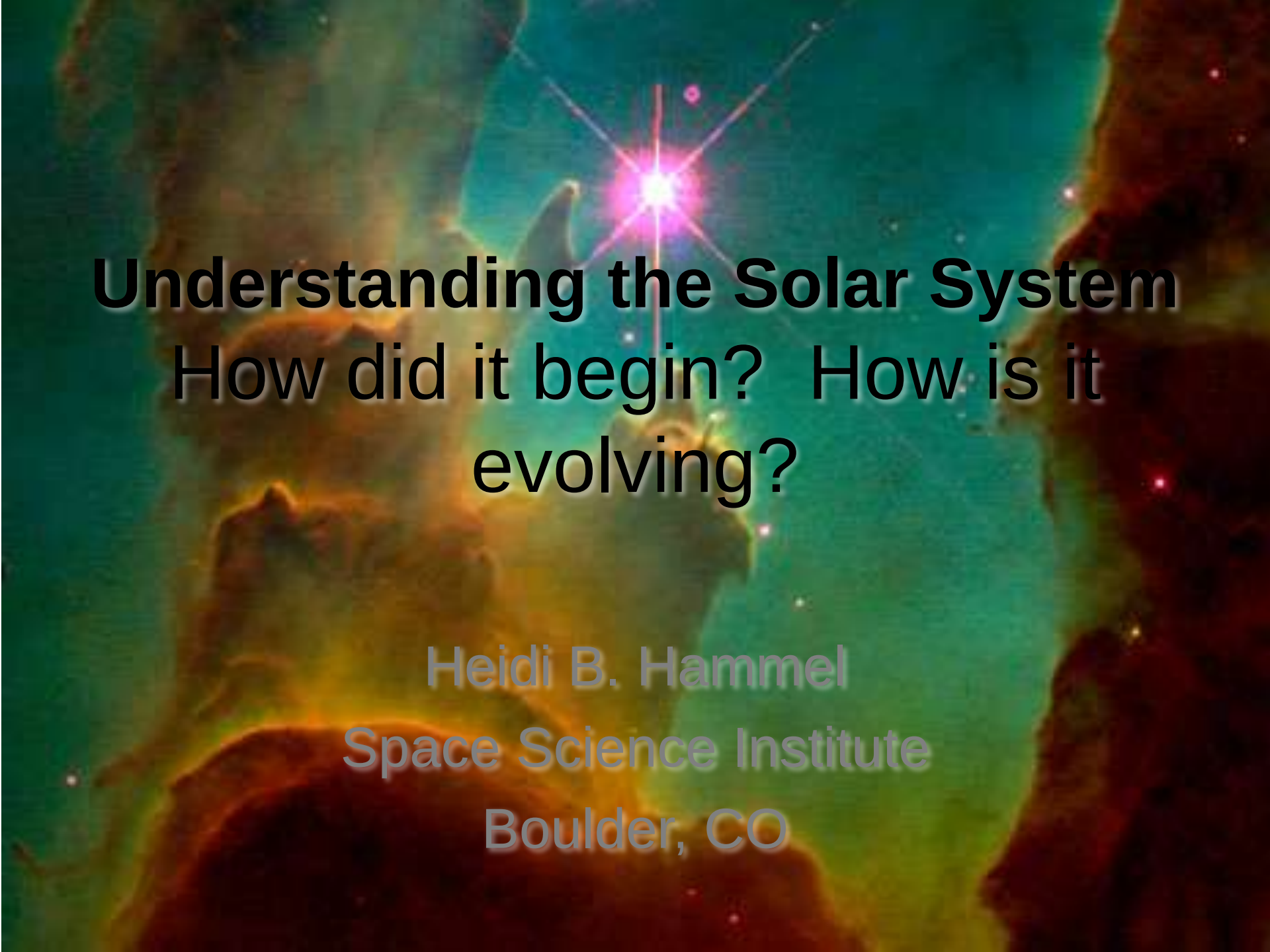
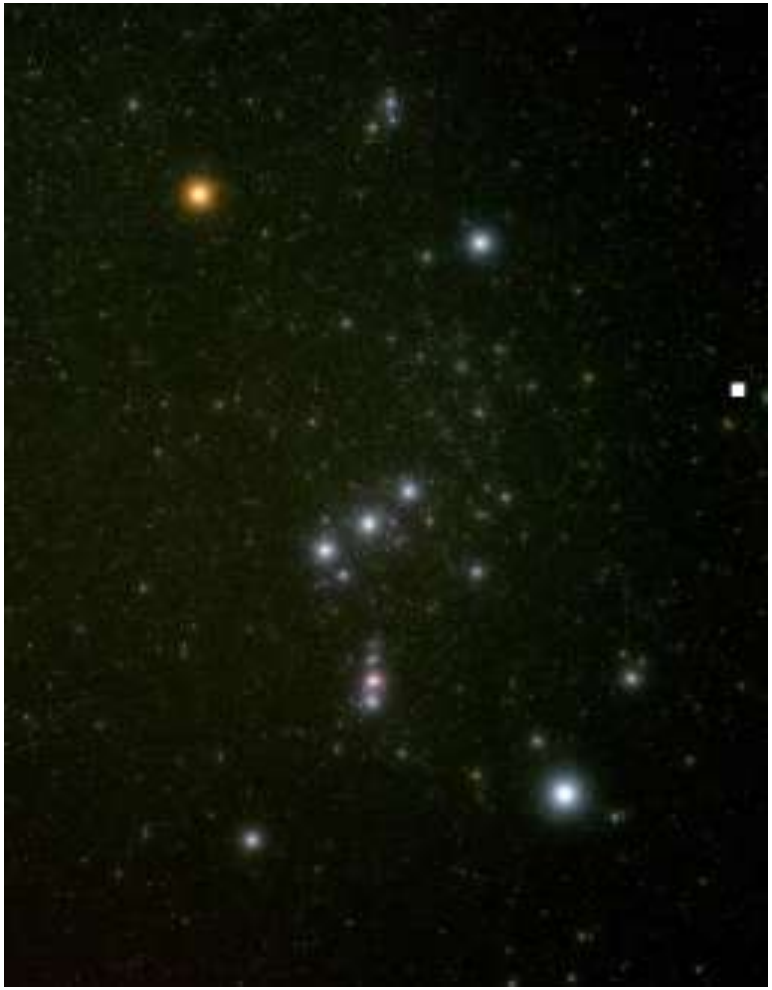


Understanding the Solar System

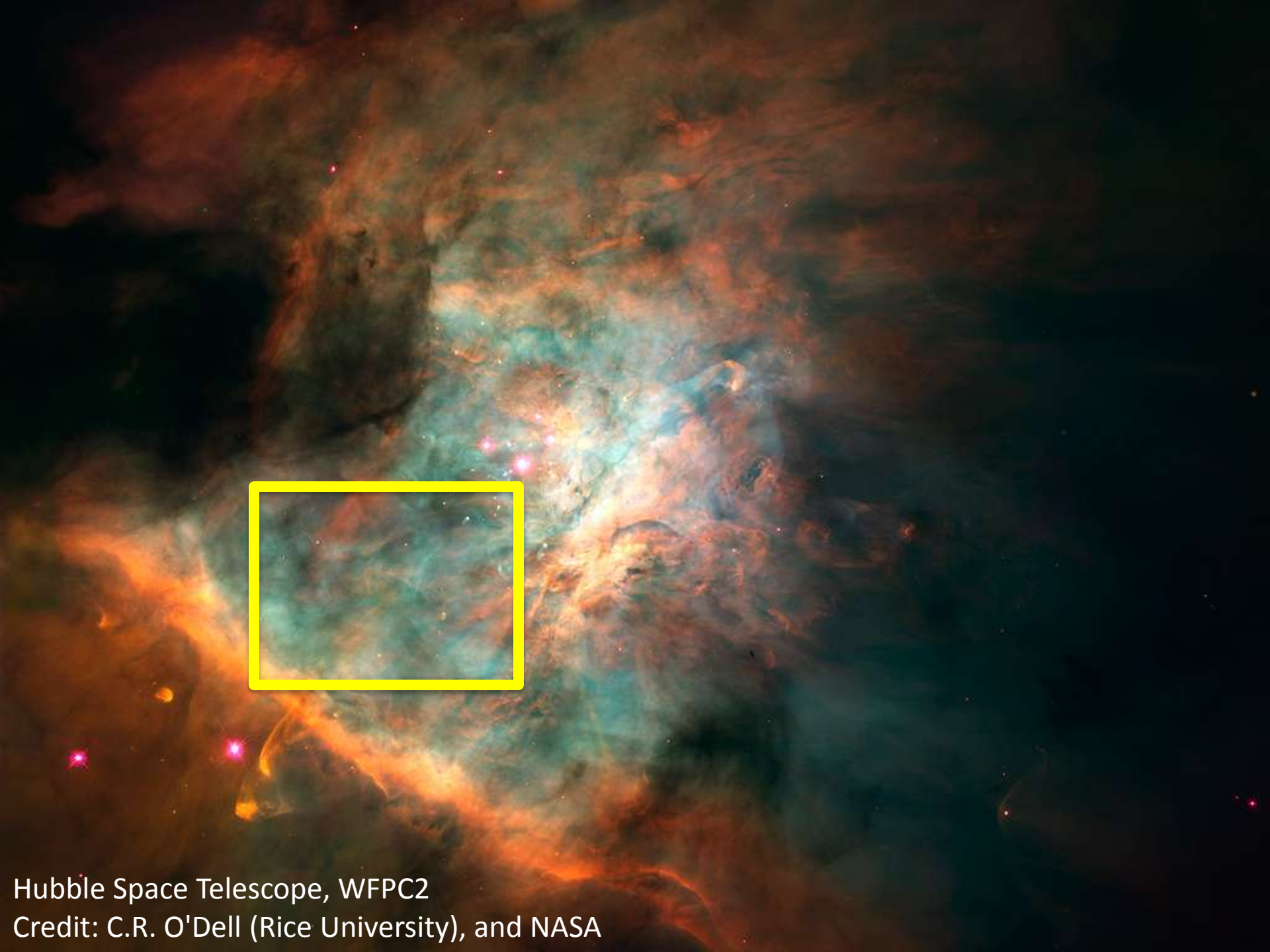
How did it begin? How is it evolving?

Heidi B. Hammel
Space Science Institute
Boulder, CO

hunting for answers

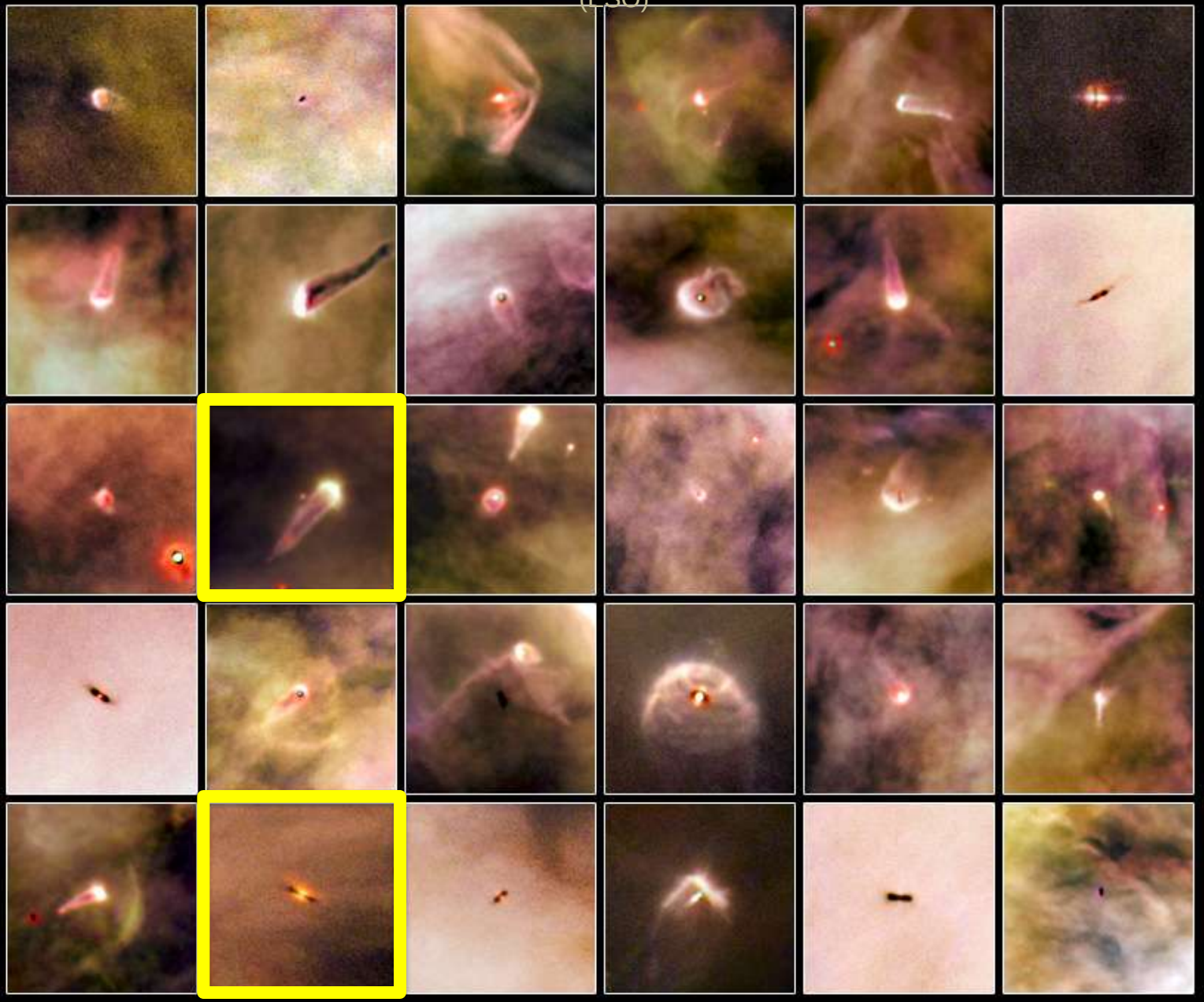


Constellation of Orion the Hunter, by John Gavreau



Hubble Space Telescope, WFPC2
Credit: C.R. O'Dell (Rice University), and NASA

Hubble Space Telescope ACS • Credit: NASA/ESA and L. Ricci (ESO)

