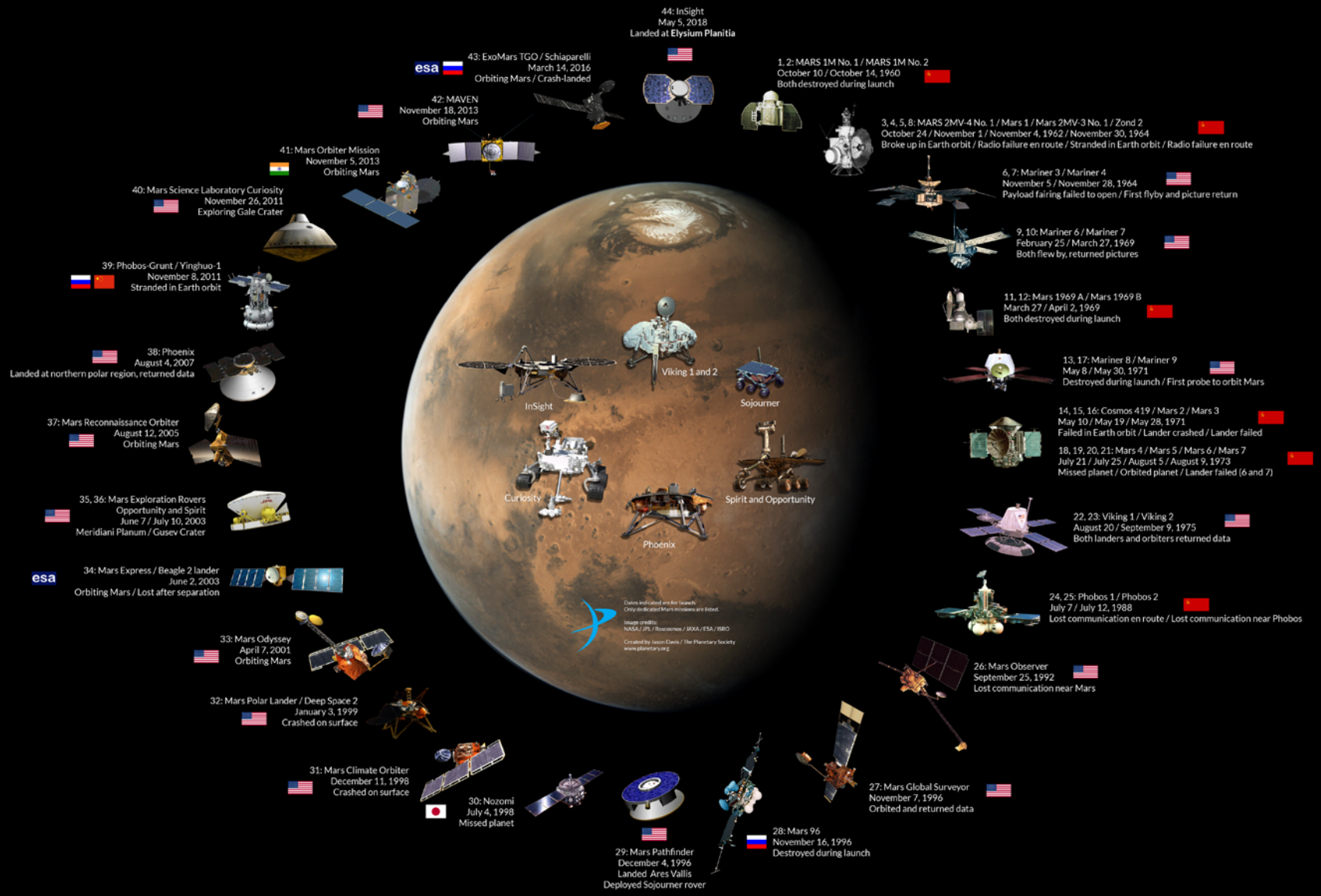
With thanks to Nikole Lewis (Cornell) and Carol Christian (STScI) for some content

Why use *HUBBLE* to look at *Solar System objects*?!?



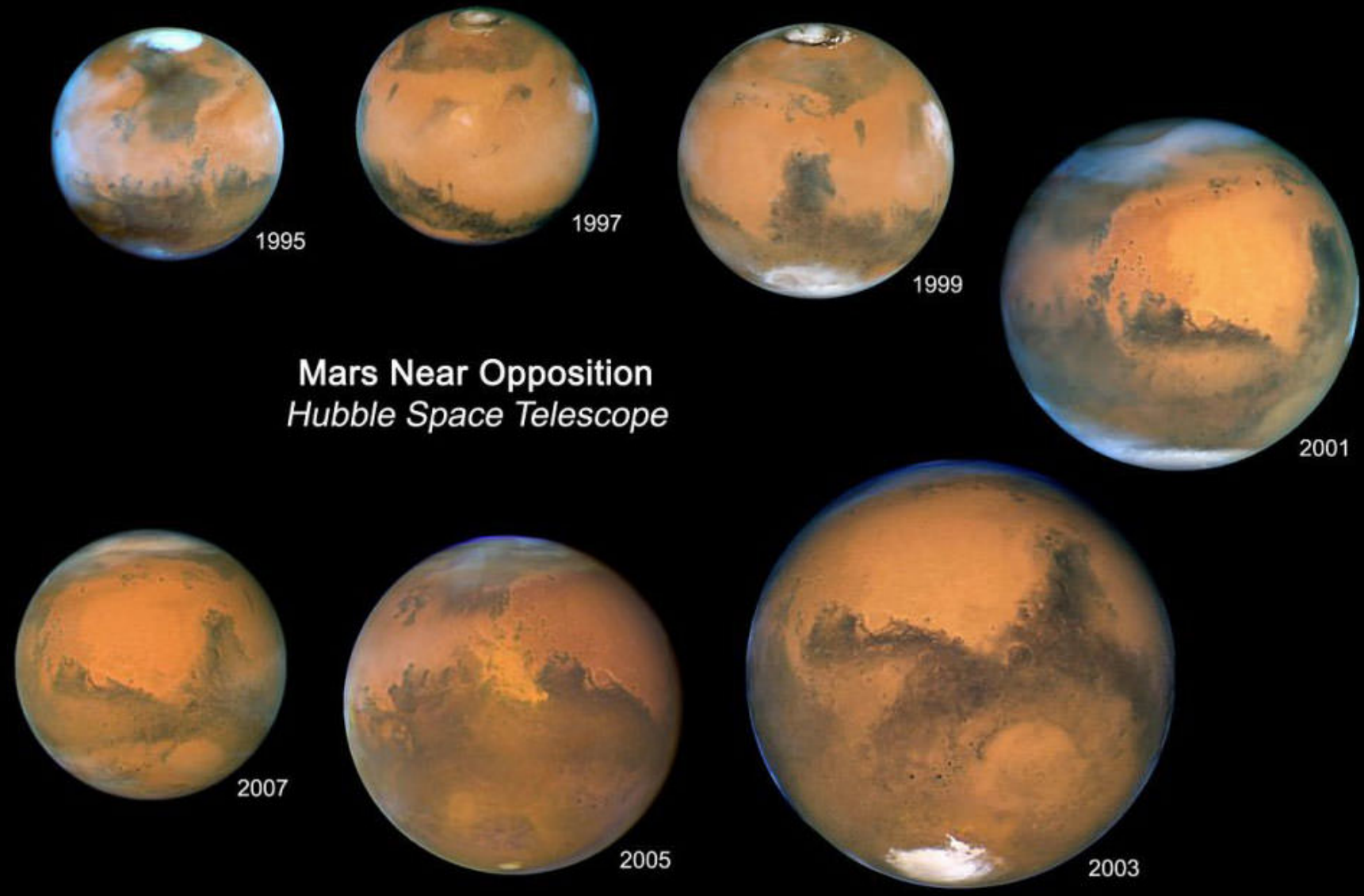
Pop Chart https://popchart.co/products/the-chart-of-cosmic-exploration

Mars Exploration Family Portrait

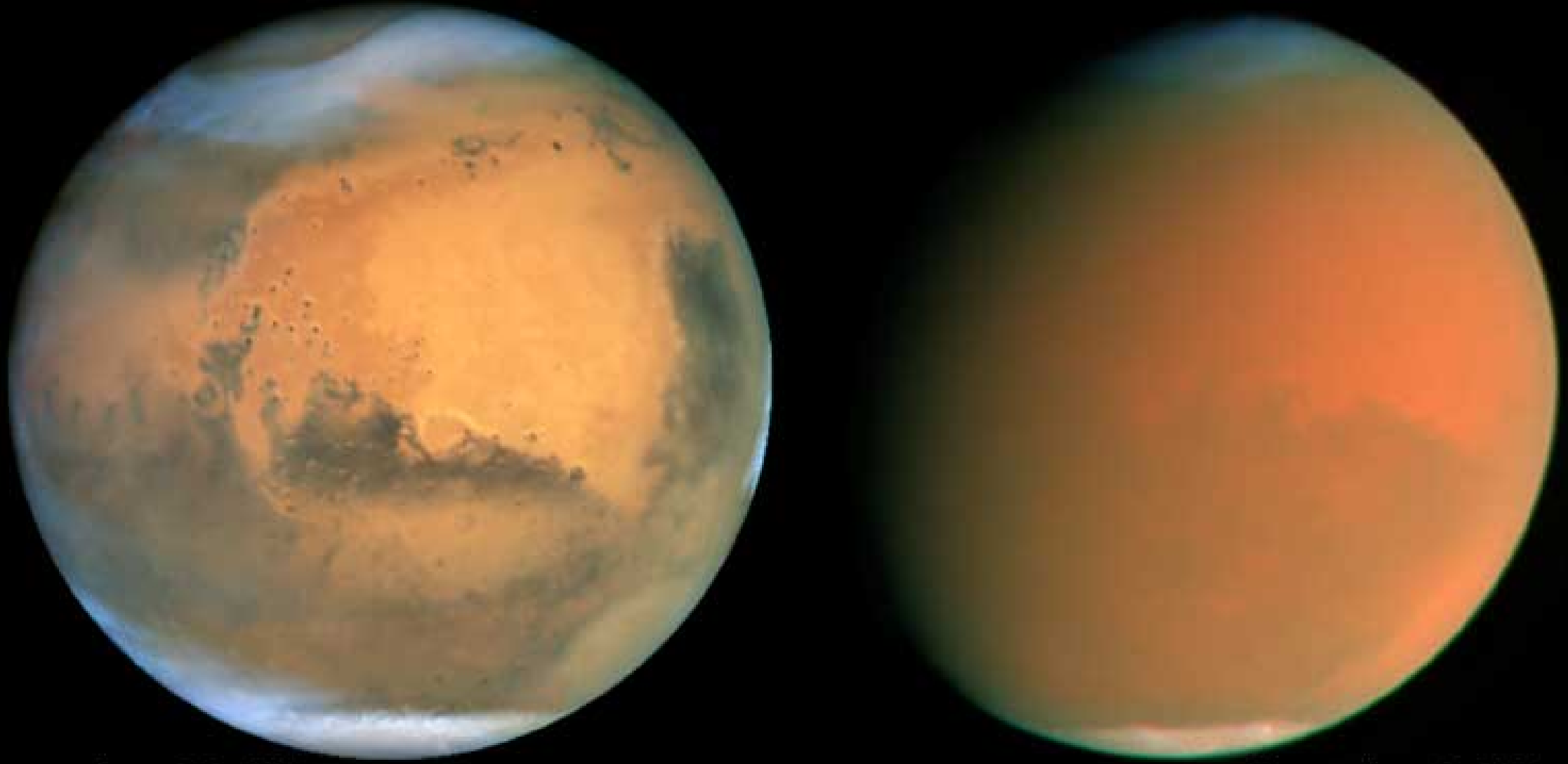


NASA / JPL / Roscosmos / JAXA / ESA / ISRO / Jason Davis / The Planetary Society

MARS as seen by Hubble over the decades



Mars • Global Dust Storm



June 26, 2001

September 4, 2001

Hubble Space Telescope • WFPC2

NASA, J. Bell (Cornell), M. Wolff (SSI), and the Hubble Heritage Team (STScI/AURA) • STScI-PRC01-31

Hubble **complements** space missions

Cassini spacecraft - orbited Saturn for nearly 18 years

NASA artist's concept of Cassini spacecraft about to dive between Saturn and its rings

Saturn's aurorae imaged by Hubble in the ultraviolet

Hubble **complements** space missions

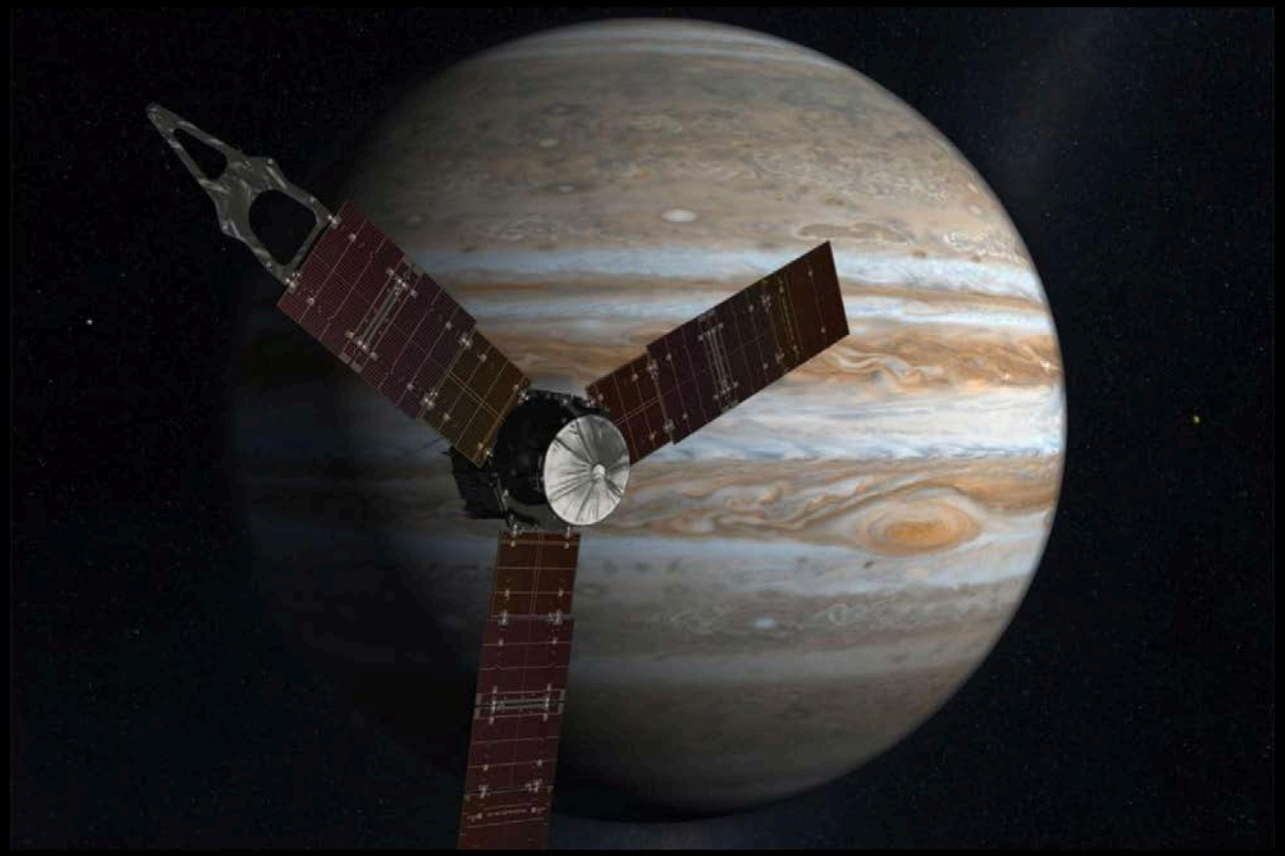


Illustration of Juno at Jupiter (courtesy NASA)