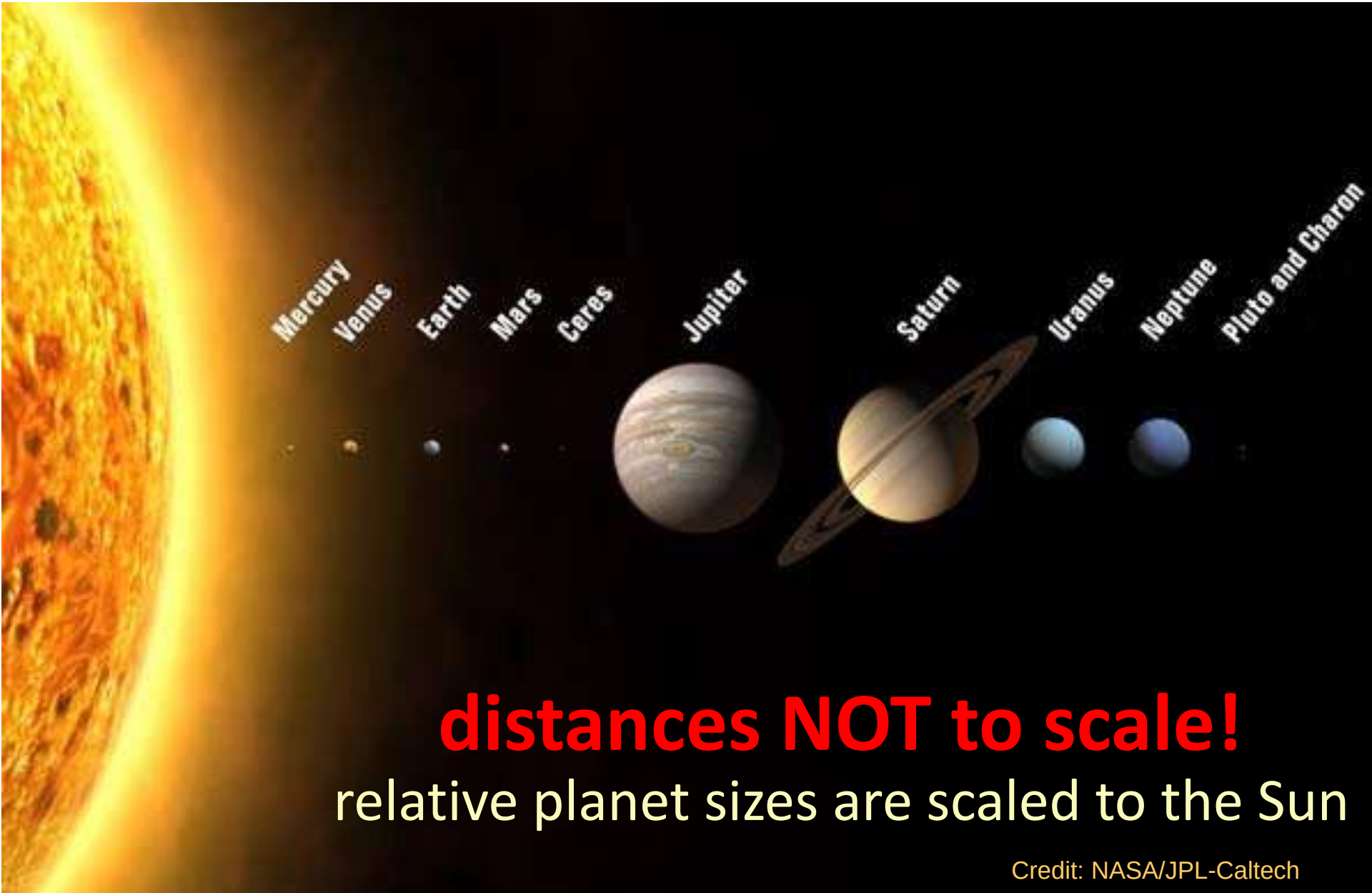


Orion's **pro**to-**pl**anetar**y** **d**isks (**proplyds**)

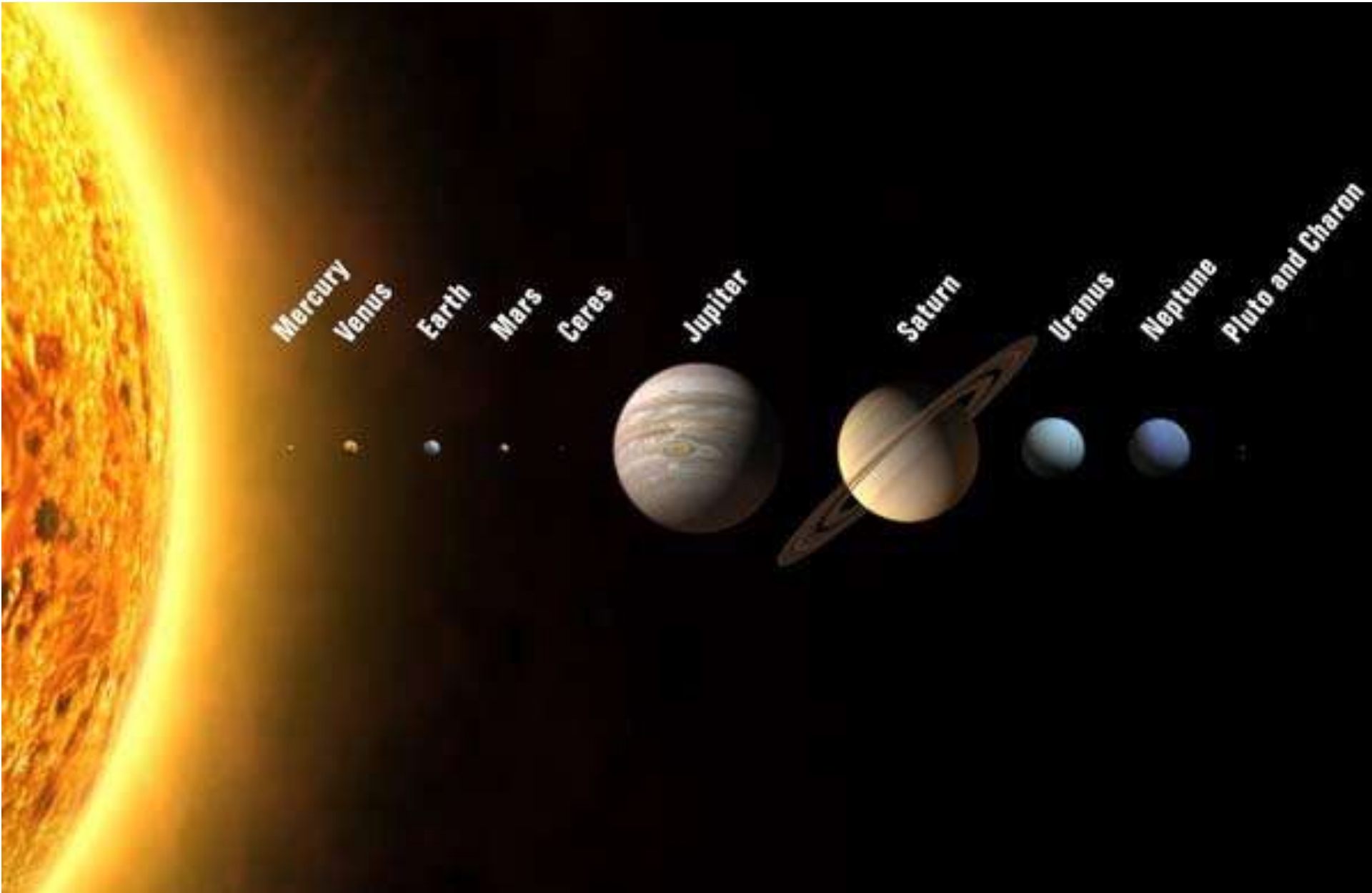
how do you get from this…

Proplyd in Orion
Hubble Space Telescope ACS
Credit: NASA/ESA and L. Ricci (ESO)

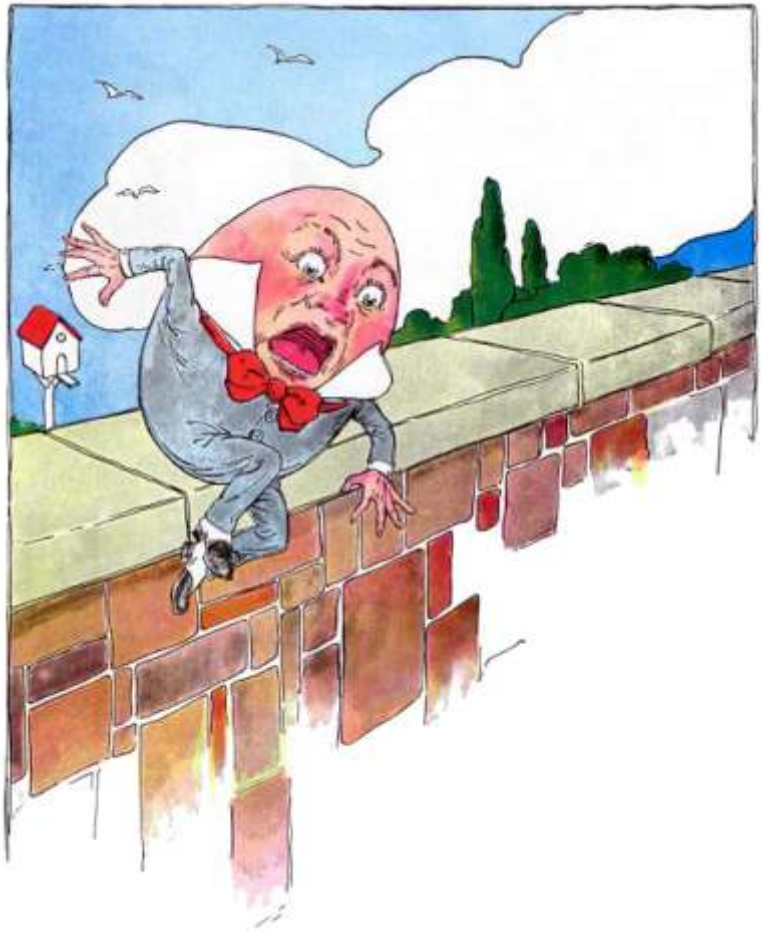
… to this?