Juno spacecraft - currently in orbit around Jupiter

Jupiter’s aurorae imaged by Hubble in the ultraviolet

Hubble **complements** space missions

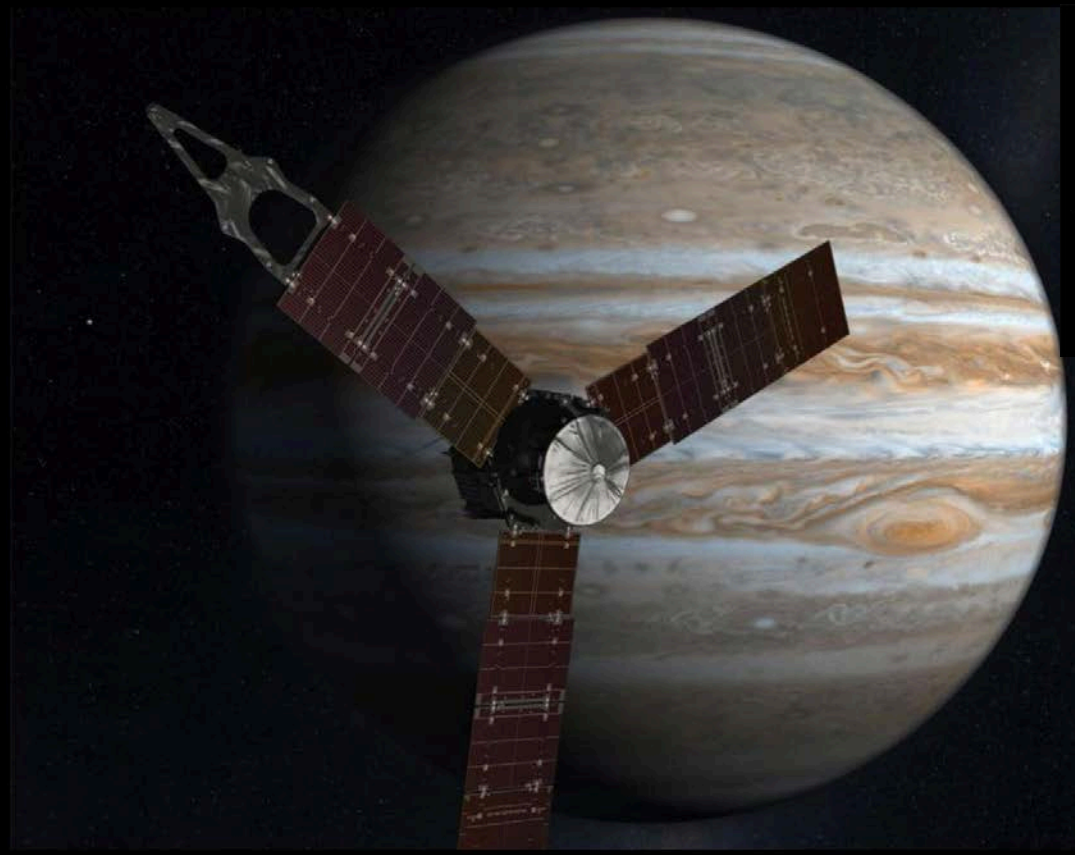
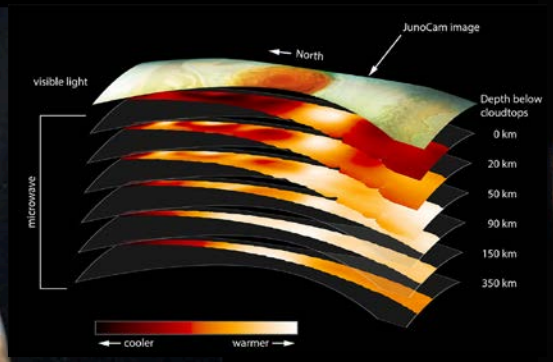


Illustration of Juno at Jupiter (courtesy NASA)

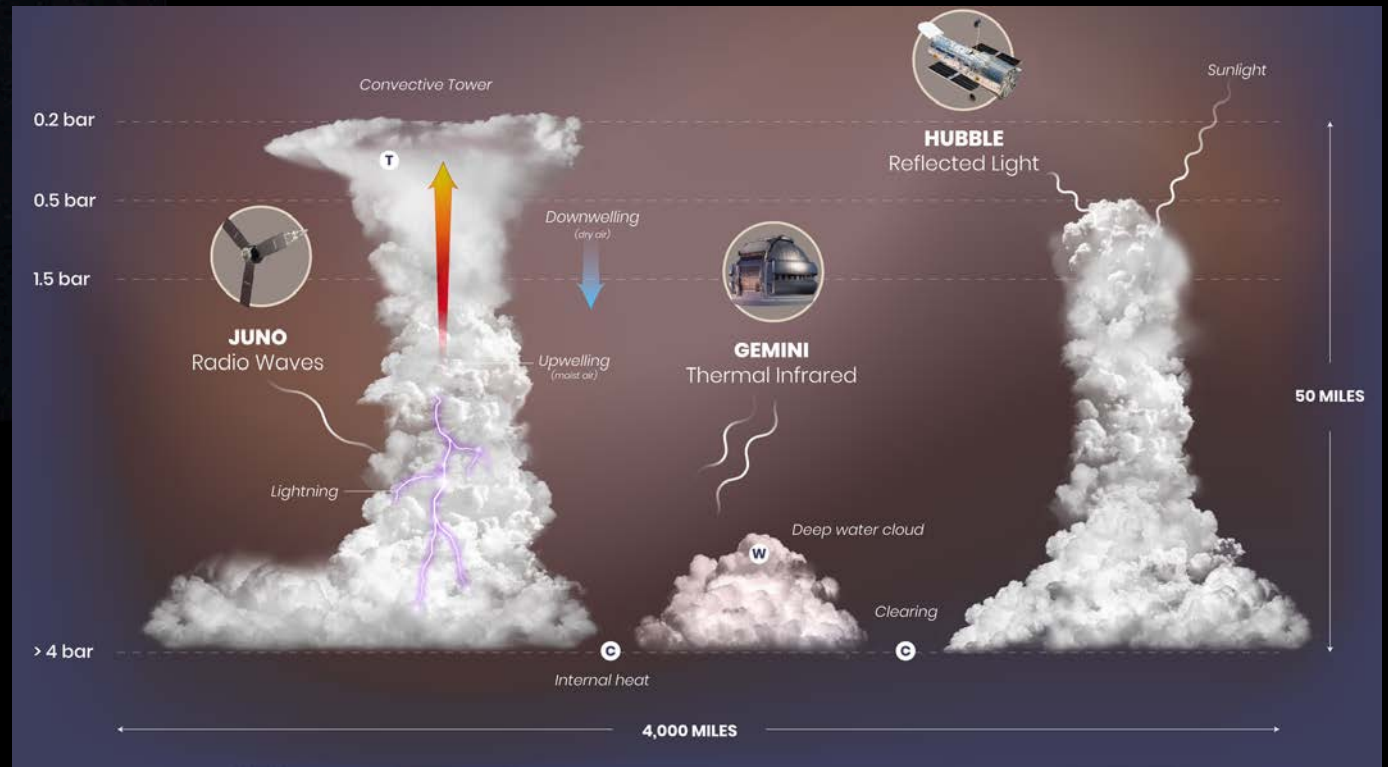


Juno

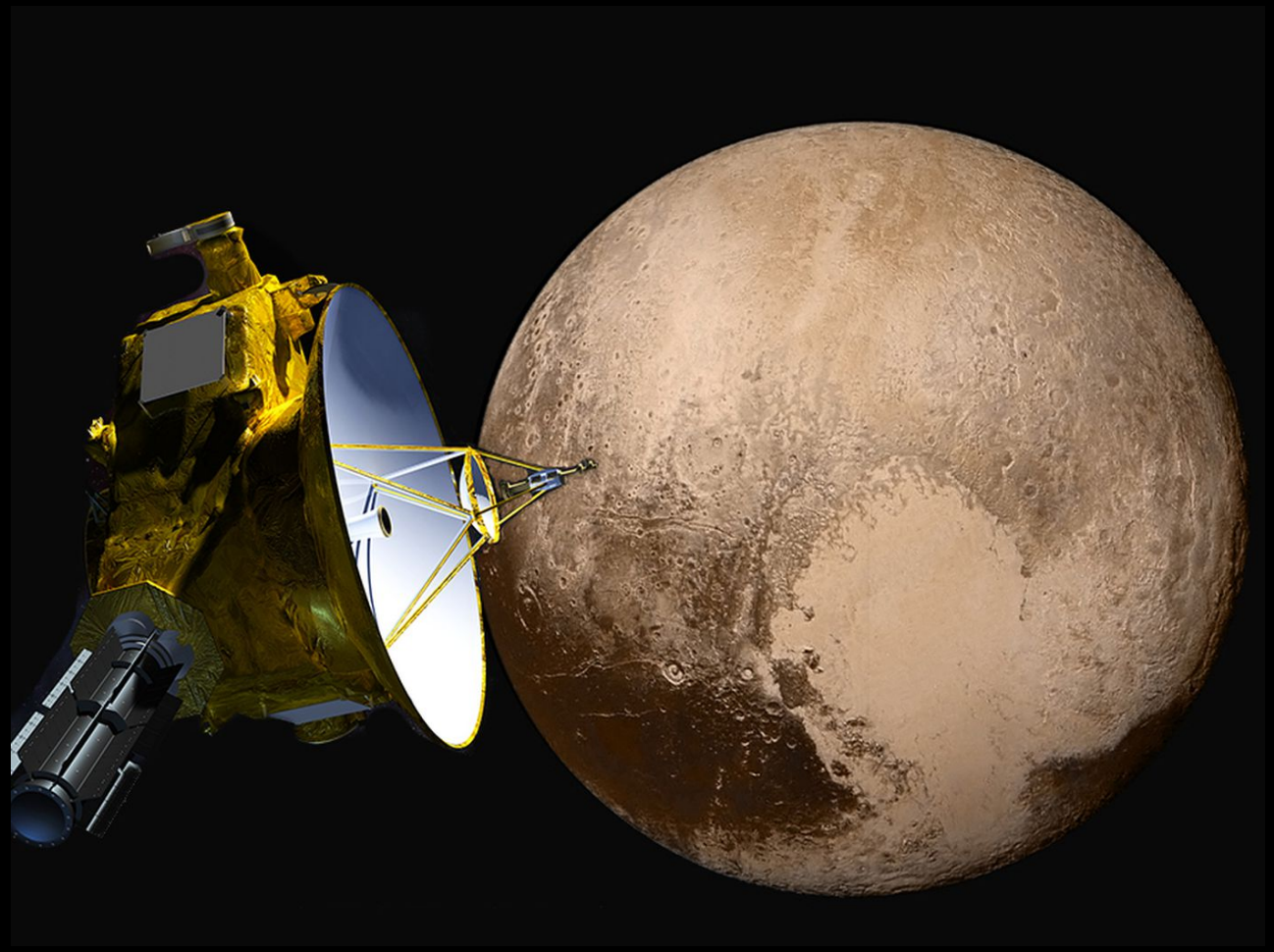
Gemini Observatory

Hubble

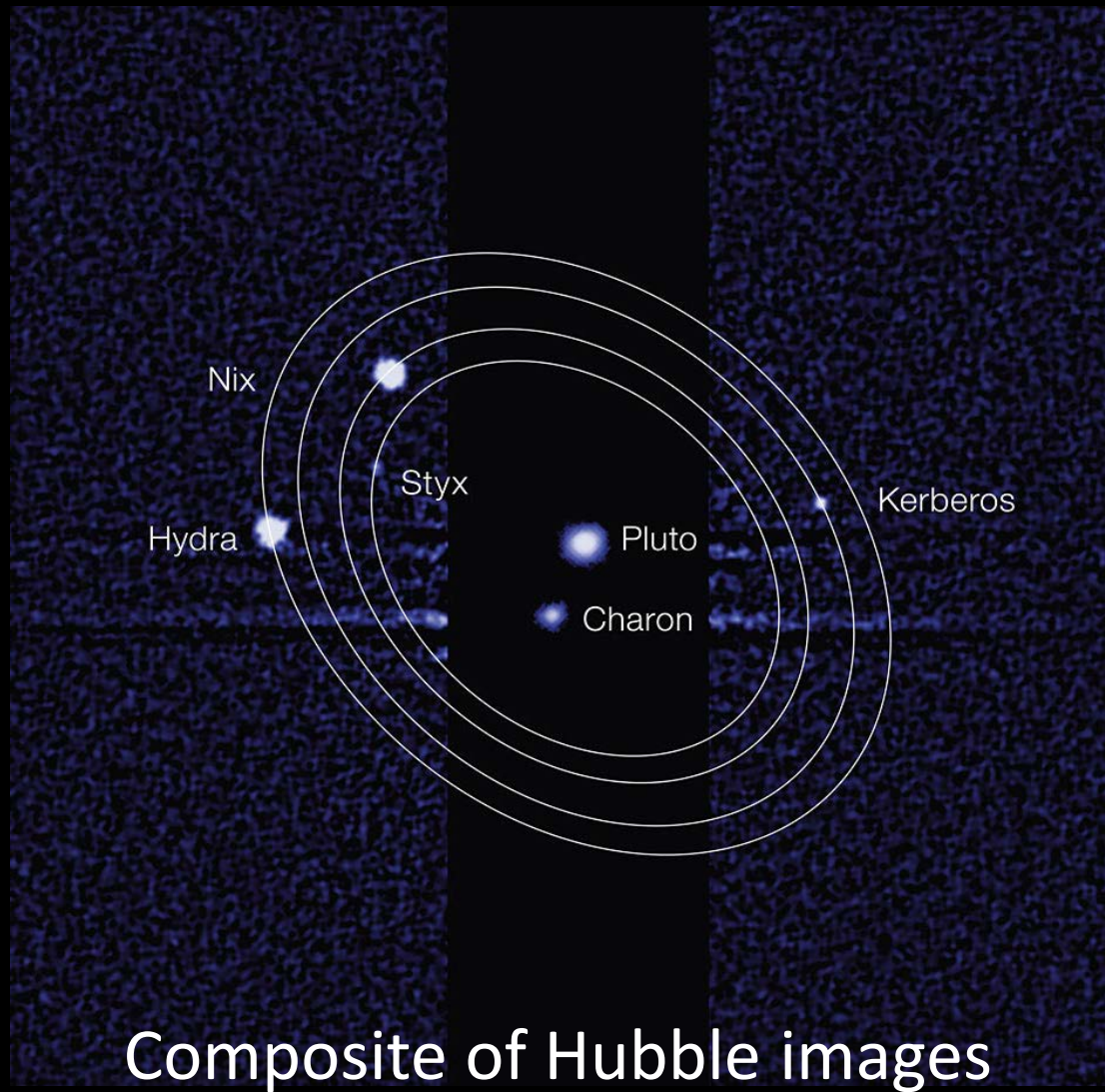
Juno spacecraft - currently in orbit around Jupiter