Mercury
Venus
Earth
Mars
Ceres
Jupiter
Saturn
Uranus
Neptune
Pluto and Charon
distances NOT to scale!
relative planet sizes are scaled to the Sun
Credit: NASA/JPL-Caltech

the story in 1988



humpty dumpty pushed in 1992

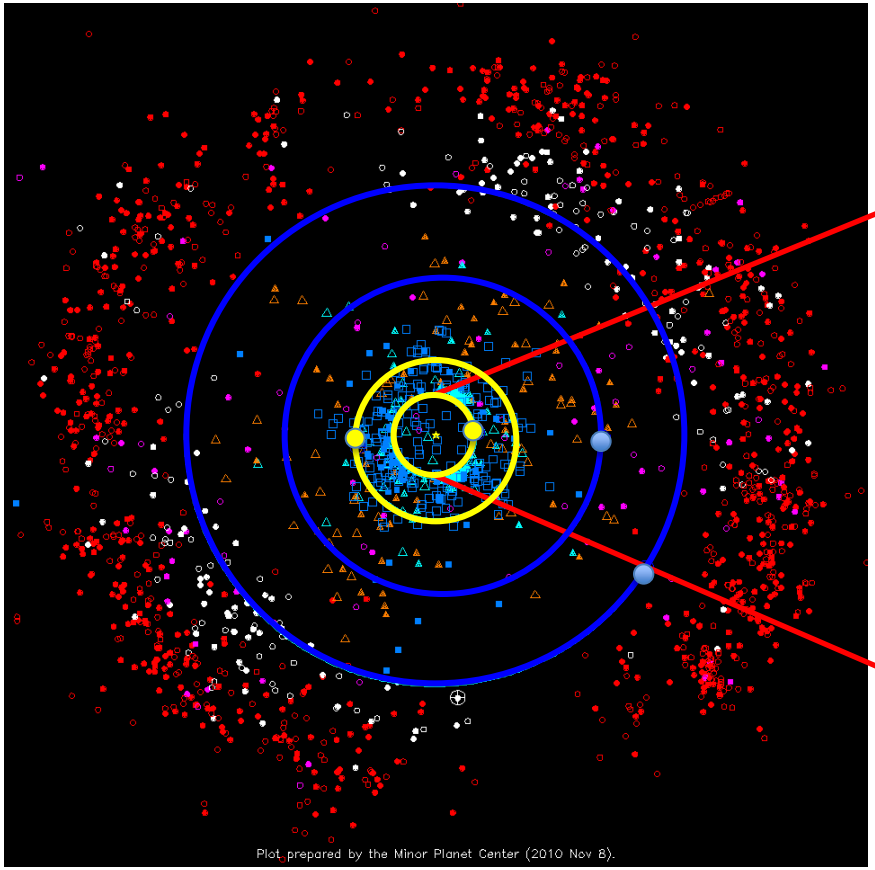


1992 QB1

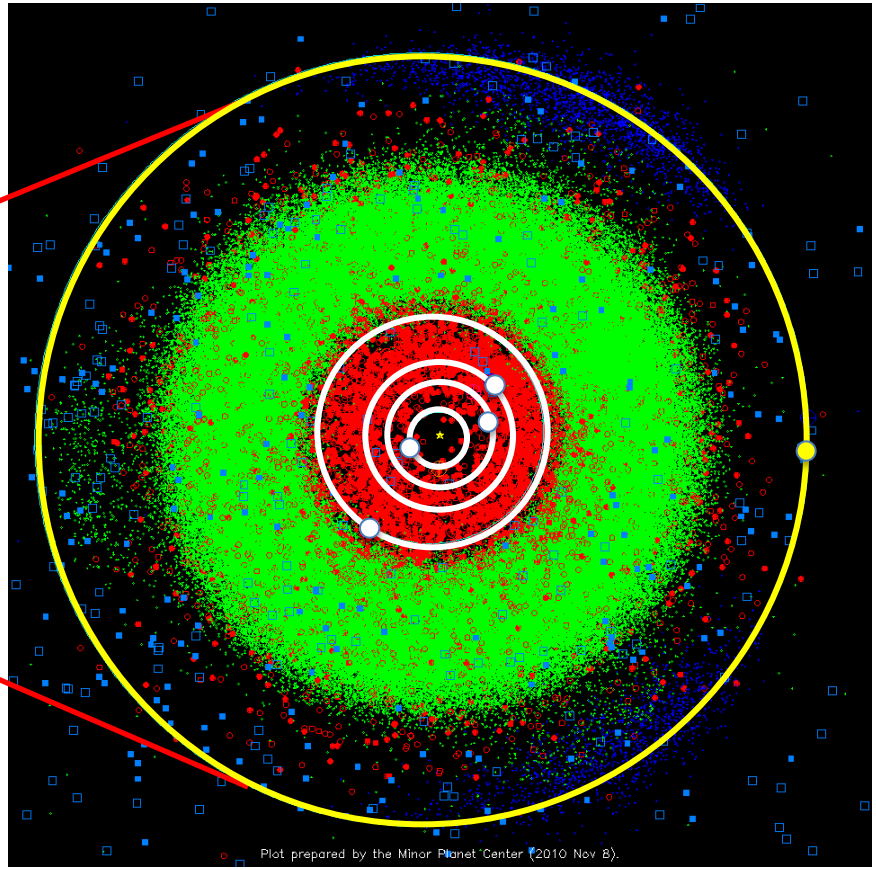
kuiper belt detected

(beginning of the end of Pluto's planethood)

the REAL solar system

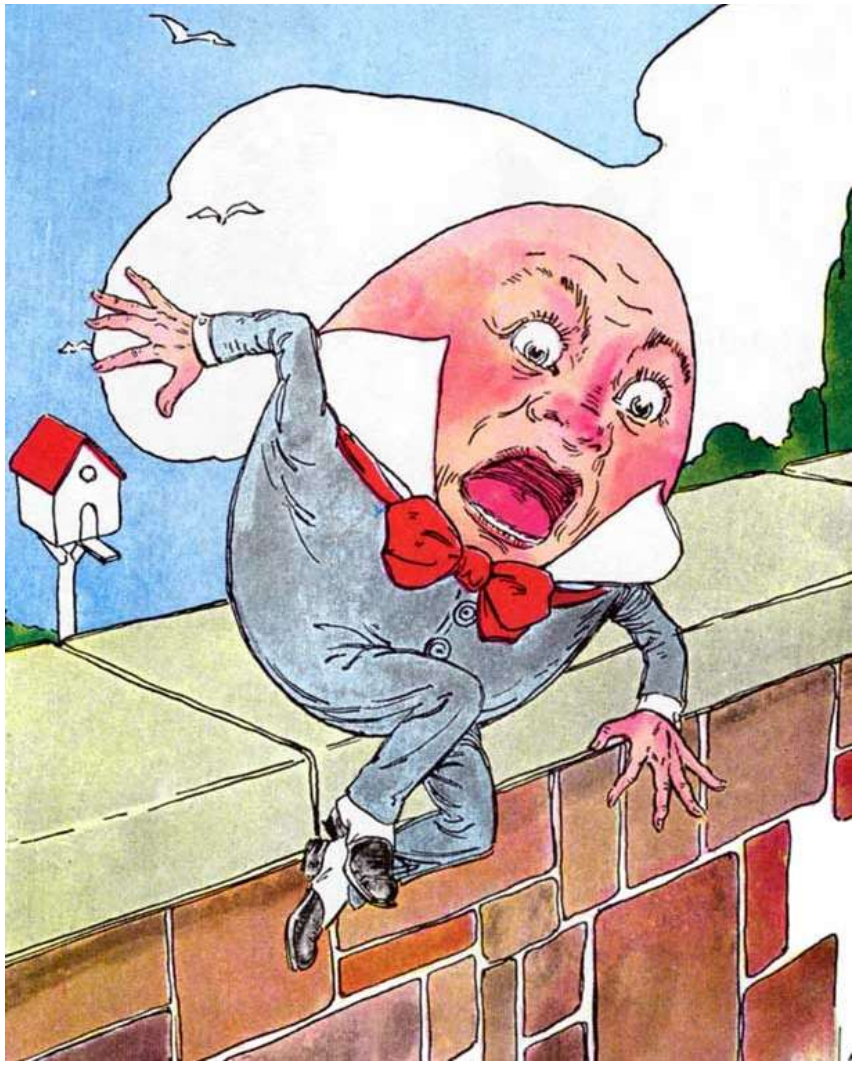


Outer Solar System
8 November 2010
Data: Minor Planet Center



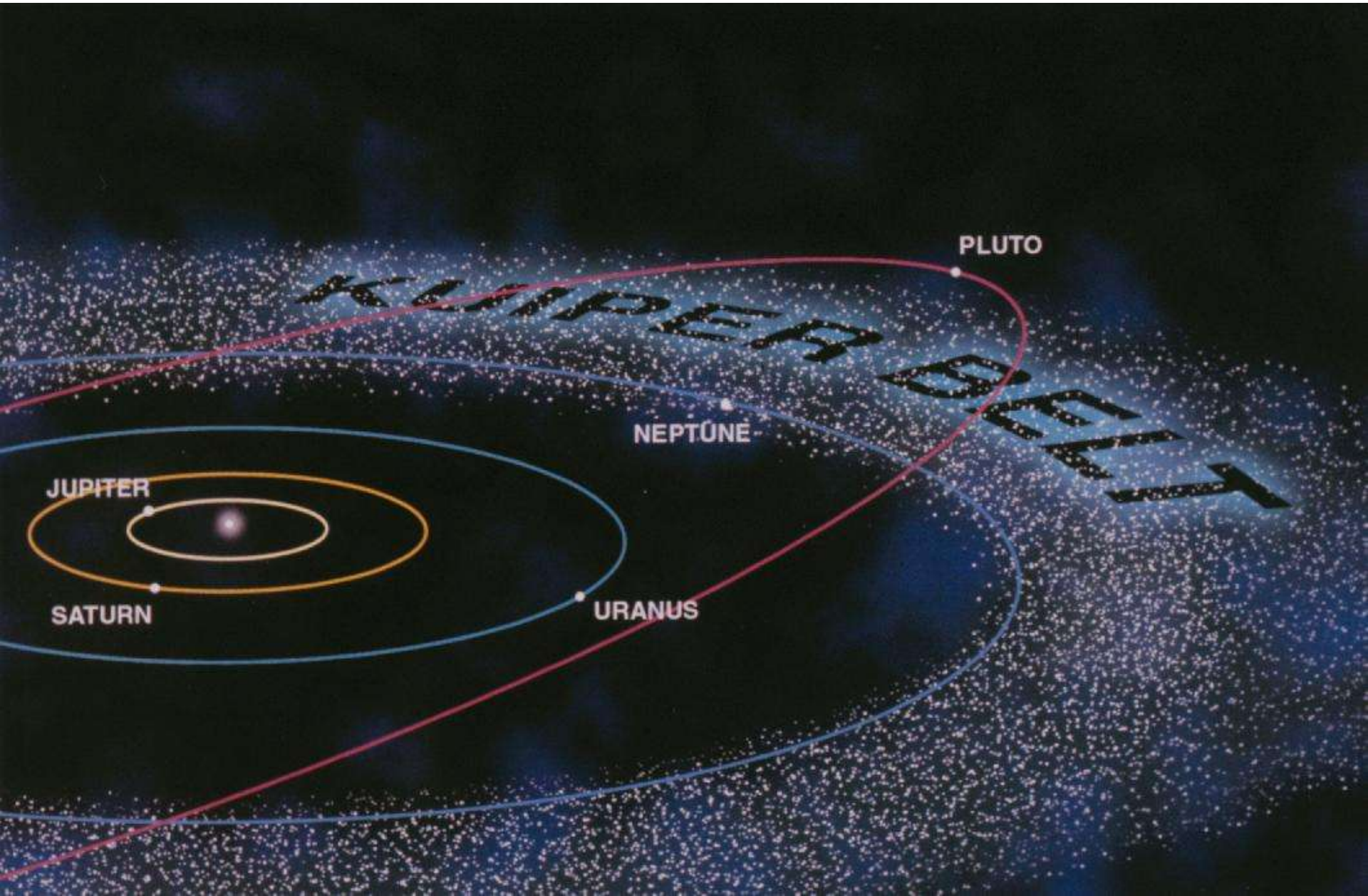
Inner Solar System
8 November 2010
Data: Minor Planet Center