Hubble **enhances** space missions

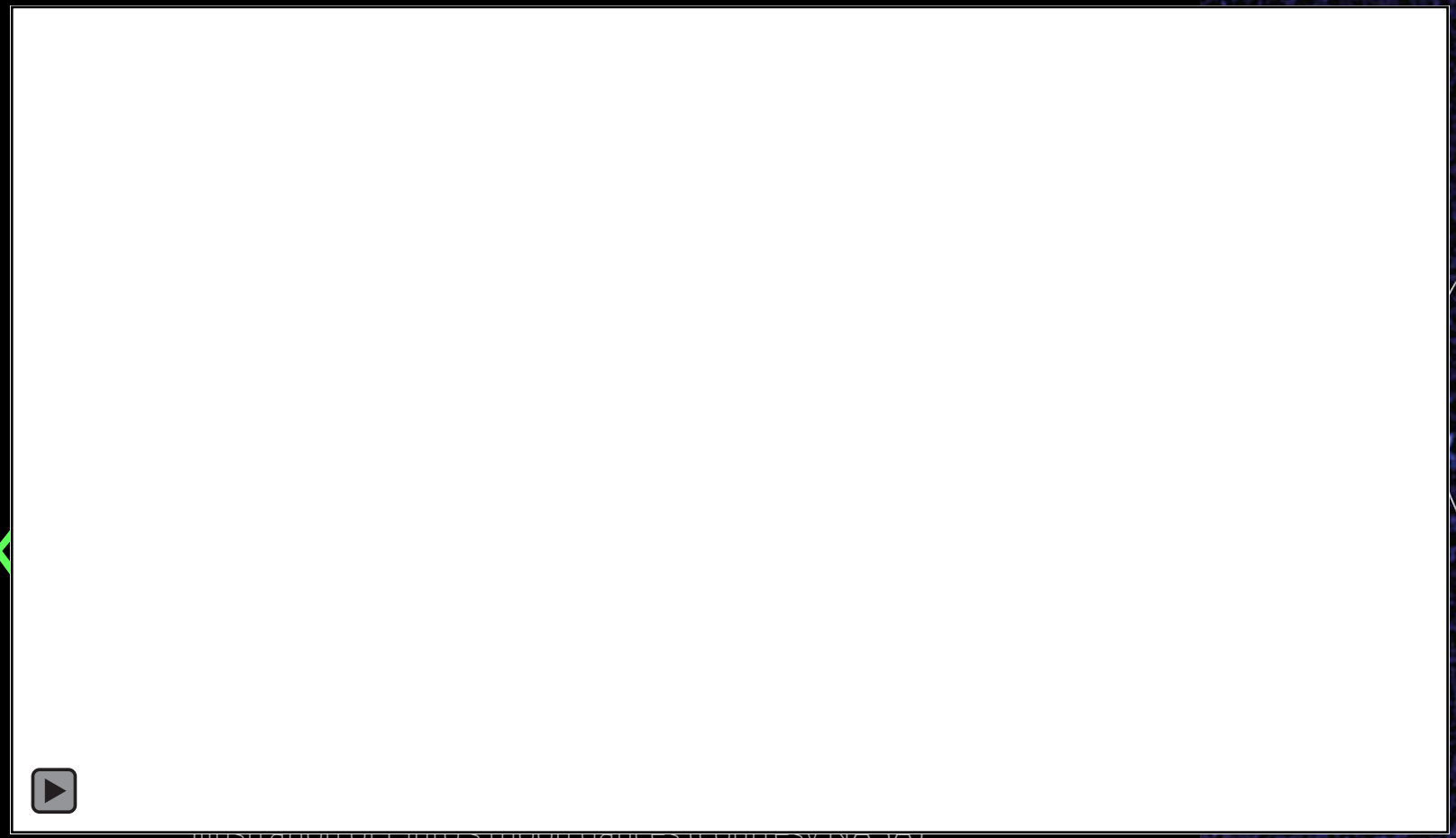


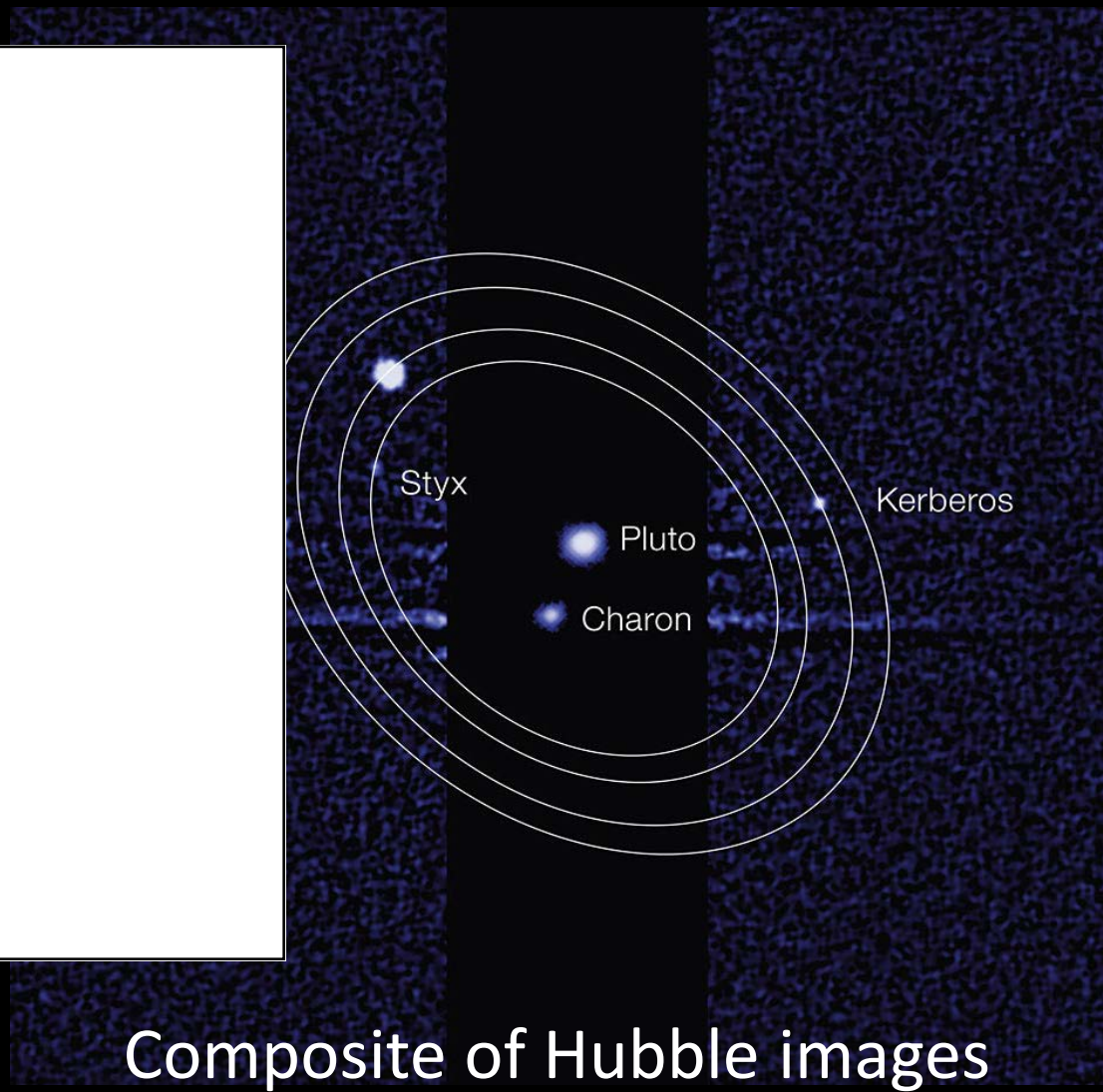
New Horizons spacecraft - studied Pluto and its moons discovered by Hubble



Composite of Hubble images shows Pluto moons

Hubble **enhances** space missions





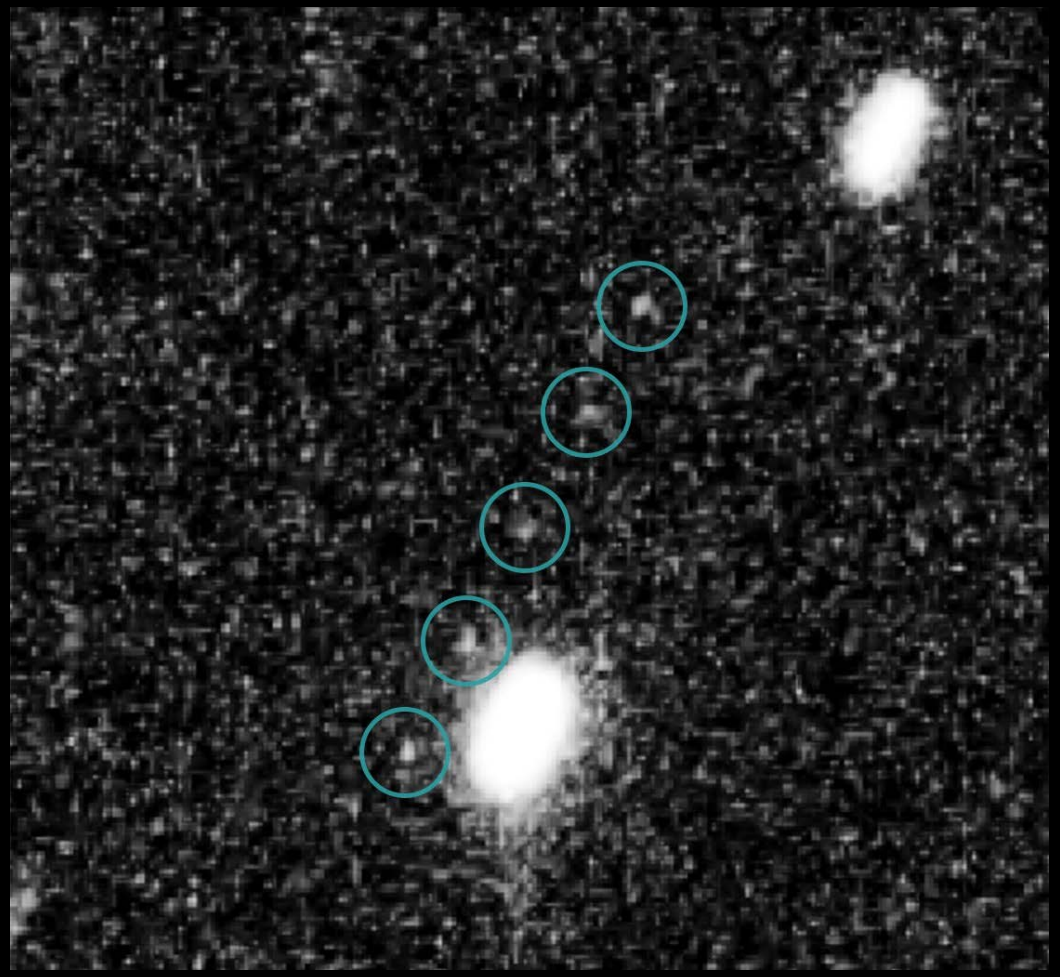
New Horizons spacecraft - studied Pluto and its moons discovered by Hubble

Composite of Hubble images shows Pluto moons

Hubble **enhances** space missions

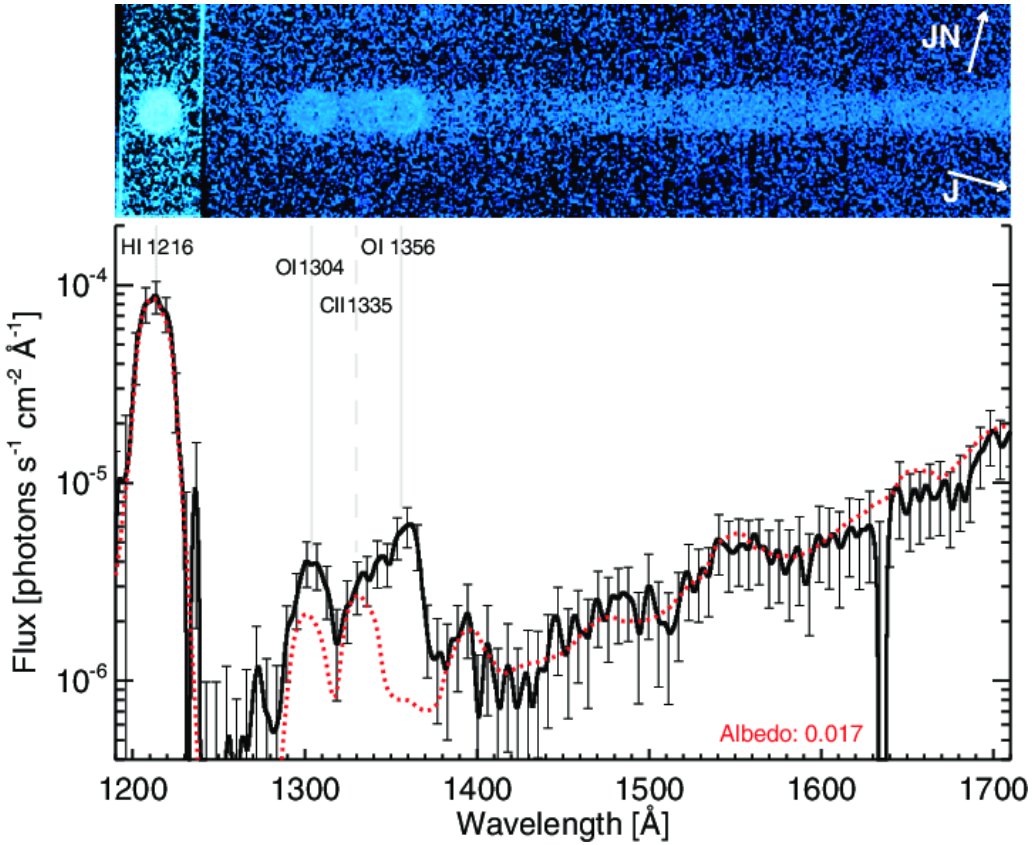
Arrokoth (2014 MU69) from New Horizons (courtesy NASA)

New Horizons spacecraft after Pluto

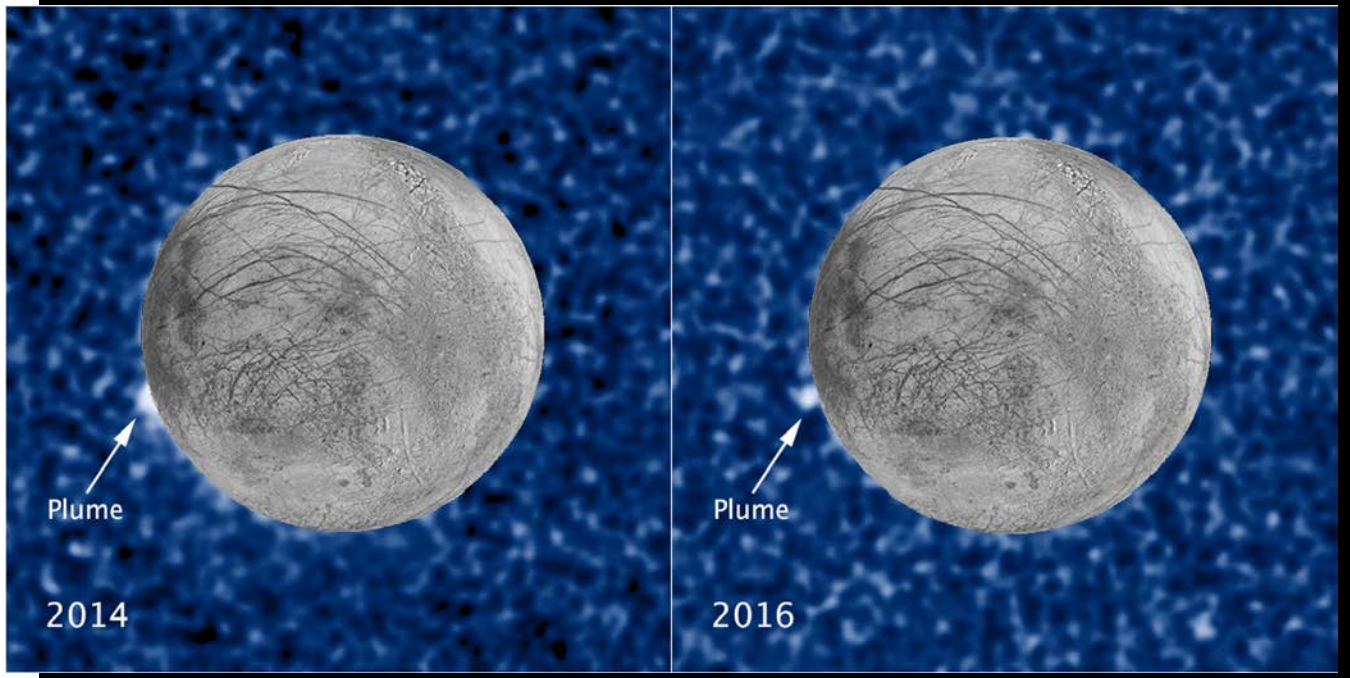


Hubble found a **new target** for NH
in 2014, YEARS after NH was launched!

Hubble **spectroscopy** yields rich results



Hubble spectra yield insights into chemistry of Europa's plumes



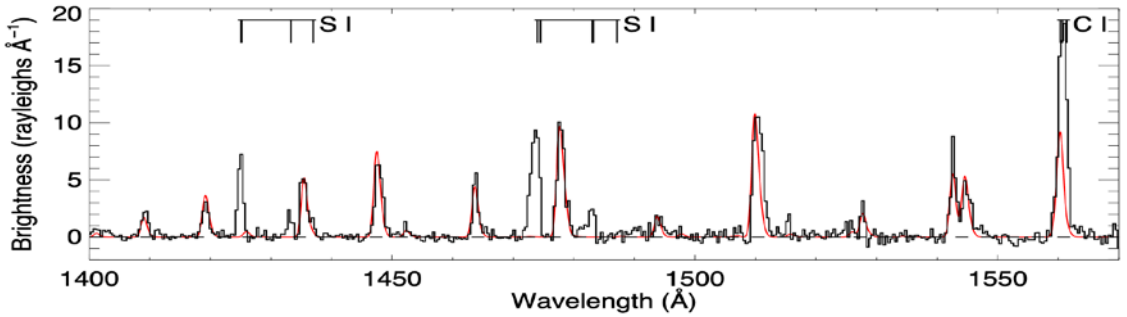
Hubble **spectroscopy** yields rich results

Comet 103P/Hartley 2
Credit: NASA EPOXI mission

Comet Lovejoy
Credit: Nick Howes

Comet ISON
Credit: Pete Lawrence

Comet Garradd, Sirene Observatory
Credit & Copyright: Olivier Sedan

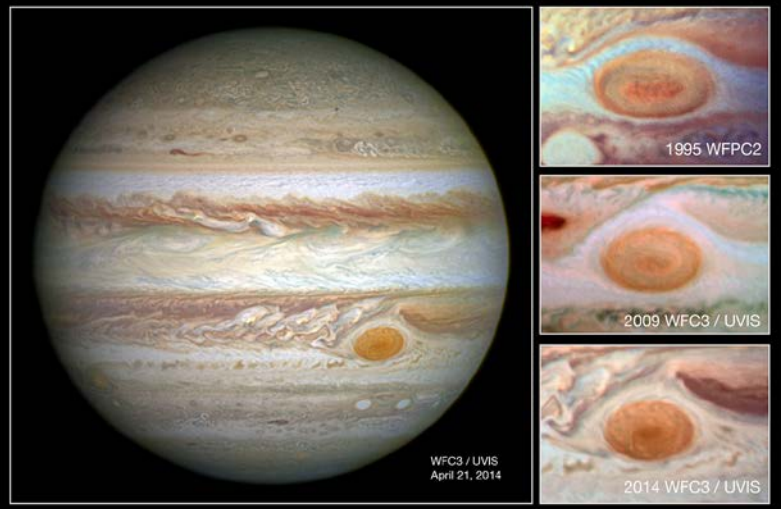


Comet	Date	r_h (au)	$\dot{r}_h$ (km s^{-1})	Δ (au)	Q(CO) ($\times 10^{28}$ molecules s^{-1})	Q(H_2O)	Q(CO)/Q(H_2O)	N(C) ($\times 10^{13}$ cm^{-2})	N(S)
103P/Hartley 2	2010 Nov 04	1.06	2.1	0.15	$2.6 \pm 1.3 \times 10^{-3}$	0.85	0.003	0.03	1.2
C/2009 P1 (Garradd)	2012 Jan 19	1.59	5.5	1.72	2.16 ± 0.28	10.	0.22	0.30	1.5
C/2012 S1 (ISON)	2013 Nov 01	0.99	–42.0	1.22	$2.6 \pm 0.4 \times 10^{-2}$	2.0	0.013	0.05	0.6
C/2014 Q2 (Lovejoy)	2015 Feb 02/03	1.29	1.2	0.81	2.23 ± 0.27	45.	0.050	1.0	12.0

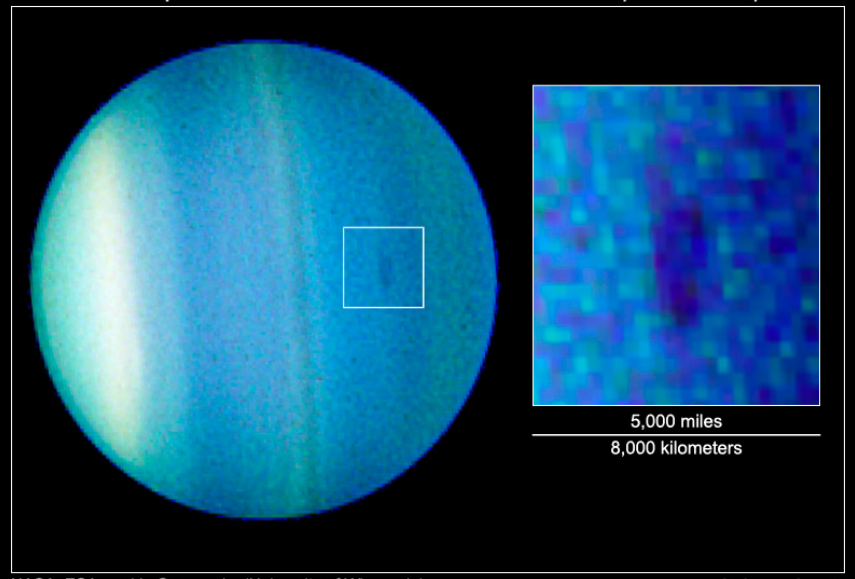
Far-ultraviolet Hubble spectroscopy of
recent comets

Hubble enables a WEALTH of Solar System science

Interstellar Comet 2I/Borisov Hubble Space Telescope

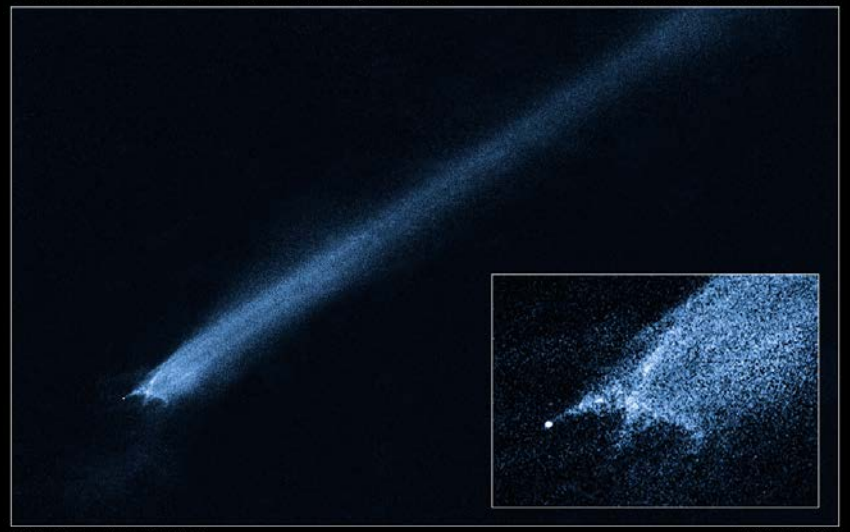


Uranus Dark Spot *Hubble Space Telescope* ▪ ACS



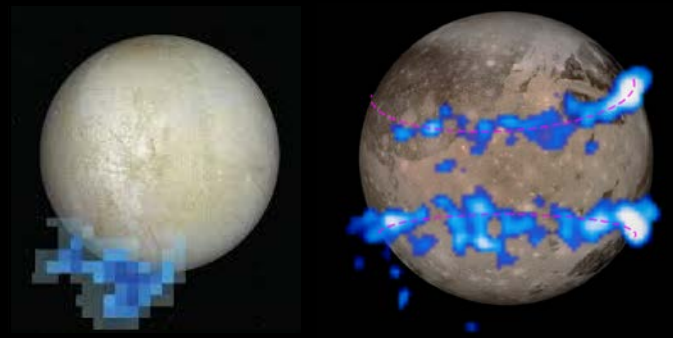
NASA, ESA, and L. Sromovsky (University of Wisconsin) STScI-PRC06-47

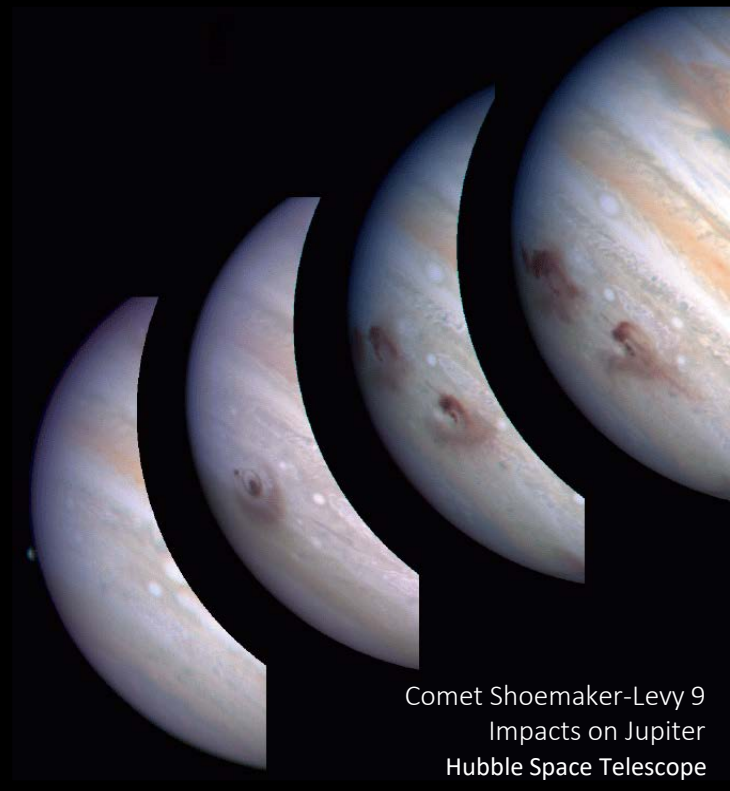
Comet-like Asteroid P/2010 A2 • January 29, 2010 *Hubble Space Telescope* • WFC3/UVIS