humpty dumpty **shoved** in mid 1990s

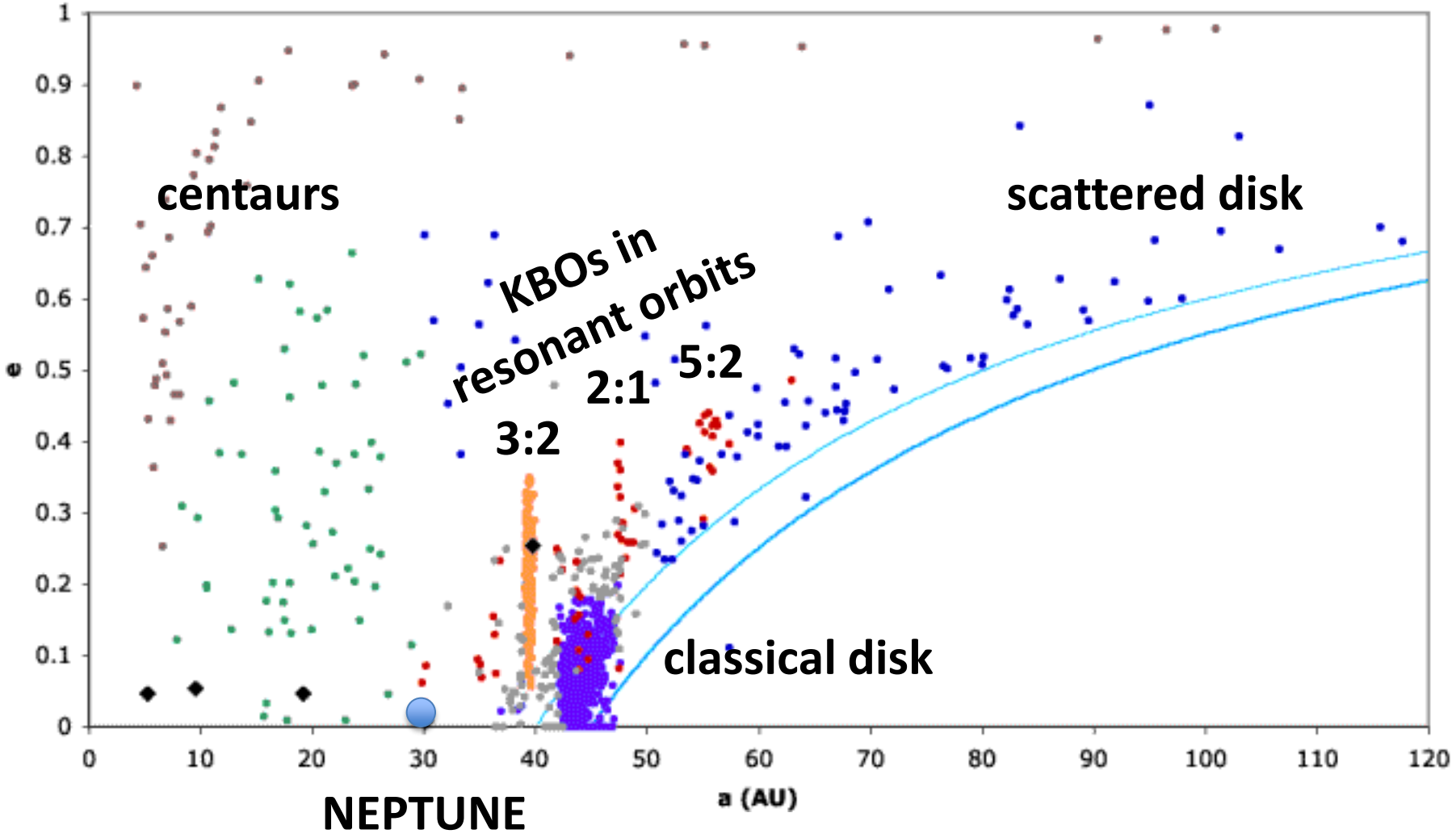


planetary migration theory

kuiper belt - pluto and his 10,000 closest friends and relations



orbits of Kuiper Belt Objects



humpty dumpty fell in 1995

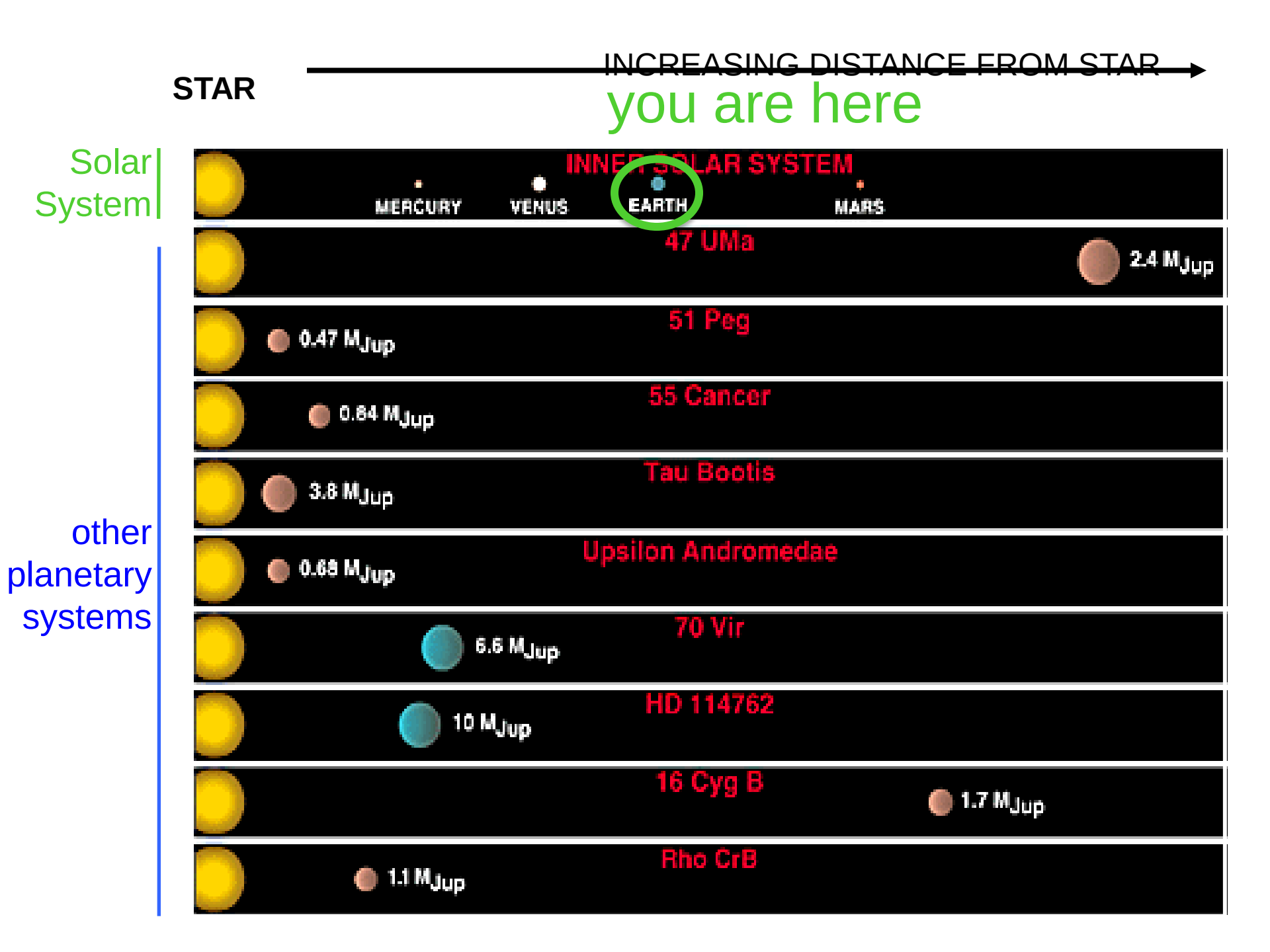
exoplanets

more exoplanets

AND MORE EXOPLANETS

490 planets around other stars

9 November 2010 *planetquest.jpl.nasa.gov*


STAR
INCREASING DISTANCE FROM STAR
you are here
Solar System
other planetary systems
INNER SOLAR SYSTEM
MERCURY
VENUS
EARTH
MARS
47 UMa
2.4 MJup
51 Peg
0.47 MJup
55 Cancer
0.84 MJup
Tau Bootis
3.8 MJup
Upsilon Andromedae
0.68 MJup
70 Vir
6.6 MJup
HD 114762
10 MJup
16 Cyg B
1.7 MJup
Rho CrB
1.1 MJup

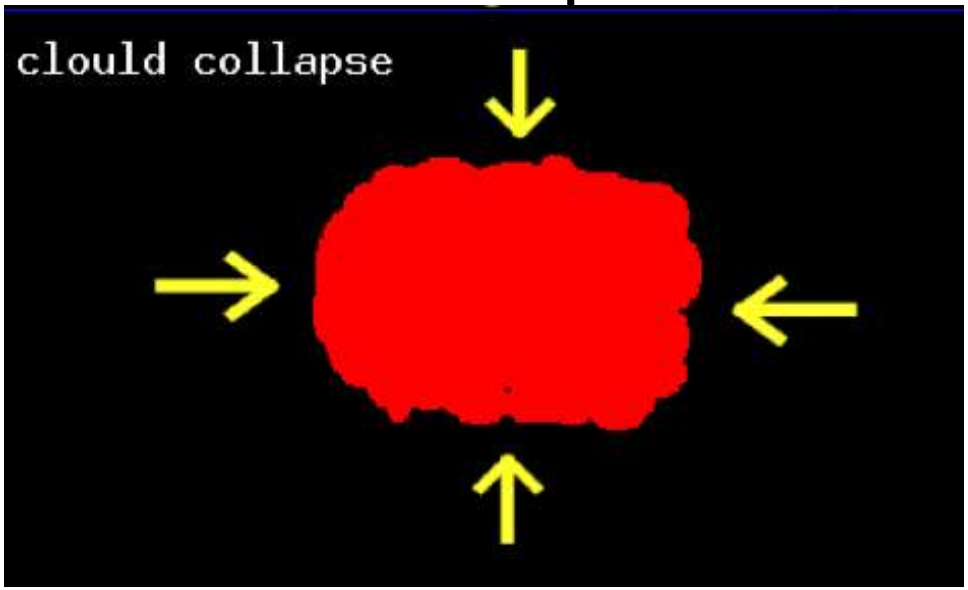
how do we put humpty dumpty together again?

how to build a solar system I of 7

according to Hal Levison et al.

Stage 1

cloud collapse

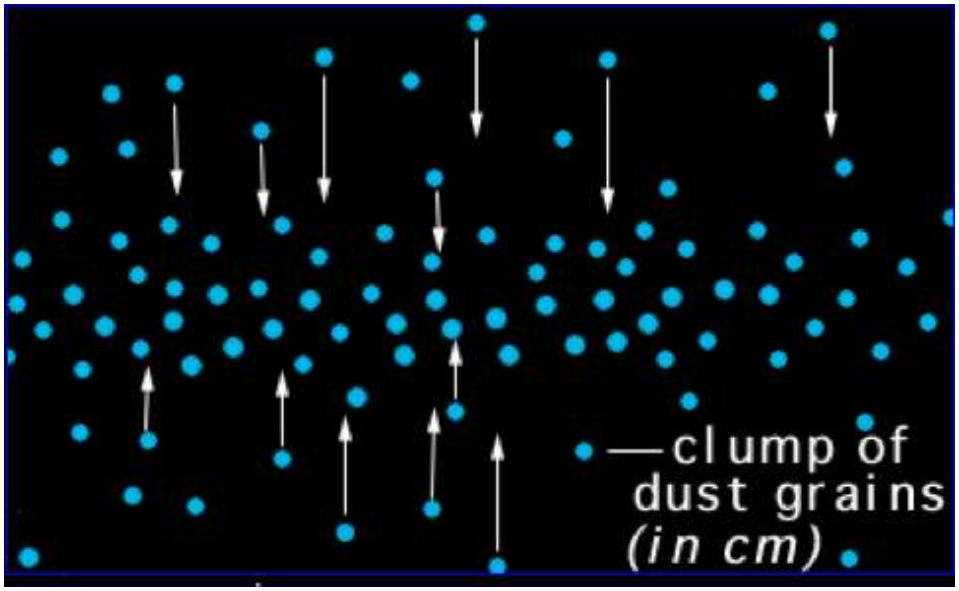


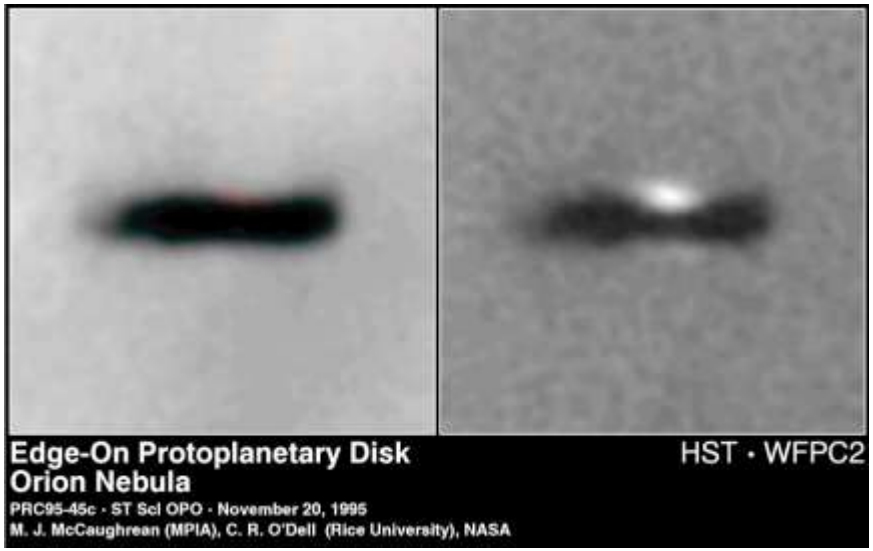
how to build a solar system 2 of 7

according to Hal Levison et al.

Stage 2

Disks form



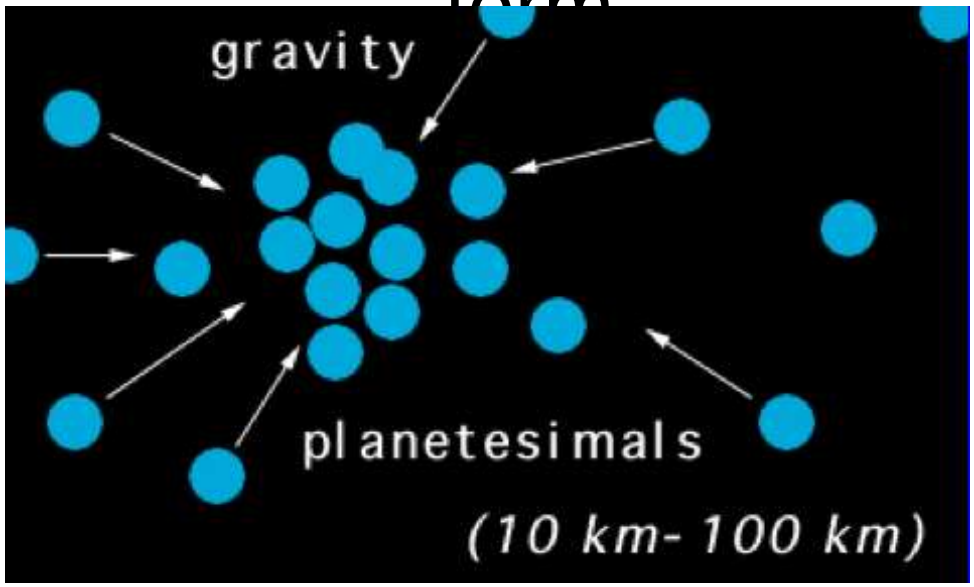


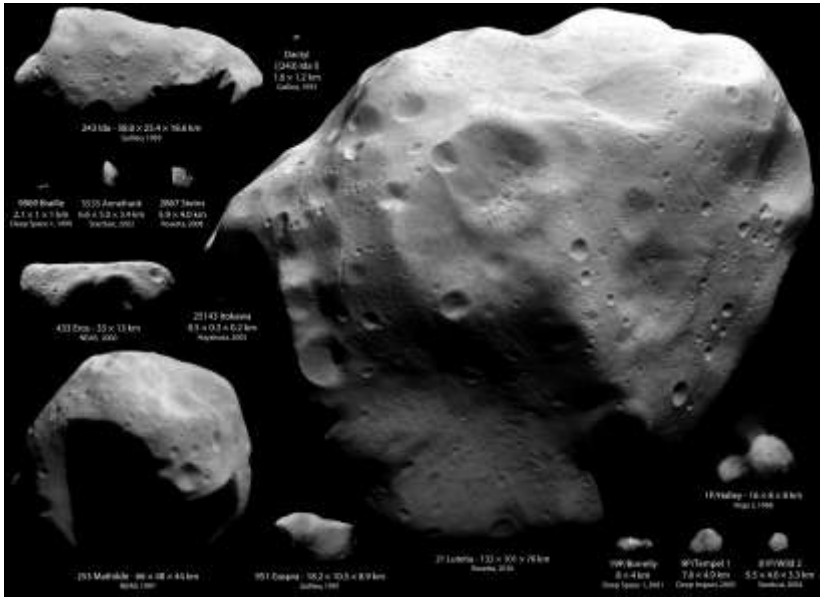
how to build a solar system 3 of 7

according to Hal Levison et al.

Stage 3

planetesimals form





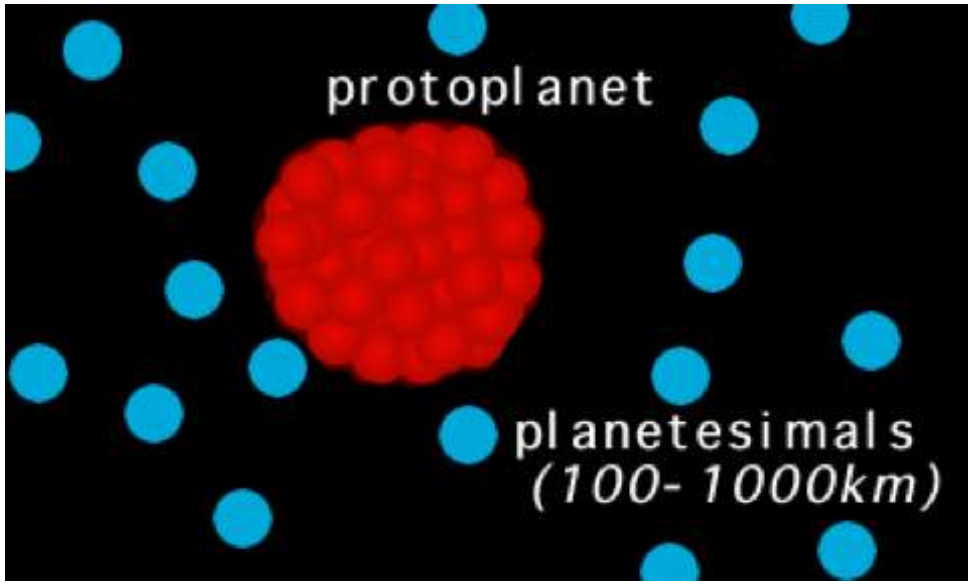
Composite by Emily Lackdawalla
The Planetary Society

how to build a solar system 4 of 7

according to Hal Levison et al.

Stage 4

protoplanets form



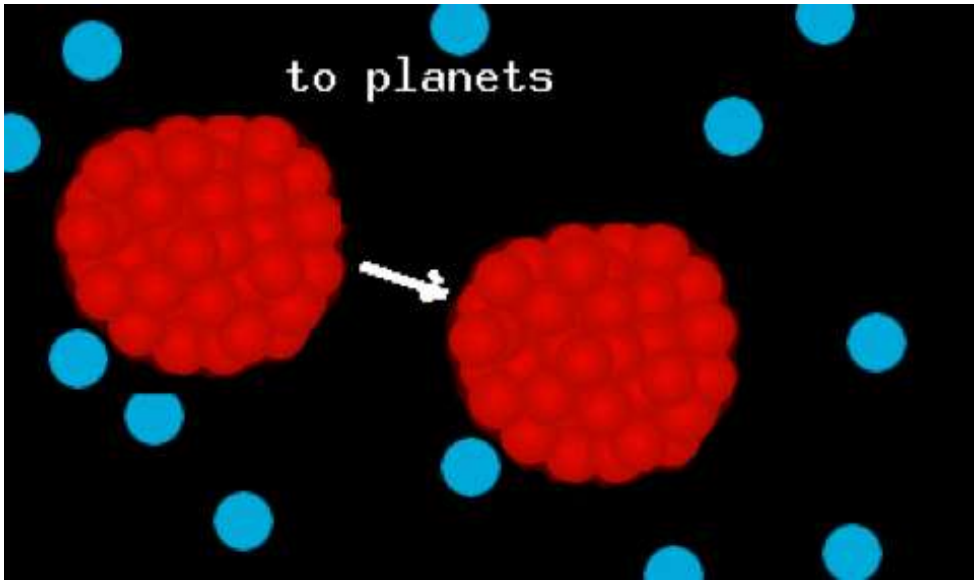
NASA, ESA, JPL, and A. Feild (STScI)

how to build a solar system 5 of 7

according to Hal Levison et al.

Stage 5

planets form



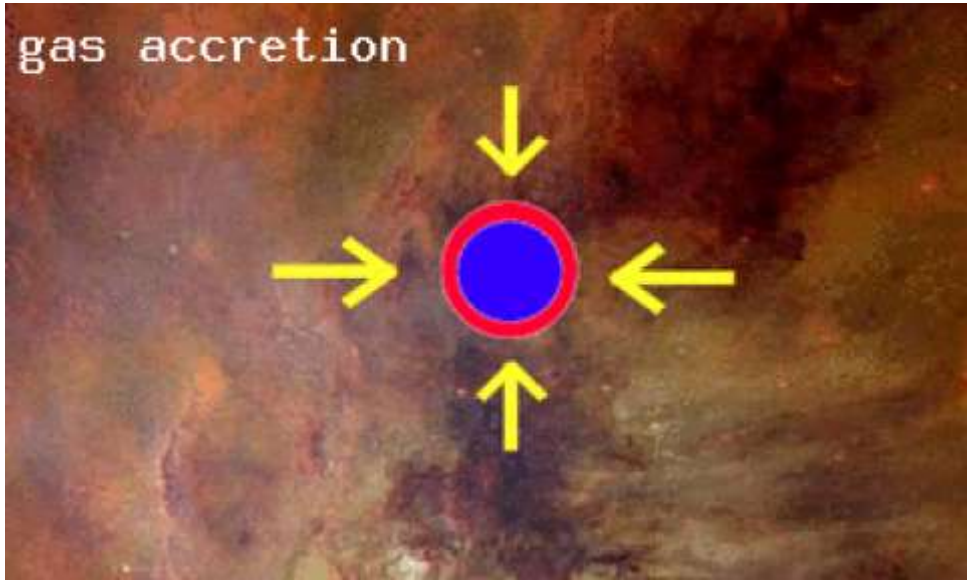
Artist's concept; credit: NASA/JPL-Caltech

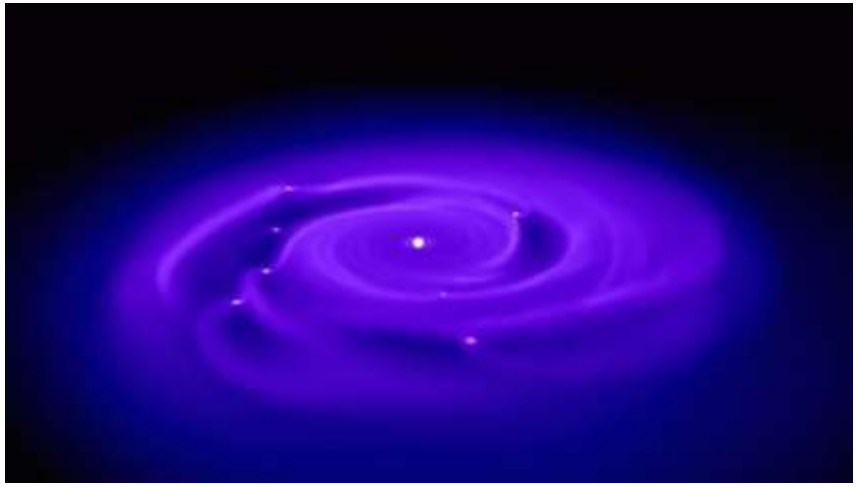
how to build a solar system 6 of 7

according to Hal Levison et al.

Stage 6

gas accretion





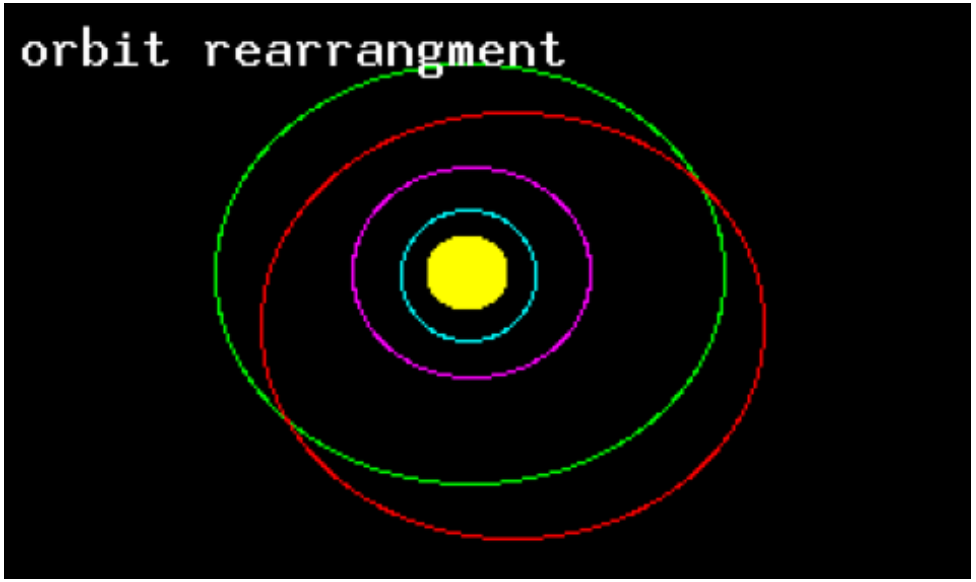
Simulation credit: Thomas Quinn, U. Washington