NASA, ESA, and D. Jewitt (UCLA) STScI-PRC10-07

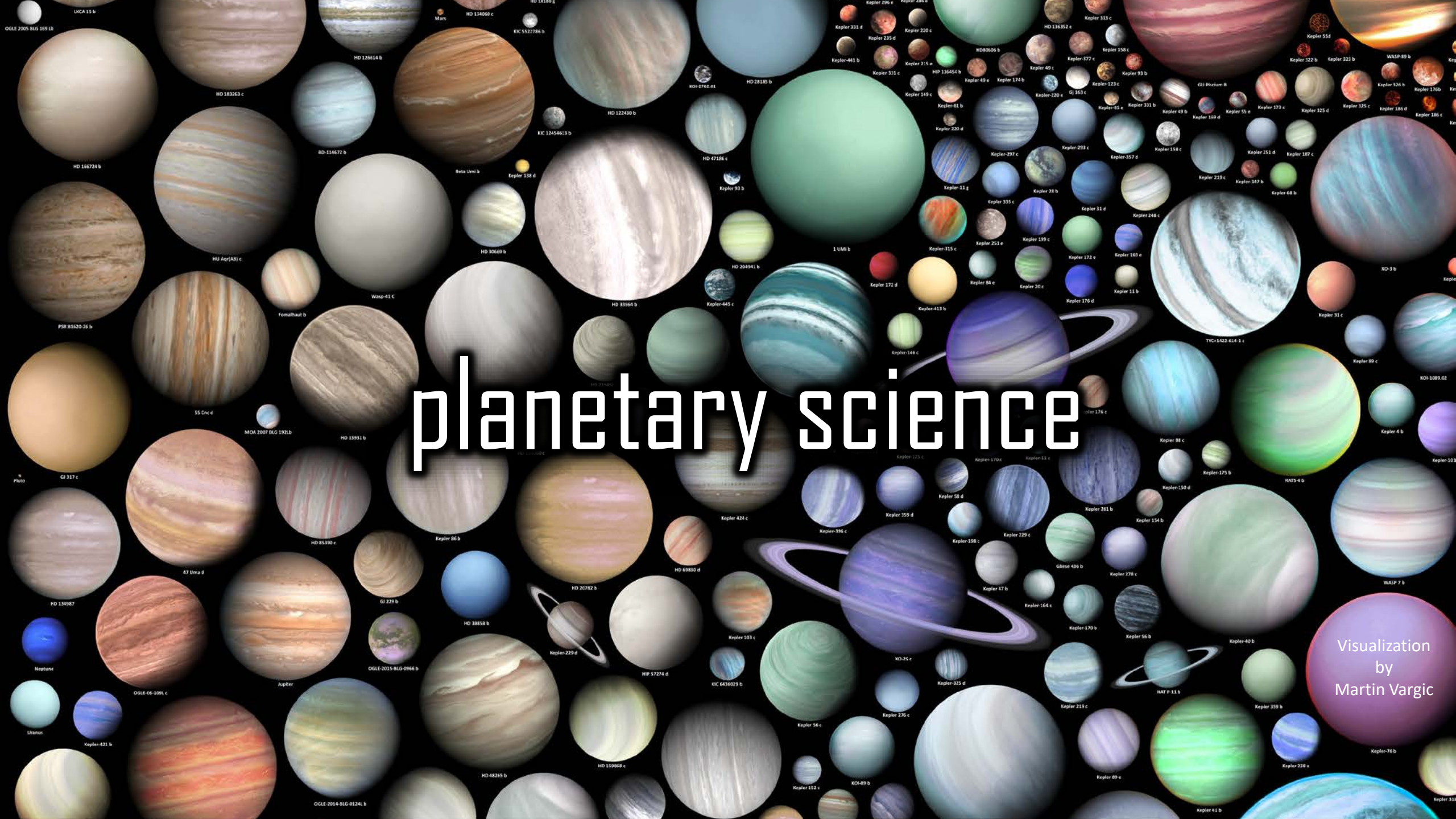
Europa Plumes and Ganymede Aurorae Hubble Space Telescope





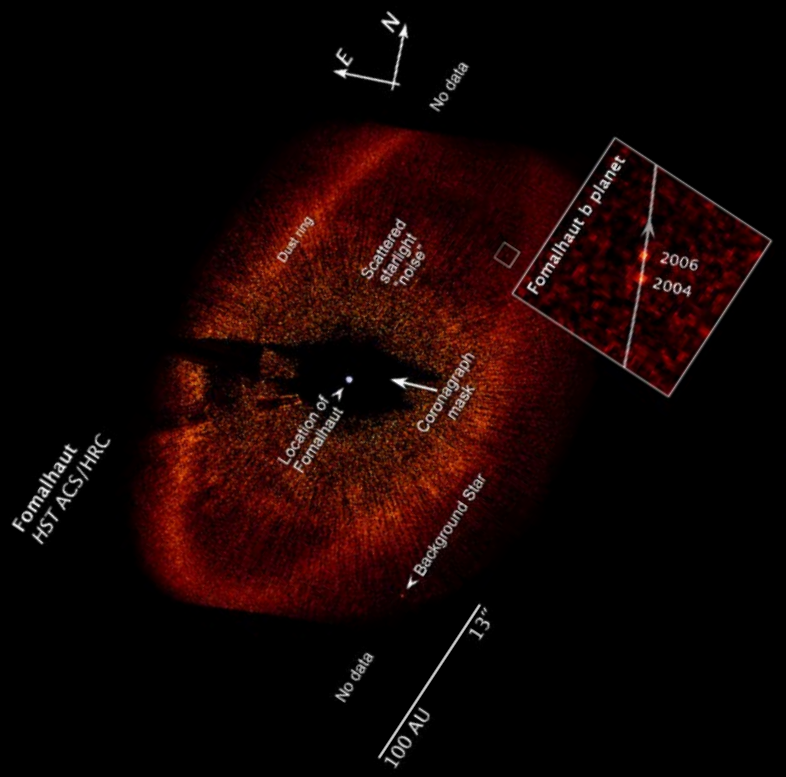
Comet Shoemaker-Levy 9
Impacts on Jupiter
Hubble Space Telescope

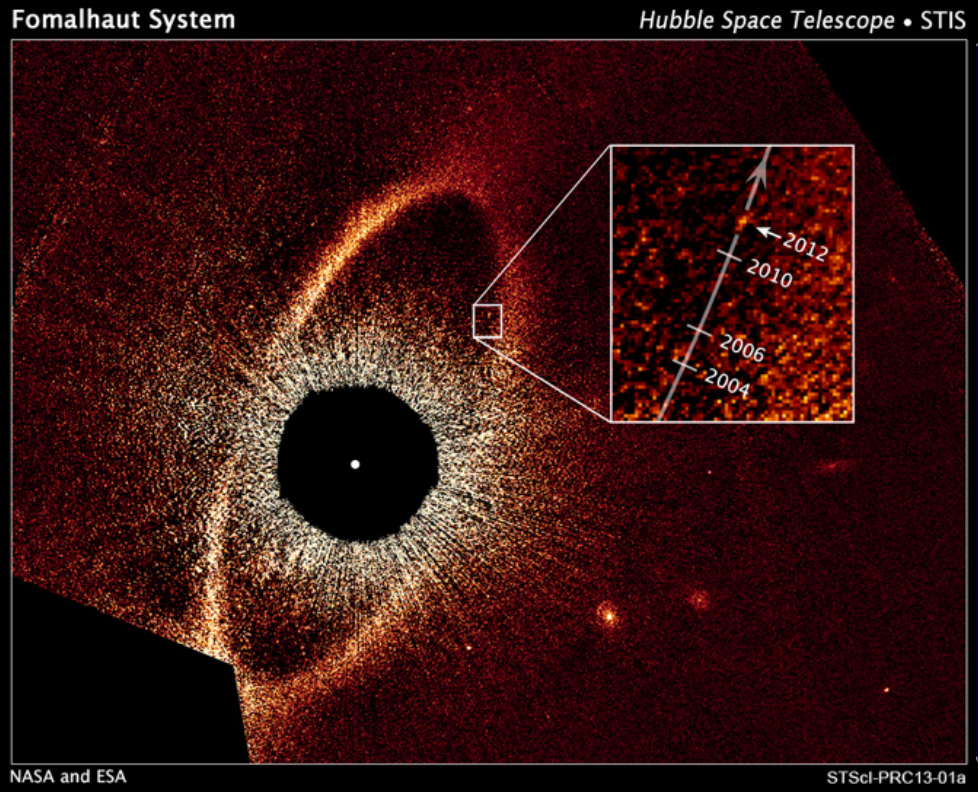
planetary science

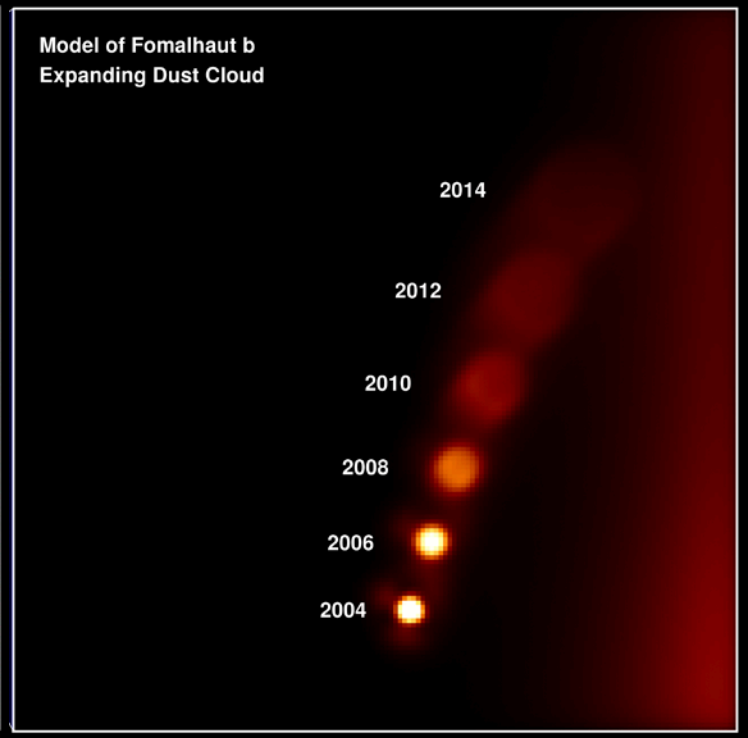

planetary science
Visualization
by
Martin Vargic

Hubble images exoplanets!

Or maybe not?







Hubble in 2006

Hubble in 2012

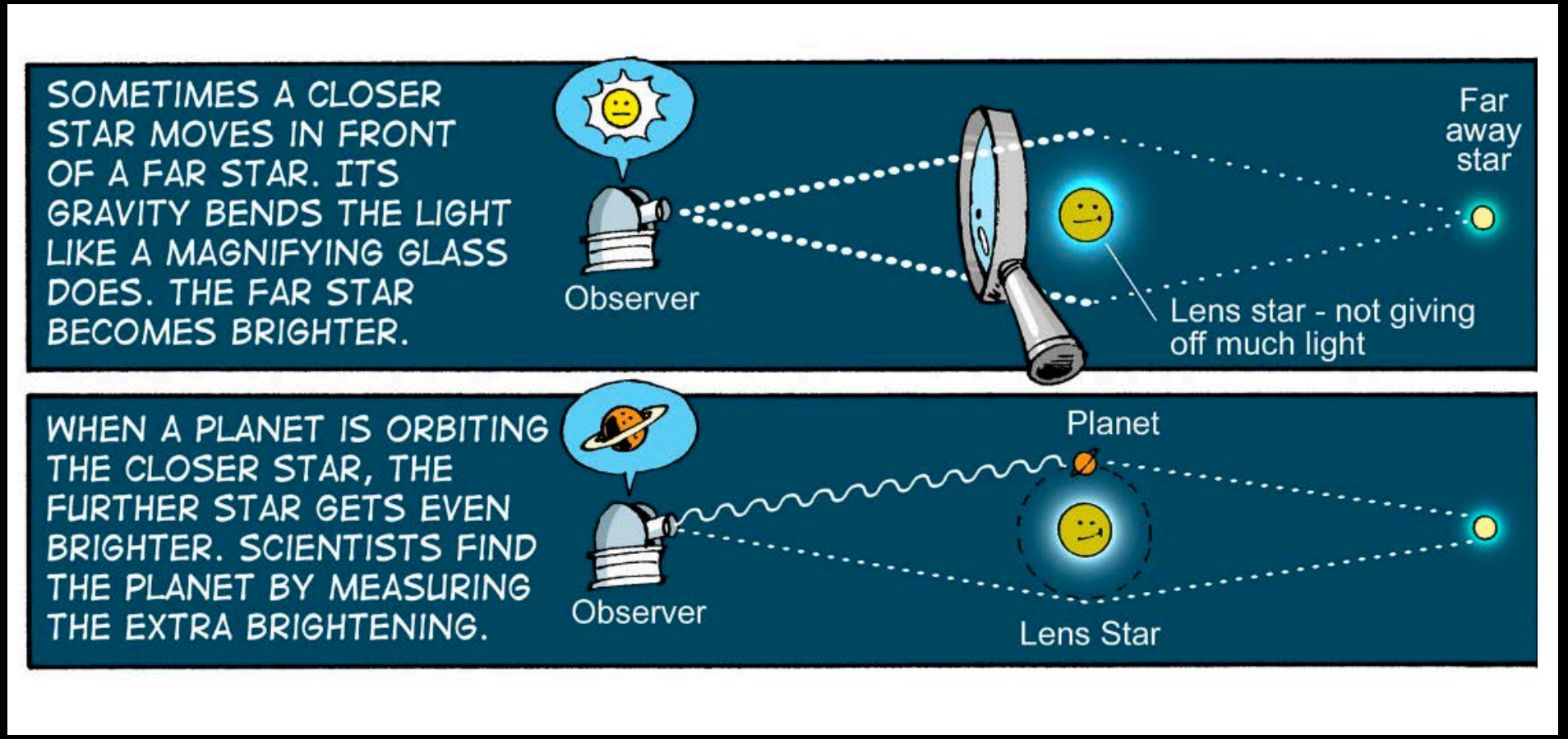
Hubble in 2020*

(about a month ago)*

Gáspár and Rieke 2020, accepted in PNAS, https://arxiv.org/abs/2004.08736

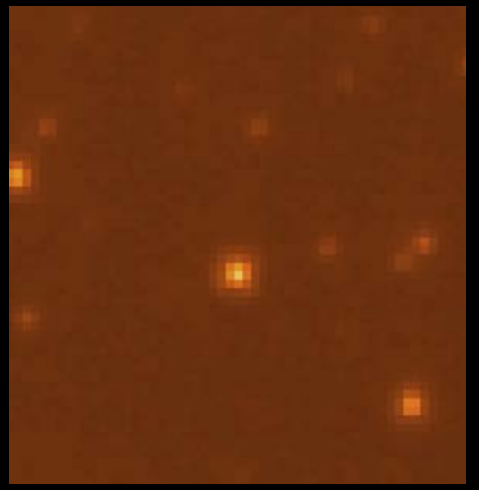
Hubble detects exoplanets *via gravitational microlensing*