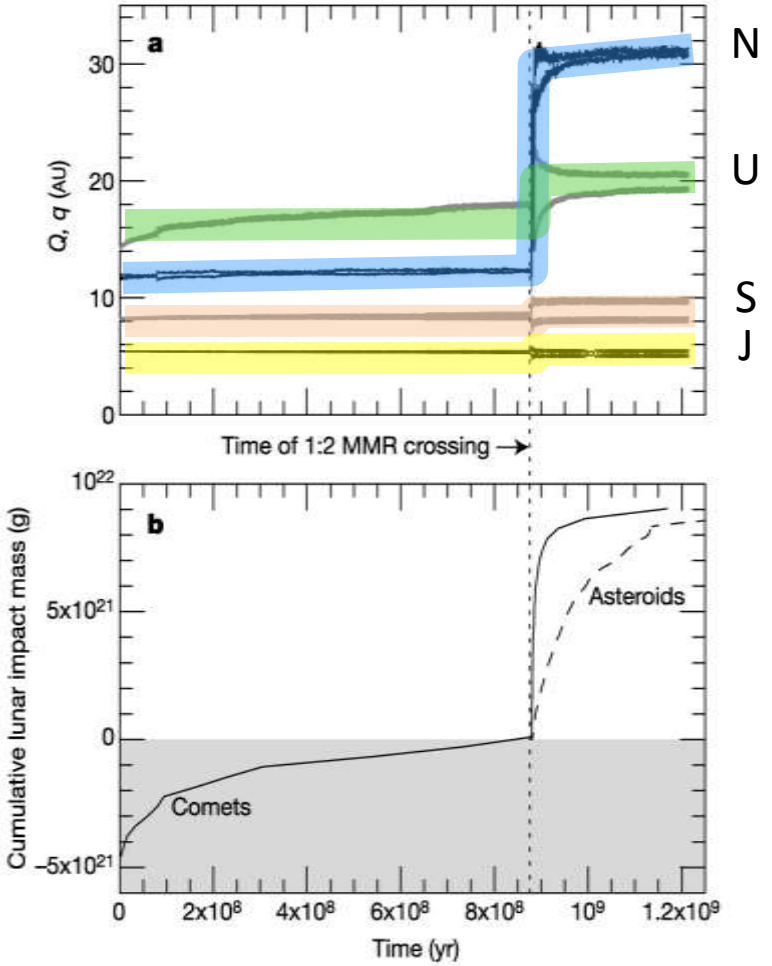
how to build a solar system 7 of 7

according to Hal Levison et al

Stage 7

dynamical





R. Gomes, H. F. Levison, K. Tsiganis and A. Morbidelli 2005. *Nature* **435**, 466-469

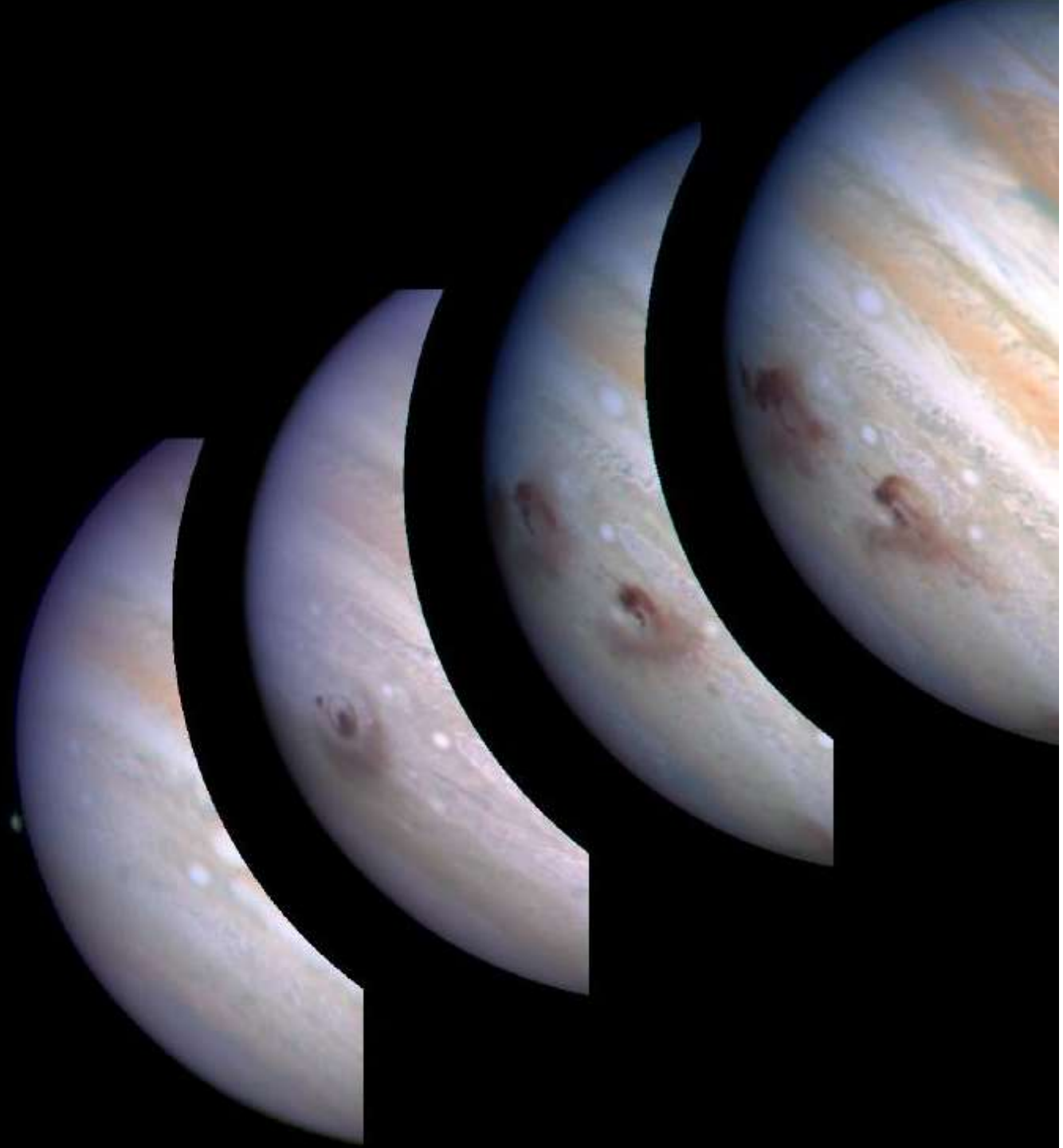
solar system formation is complex and messy

smooshing and smashing!
whooshing and crashing!

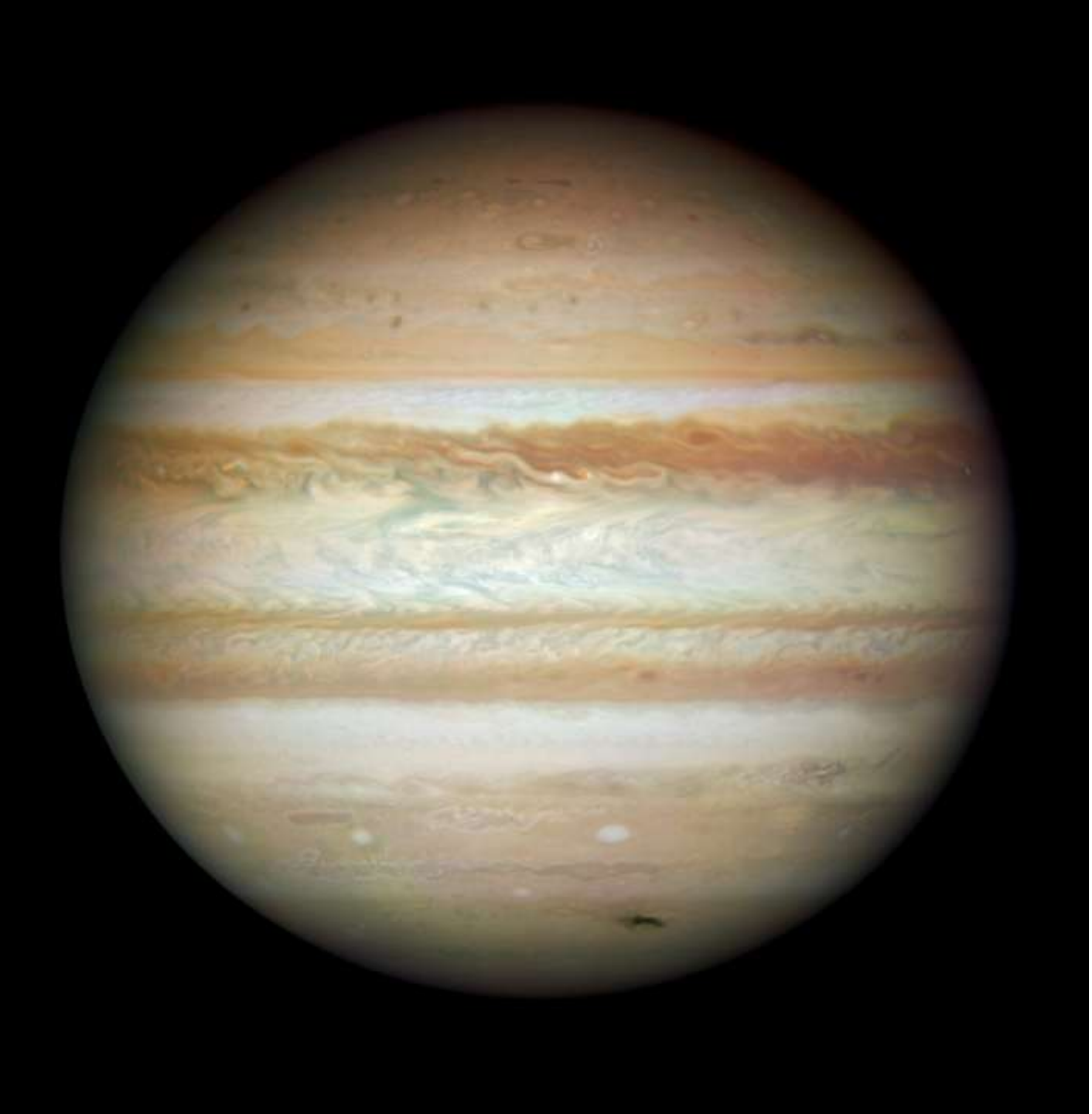
understanding solar system formation very much a work in progress

AND FURTHERMORE…

THE SOLAR SYSTEM ITSELF IS A WORK IN PROGRESS

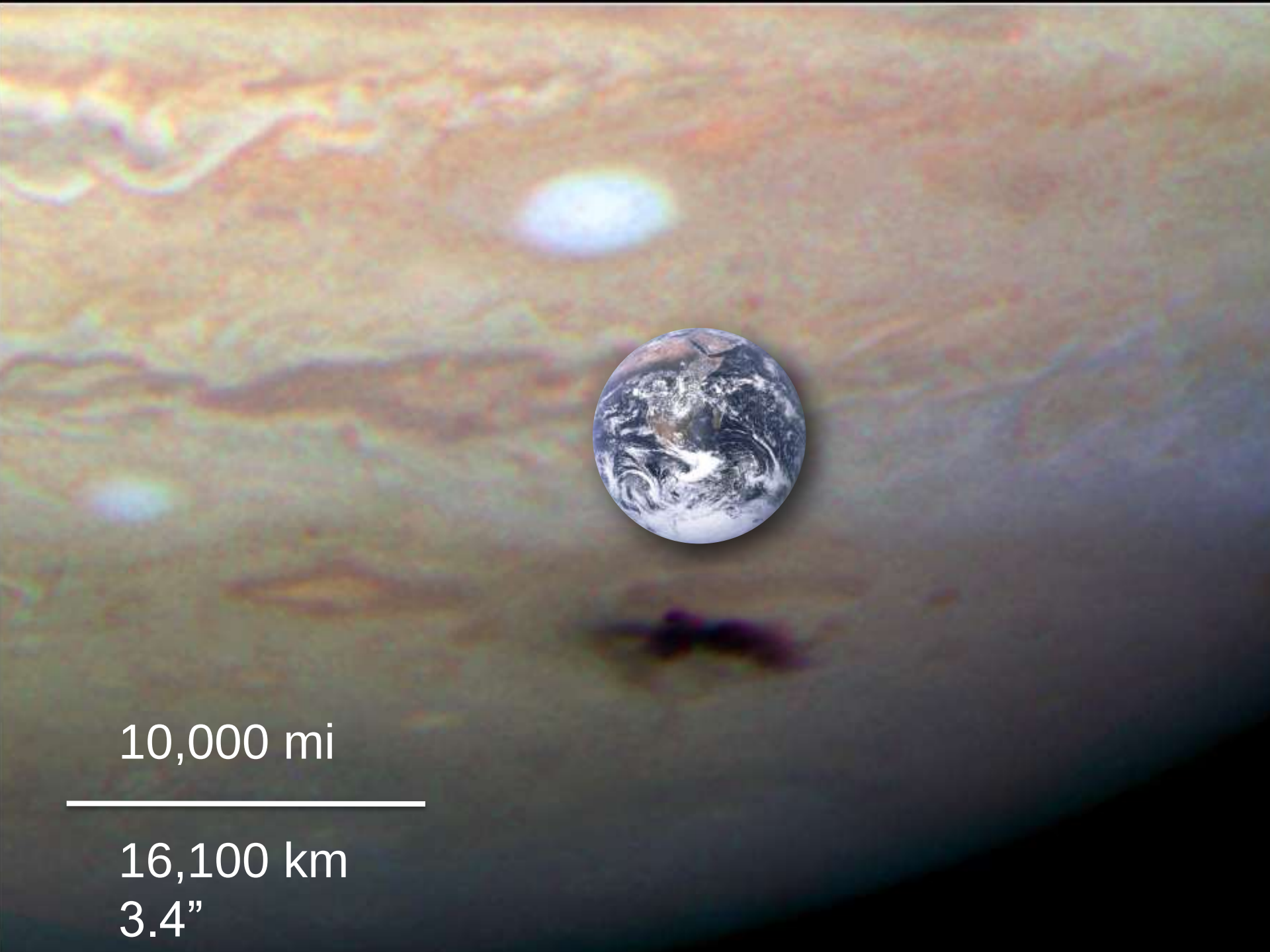


impacts
happen
NOW

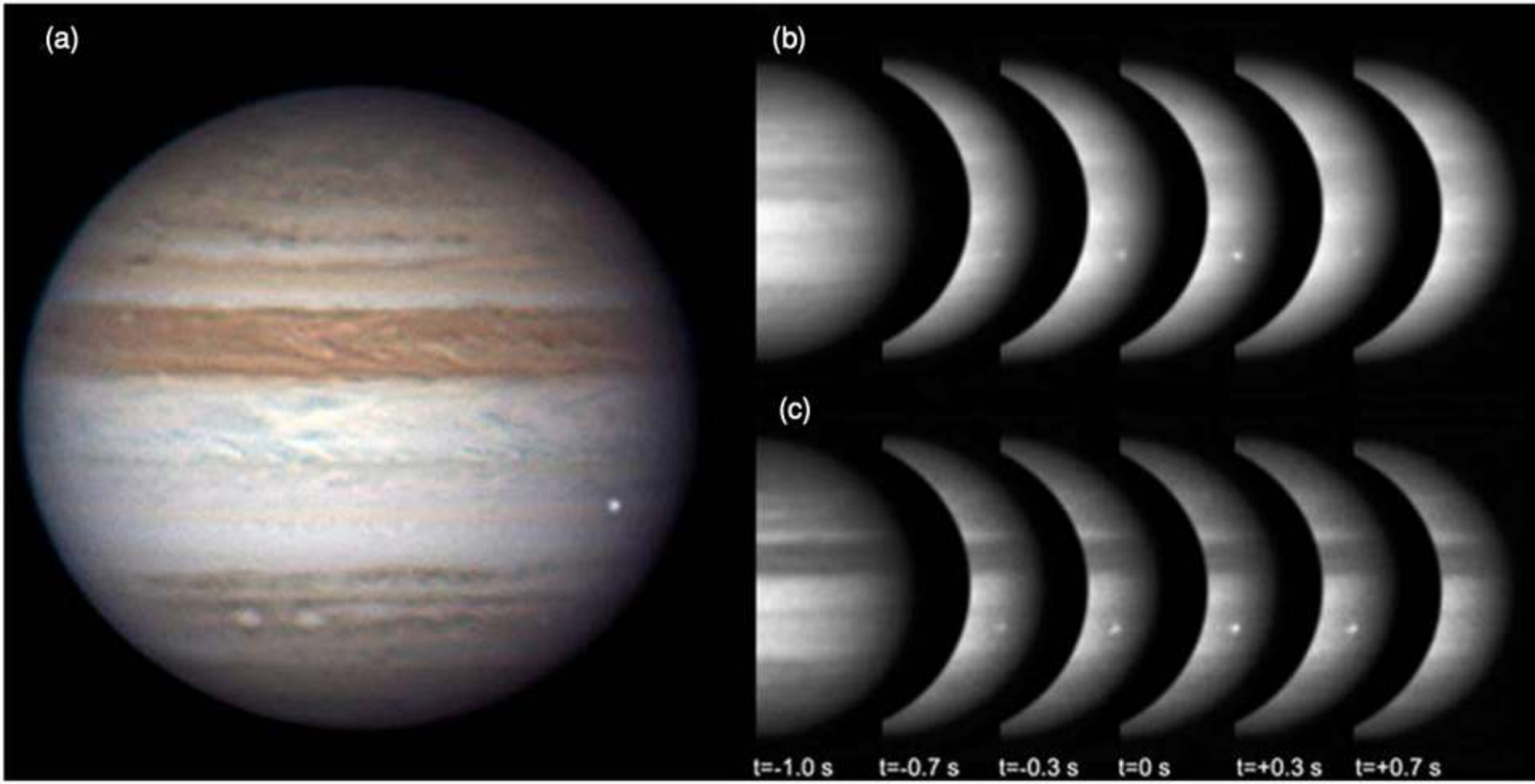


First Hubble science image with WFC3

July 2009

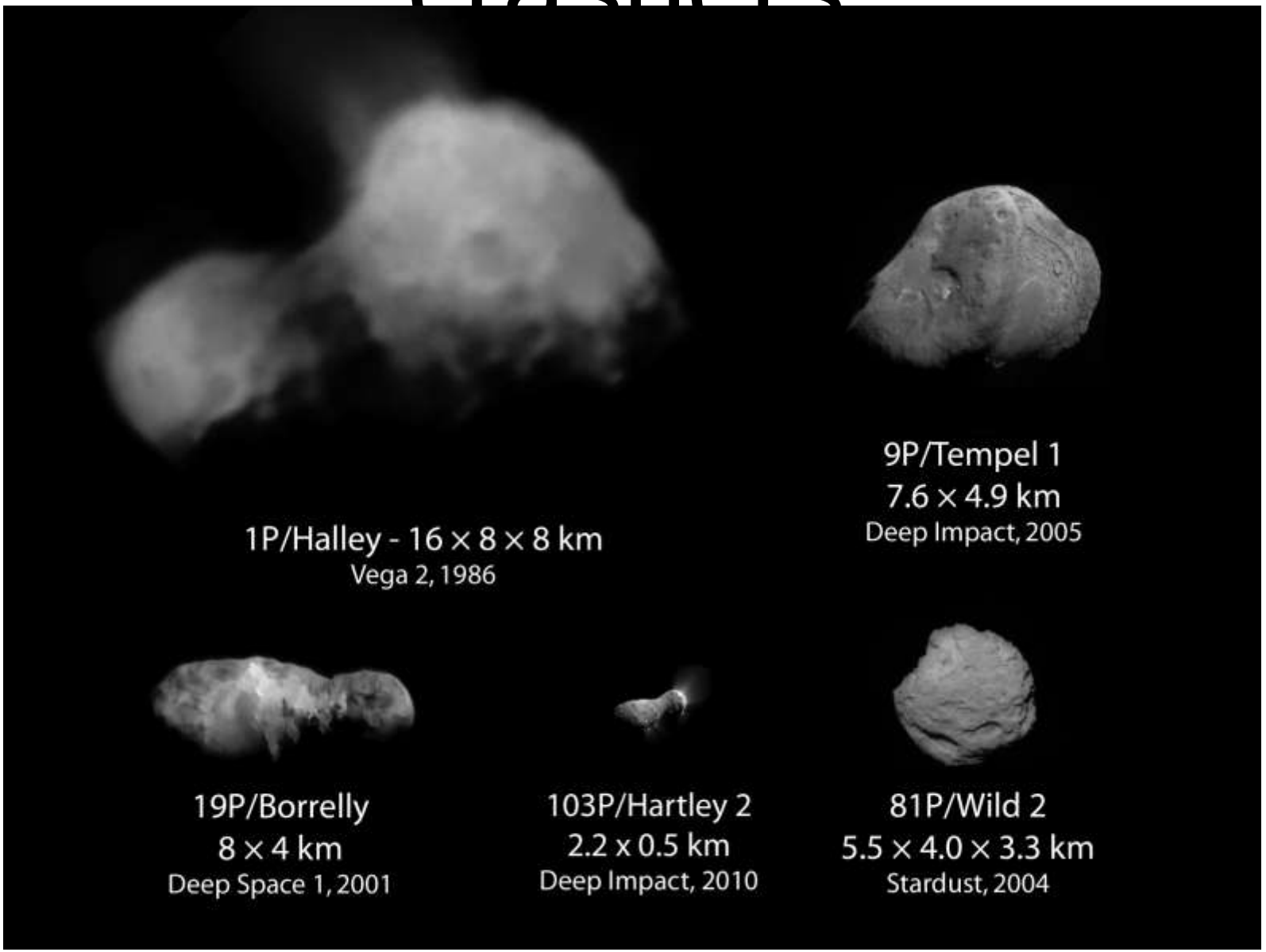

10,000 mi
16,100 km
3.4”