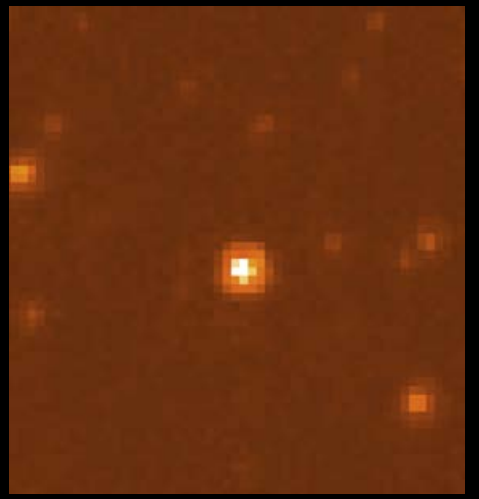
Star: OGLE-2007-BLG-349



https://saasta.ac.za/astronomy/downloads.shtml

Hubble - 2007 Oct 8

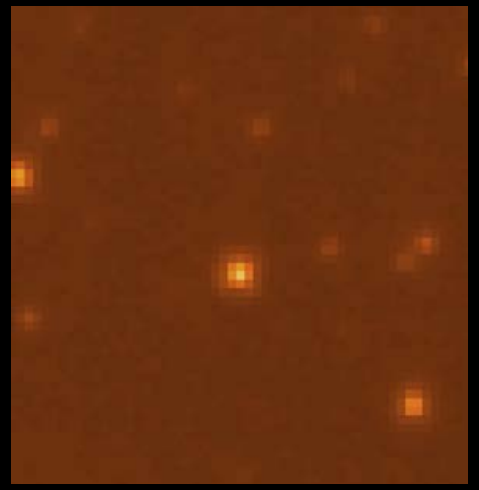


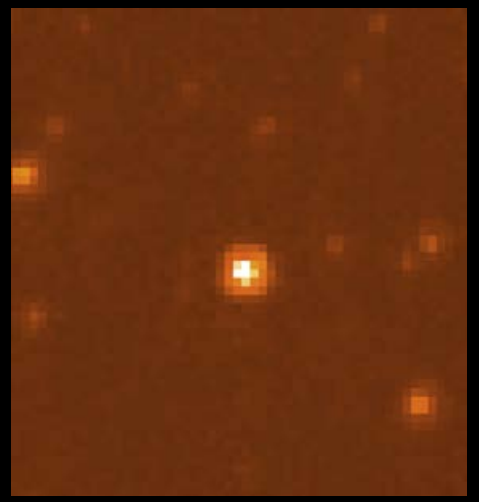


Hubble - 2008 May 4

Hubble detects exoplanets *via gravitational microlensing*

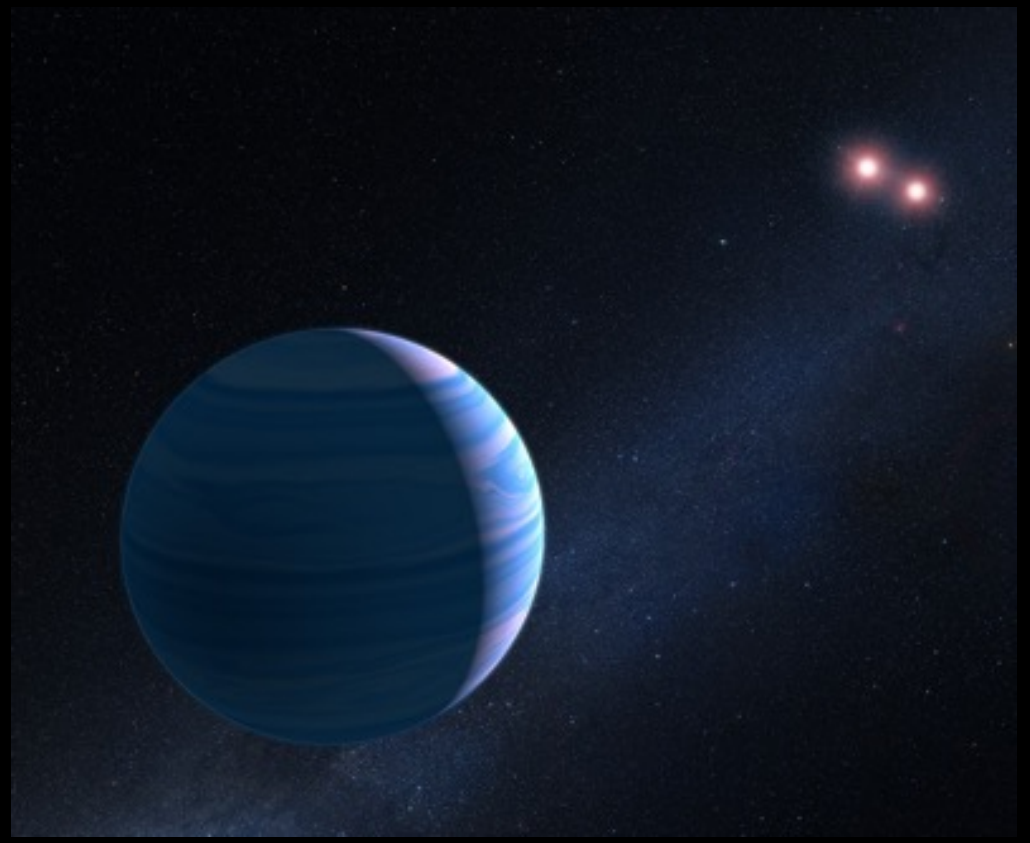
Hubble - 2007 Oct 8





Hubble - 2008 May 4

Star: OGLE-2007-BLG-349



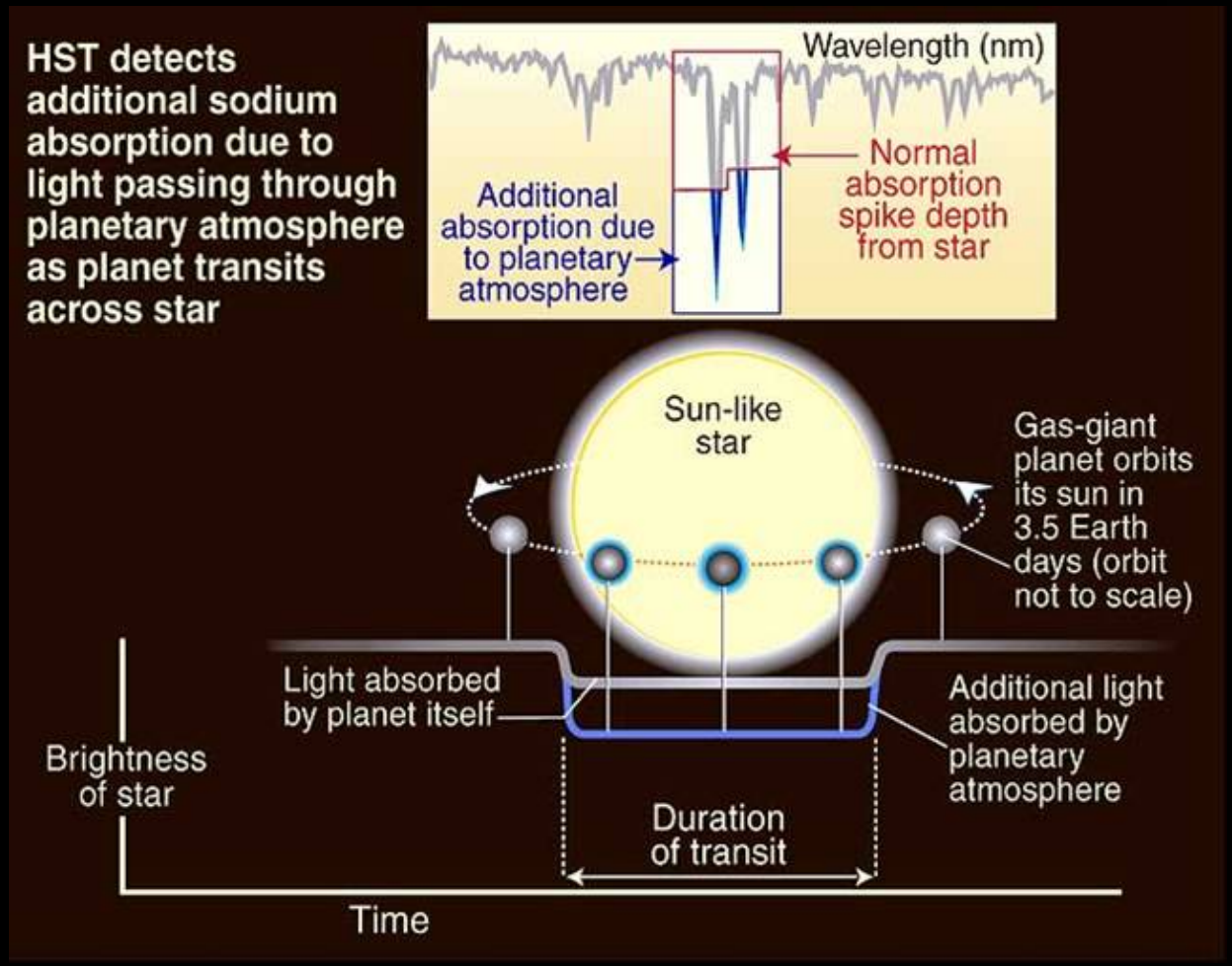
DISCLAIMER: the "picture" above is an ARTIST'S CONCEPT – not a Hubble image of this planet

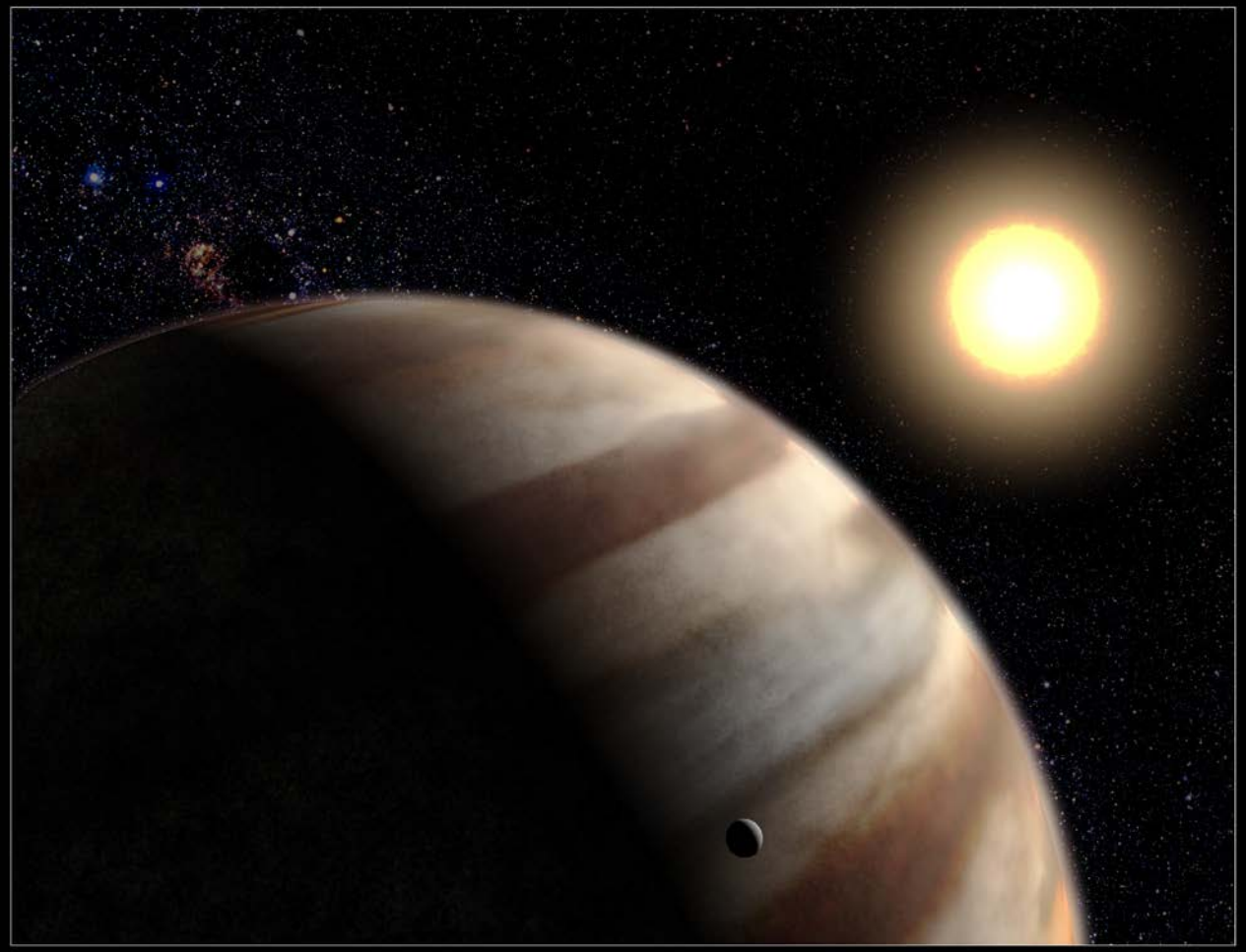
Hubble spots Saturn-sized 'Tatooine planet' orbiting TWO suns

- Astronomers spotted the strange star system 8,000 light years from Earth
- They used the Hubble Space Telescope to spot light being bent by gravity
- This allowed them to determine the system was a planet orbiting two stars

Bennett et al. 2016, Astronomical Journal 152, 125 http://dx.doi.org/10.3847/0004-6256/152/5/125

Hubble – first detection of an exoplanet atmosphere

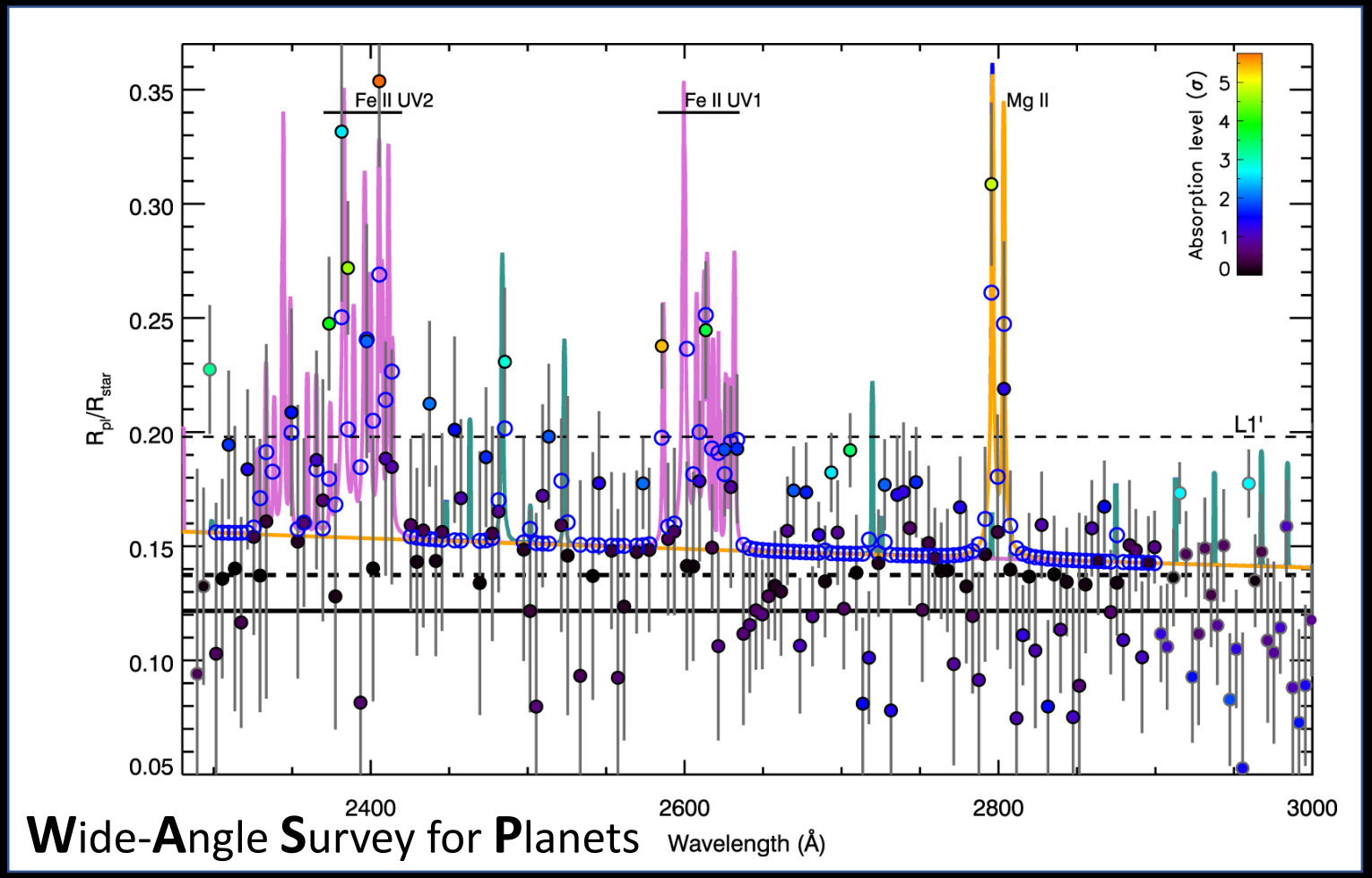




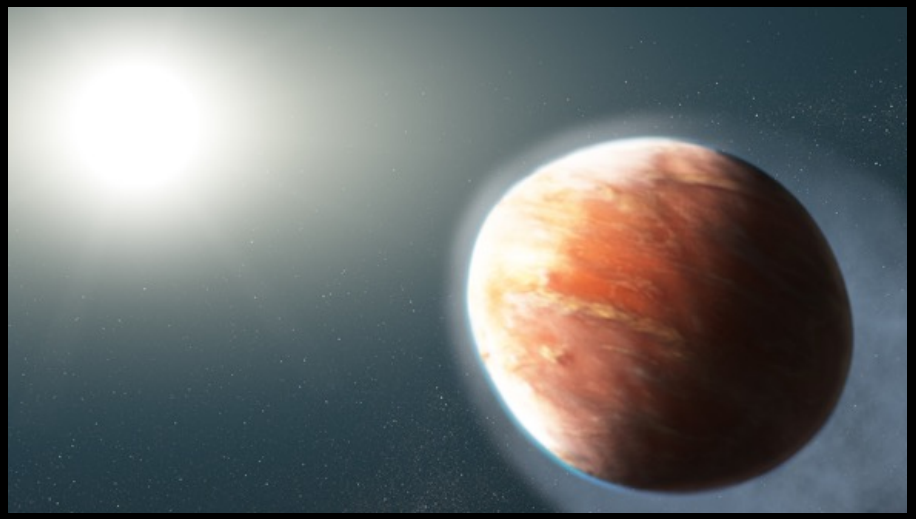
Artist's View of Planet around the Star HD 209458

NASA and G. Bacon (STScI) • STScI-PRC01-38

Hubble spectrum of WASP-121b



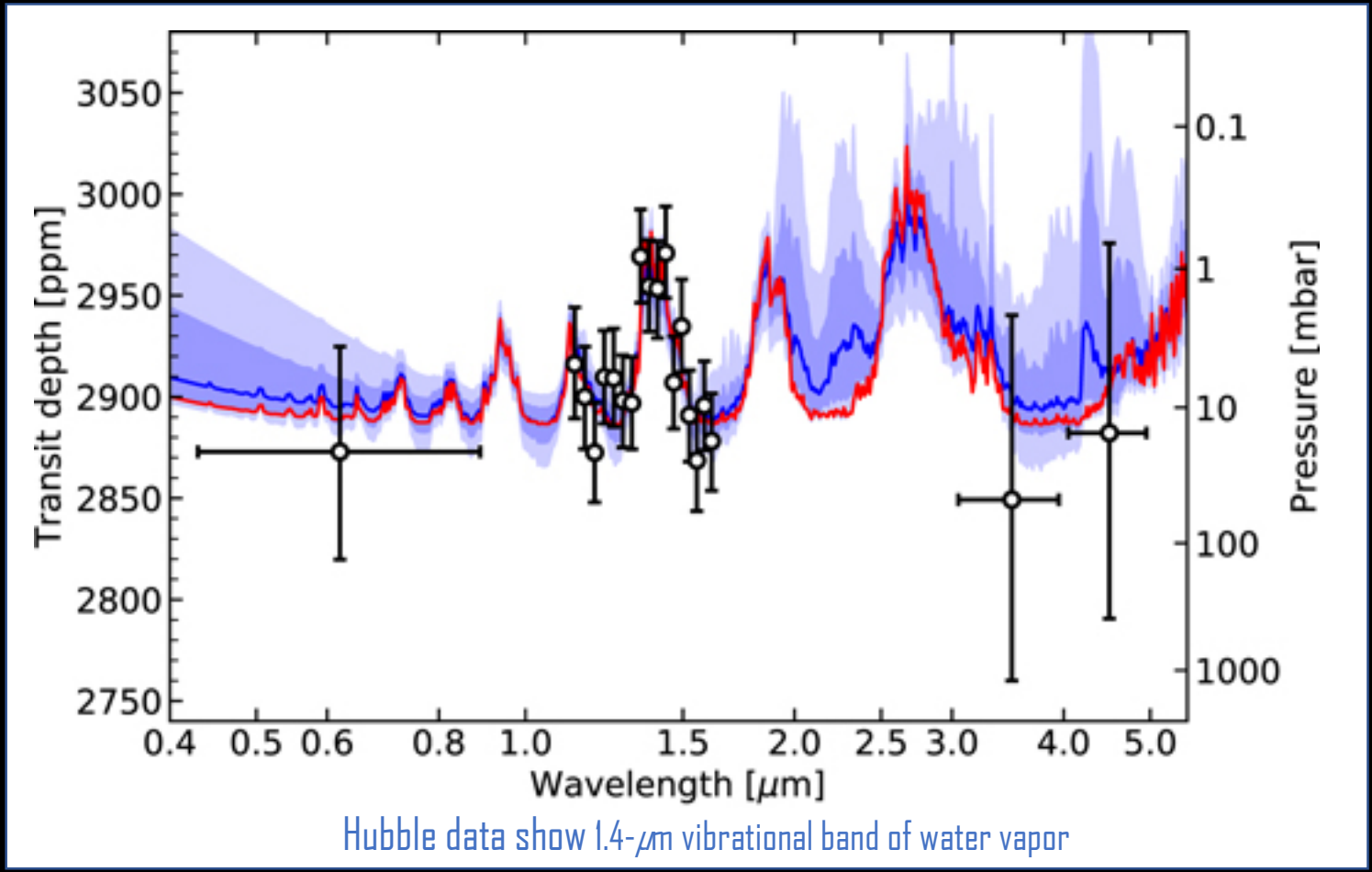
Wide-**A**ngle **S**urvey for **P**lanets



DISCLAIMER: the "picture" above is an ARTIST'S CONCEPT – not a Hubble image of this planet

Not nice for humans

Hubble spectrum of K2-18b



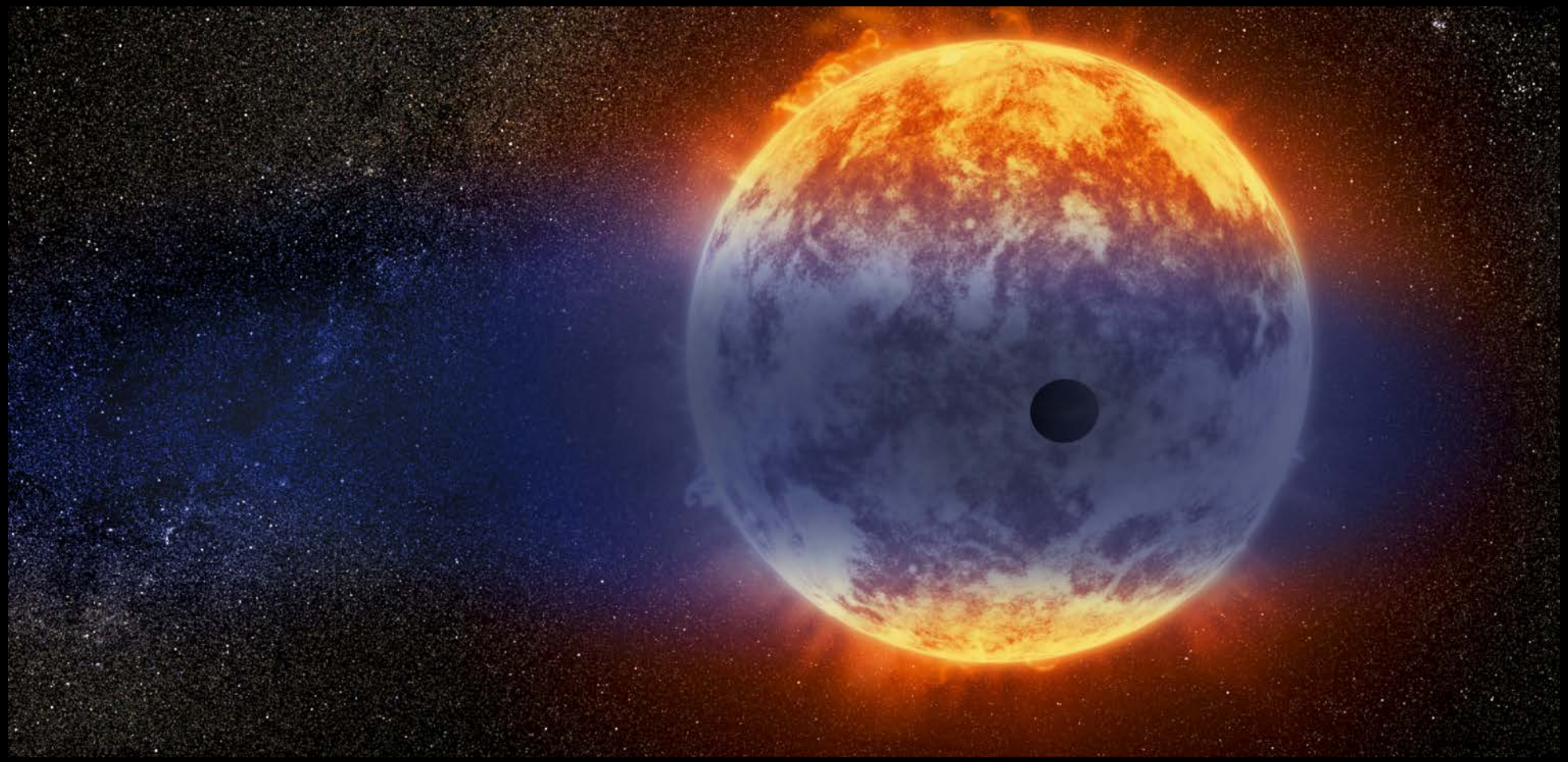
Hubble data show 1.4-μm vibrational band of water vapor

DISCLAIMER: the "picture" above is an ARTIST'S CONCEPT – not a Hubble image of this planet

Maybe nice for humans?

Hubble – exoplanet powerhouse

Hubble revealed atmospheric escape from exo-atmospheres



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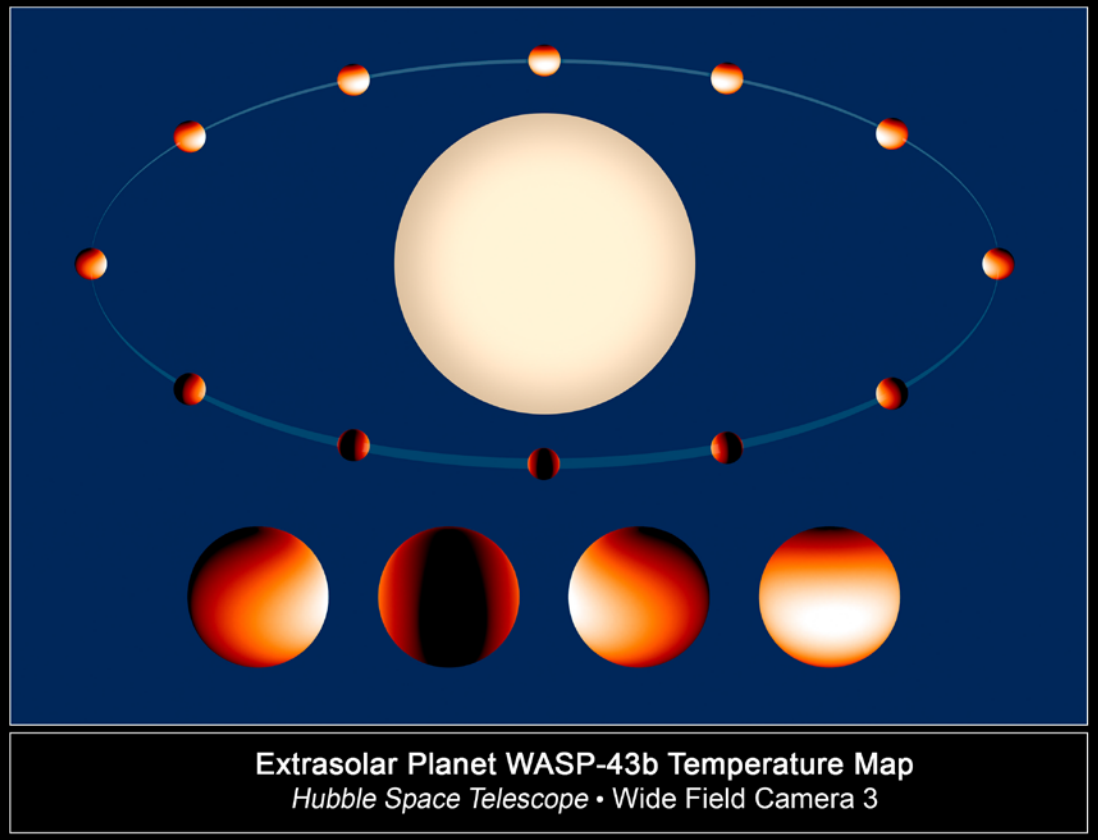
Hubble – exoplanet powerhouse

Hubble has mapped surface temperatures of exoplanets

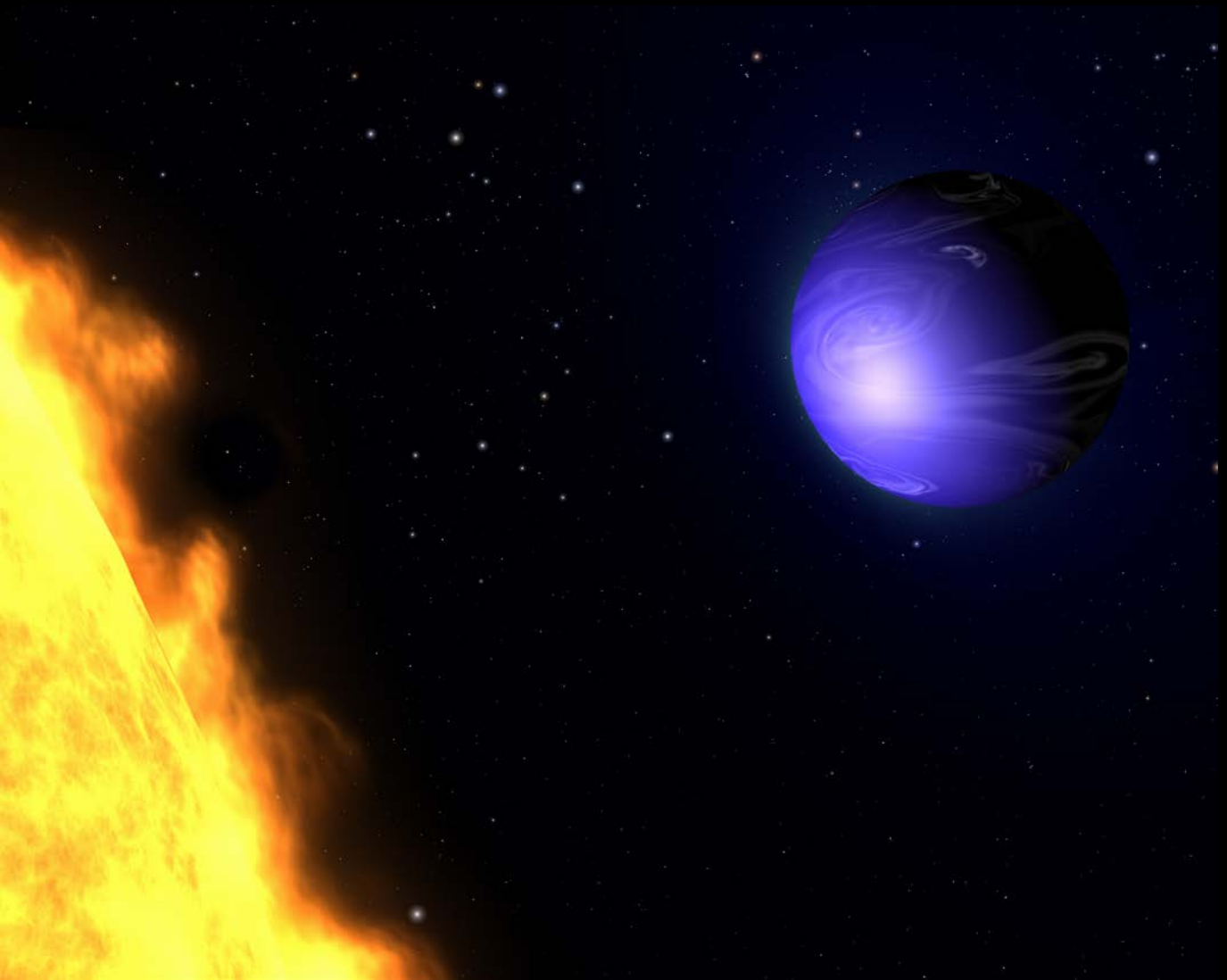


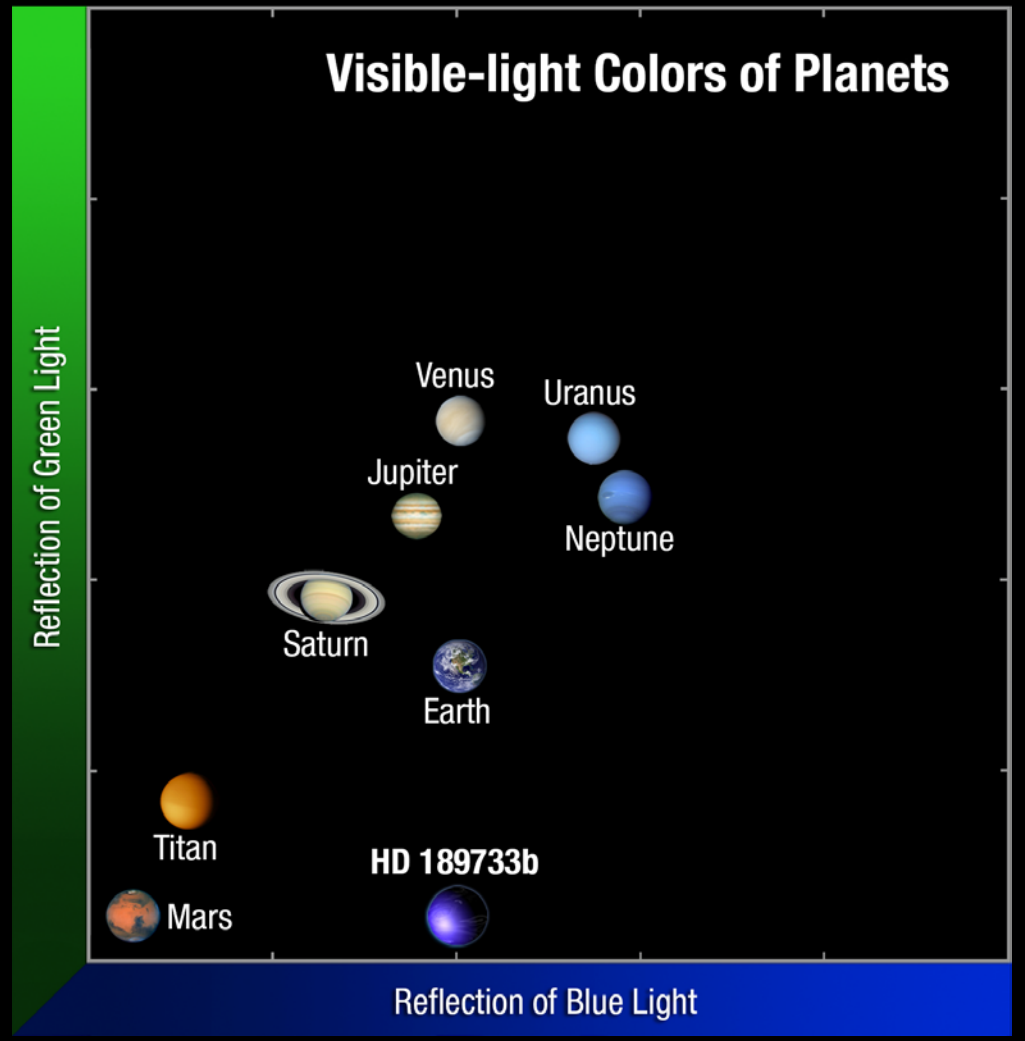
Extrasolar Planet WASP-43b Temperature Map
Hubble Space Telescope • Wide Field Camera 3

NASA and ESA STScI-PRC14-28

Hubble – exoplanet powerhouse

Hubble has shown us the colors of the skies on alien worlds





Hubble – exoplanet powerhouse

Hubble heralded the era of comparative exoplanetology

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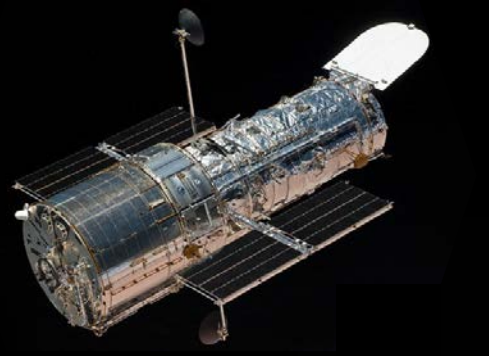
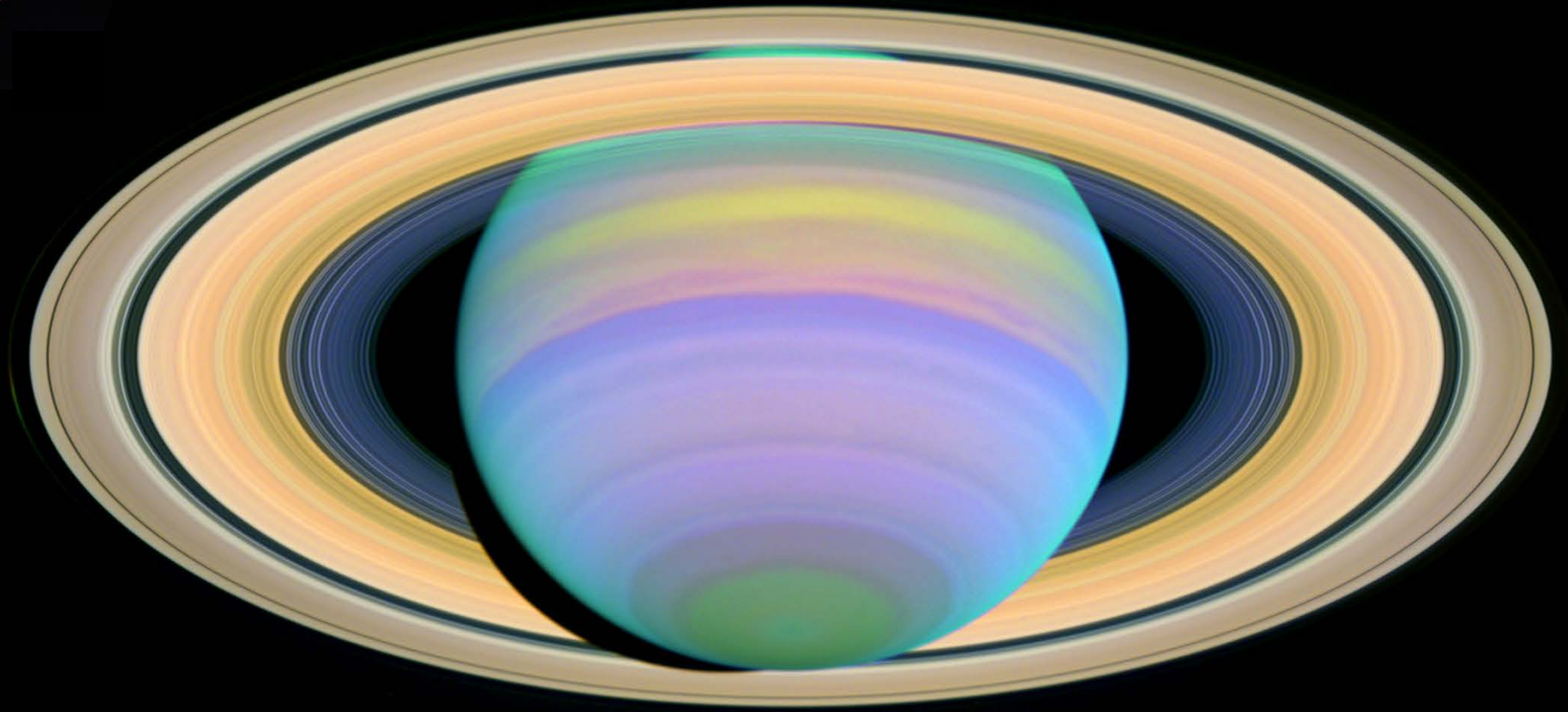


Hubble Space Telescope



30 years of revolutionary planetary science
in our Solar System and beyond...

hbhammel

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