Jupiter smashed AGAIN in June 2010

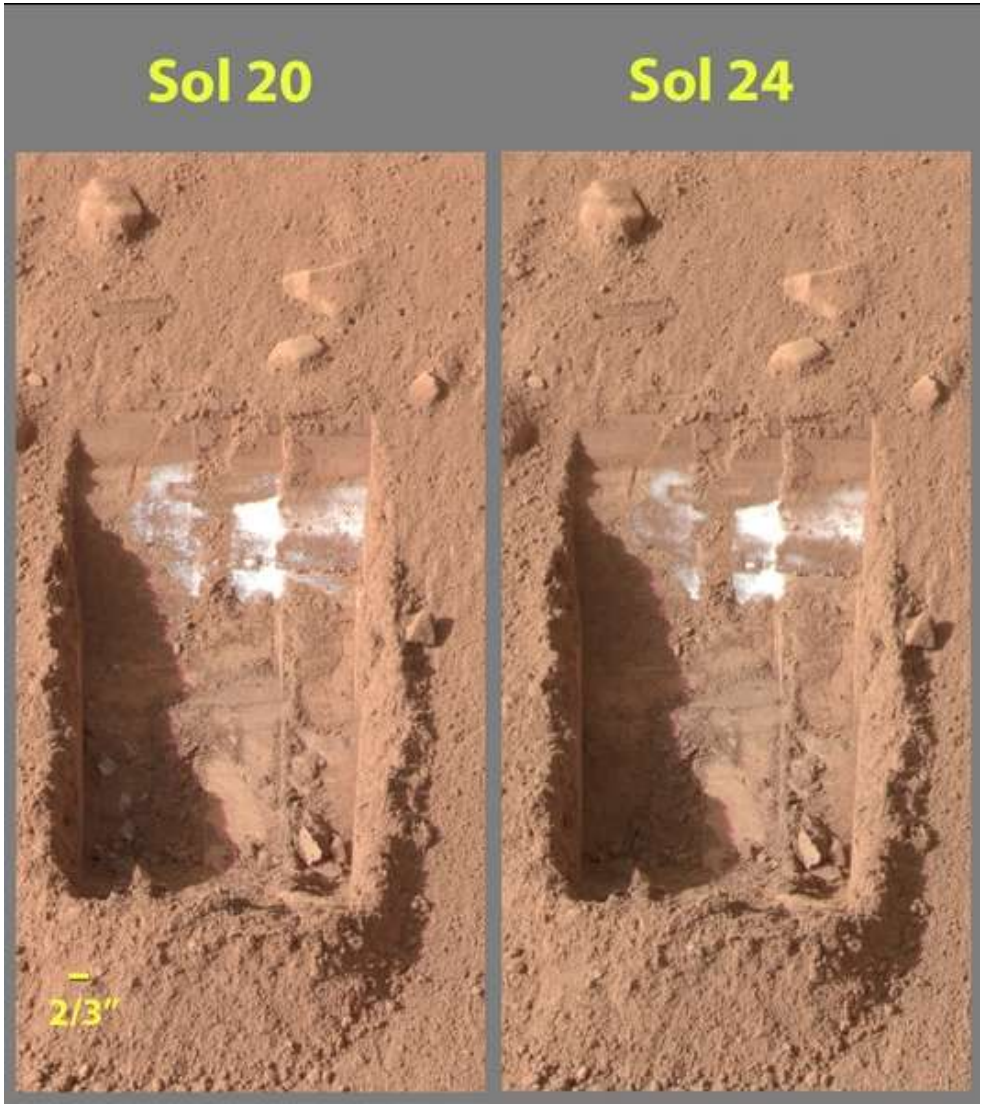


and AGAIN in August 2010

prototype smashers & crashers

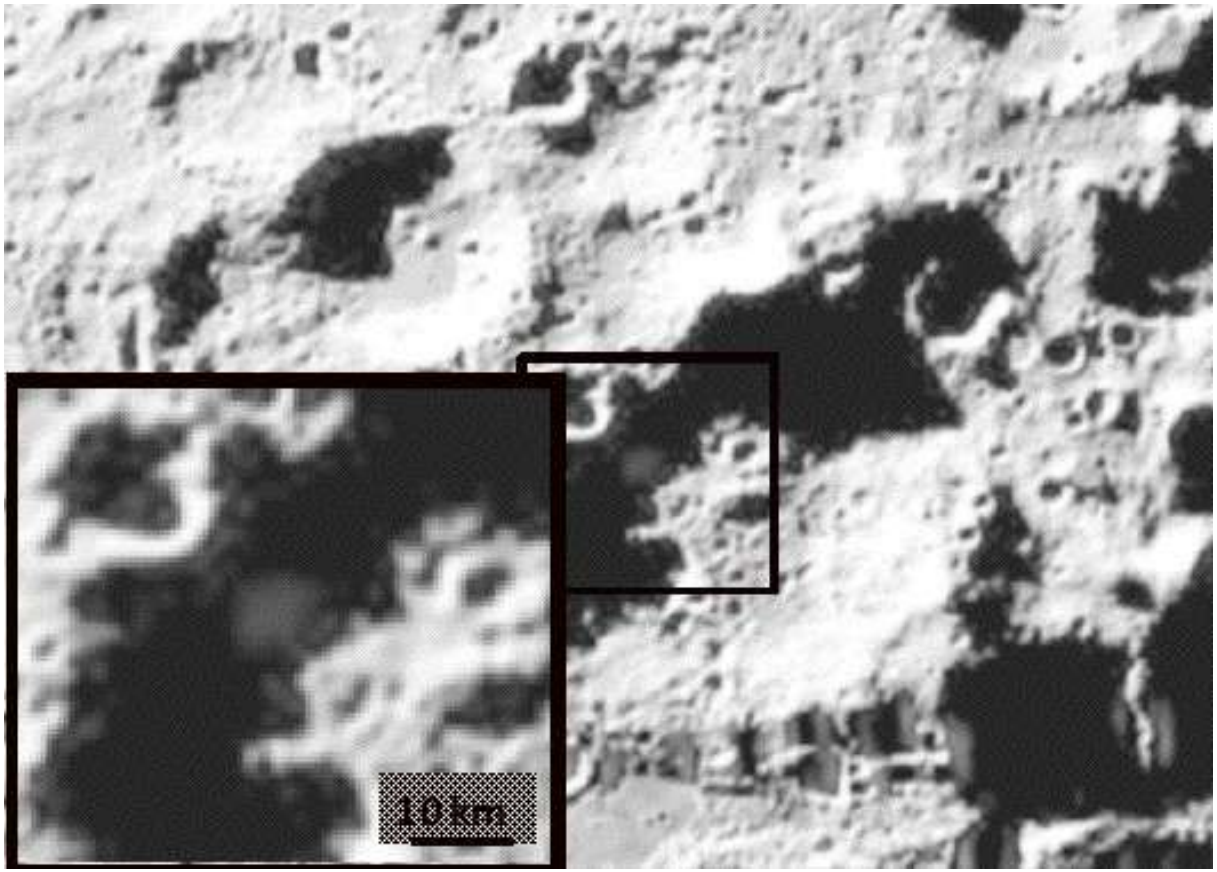


delivering water, everywhere

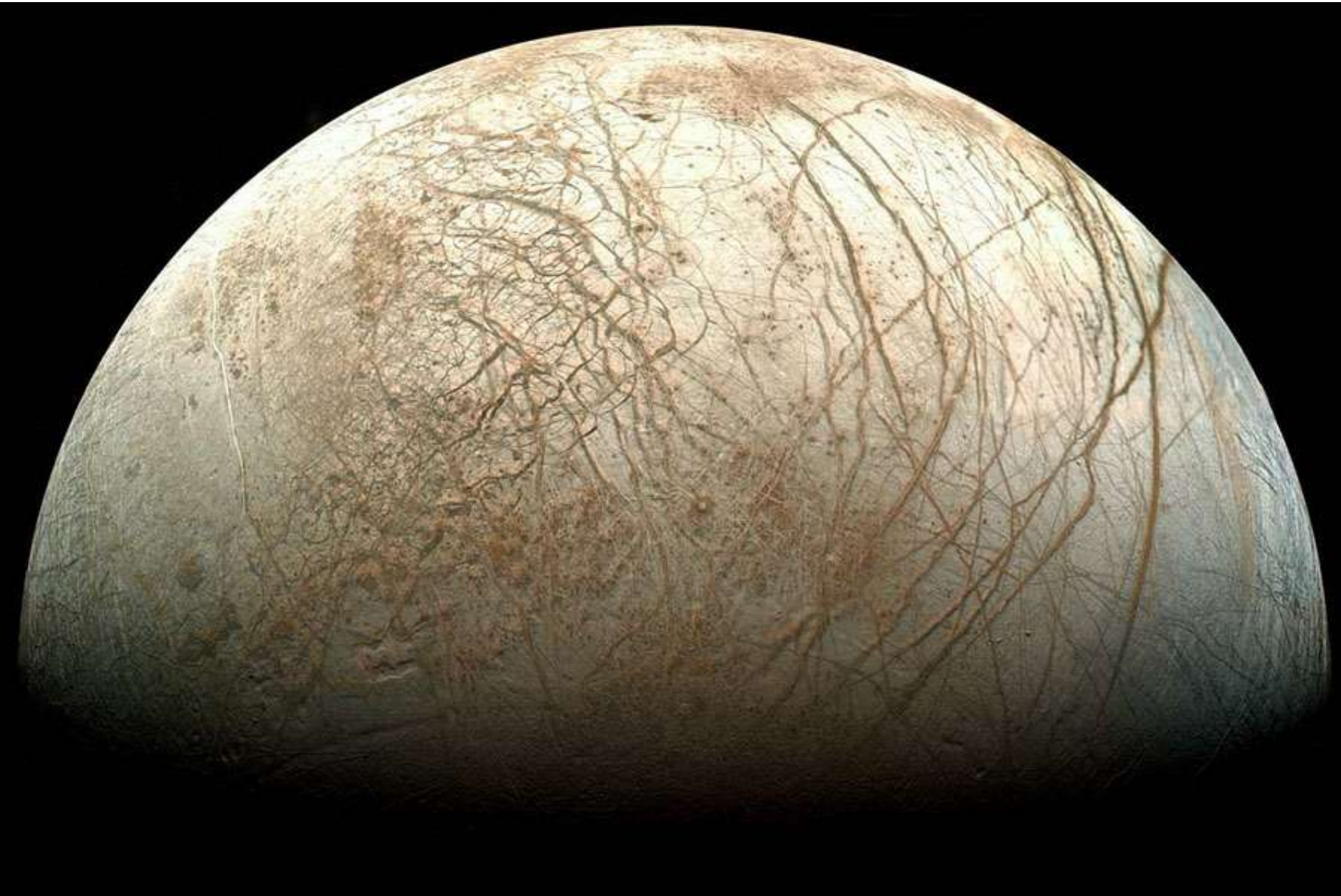


Phoenix Lander on Mars

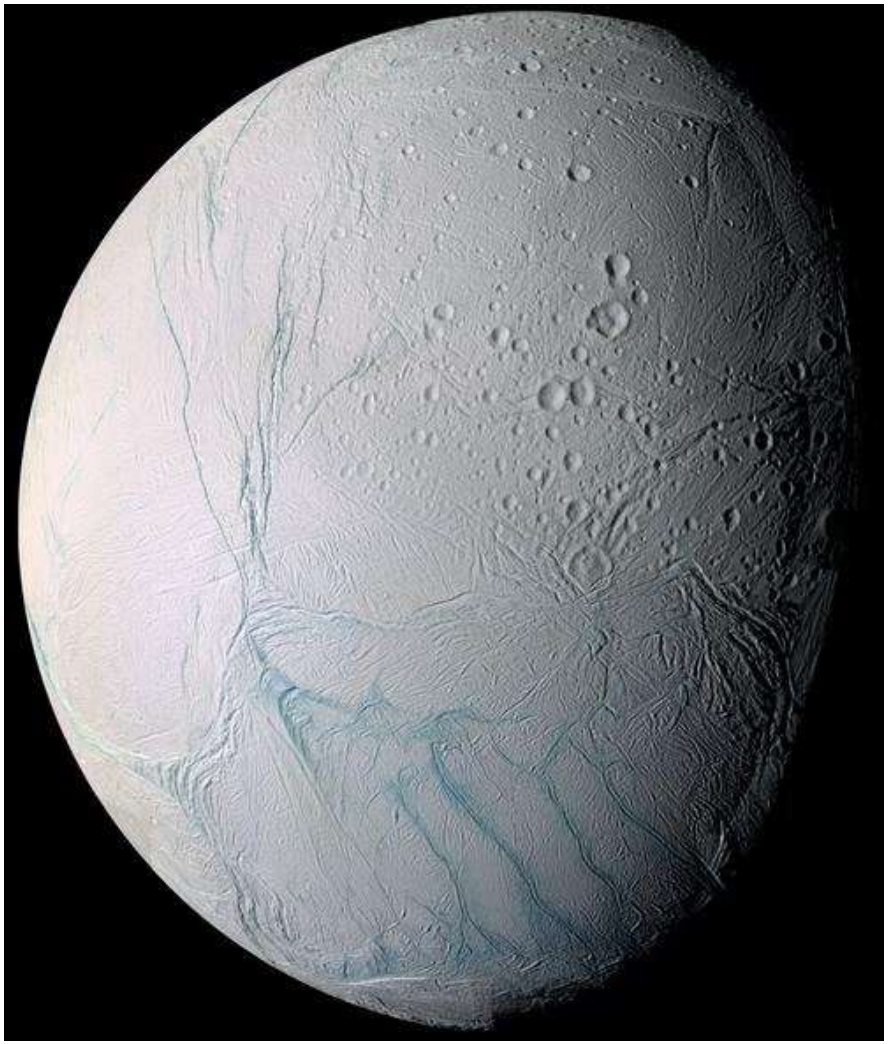
water on the moon



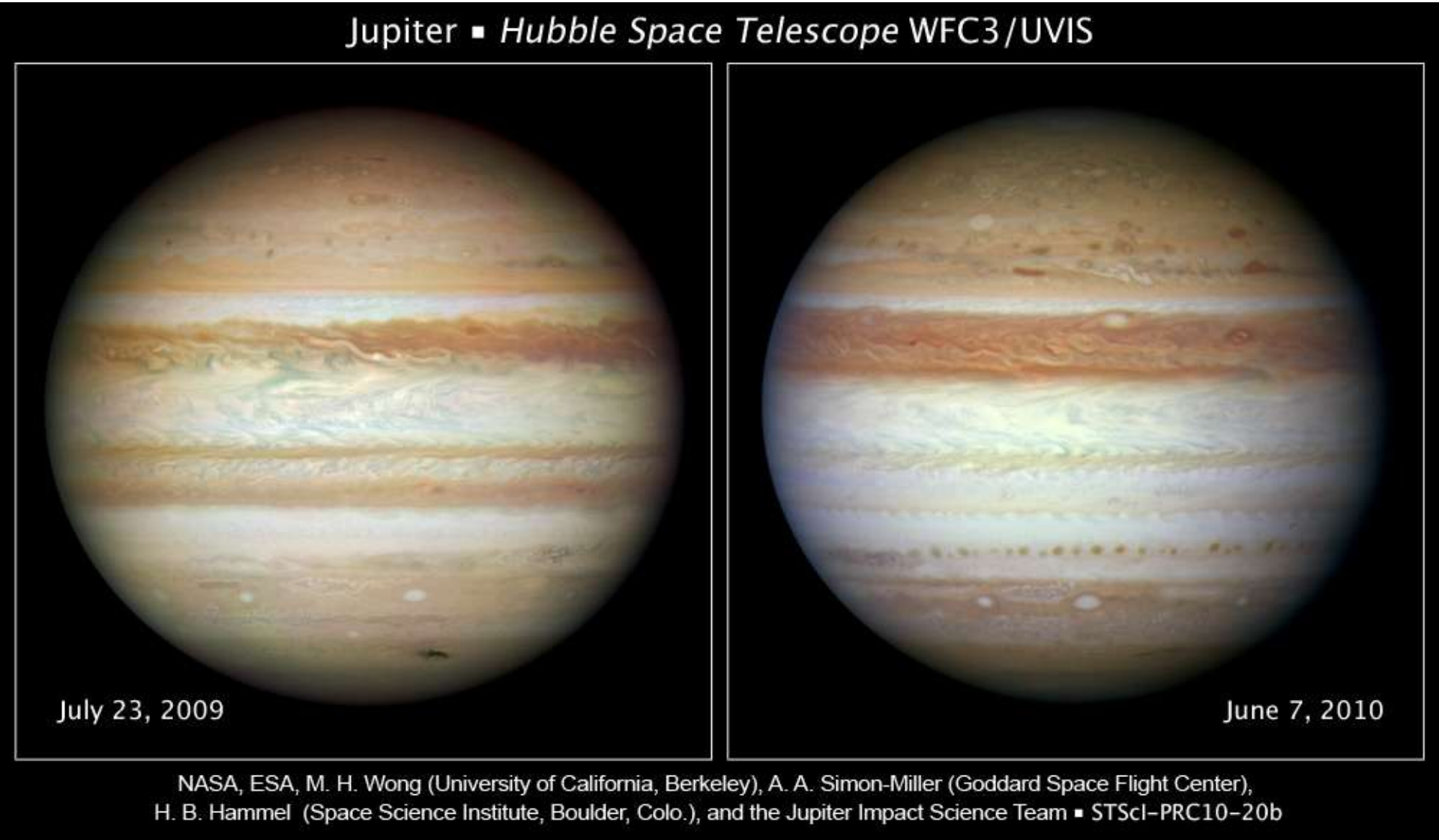
speaking of WATER



we *were* talking about WATER, right?

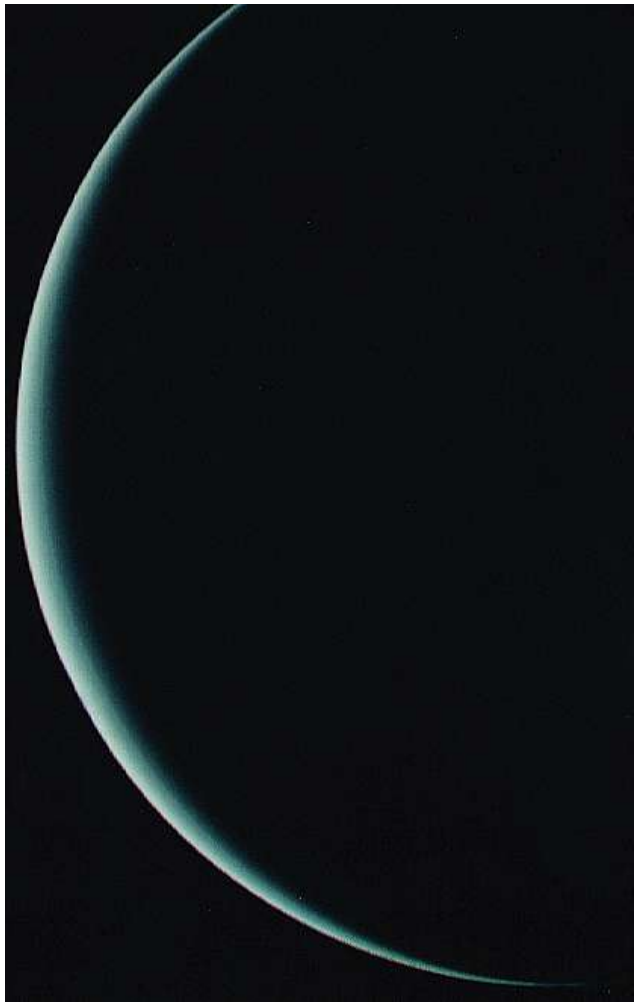


planetary evolution

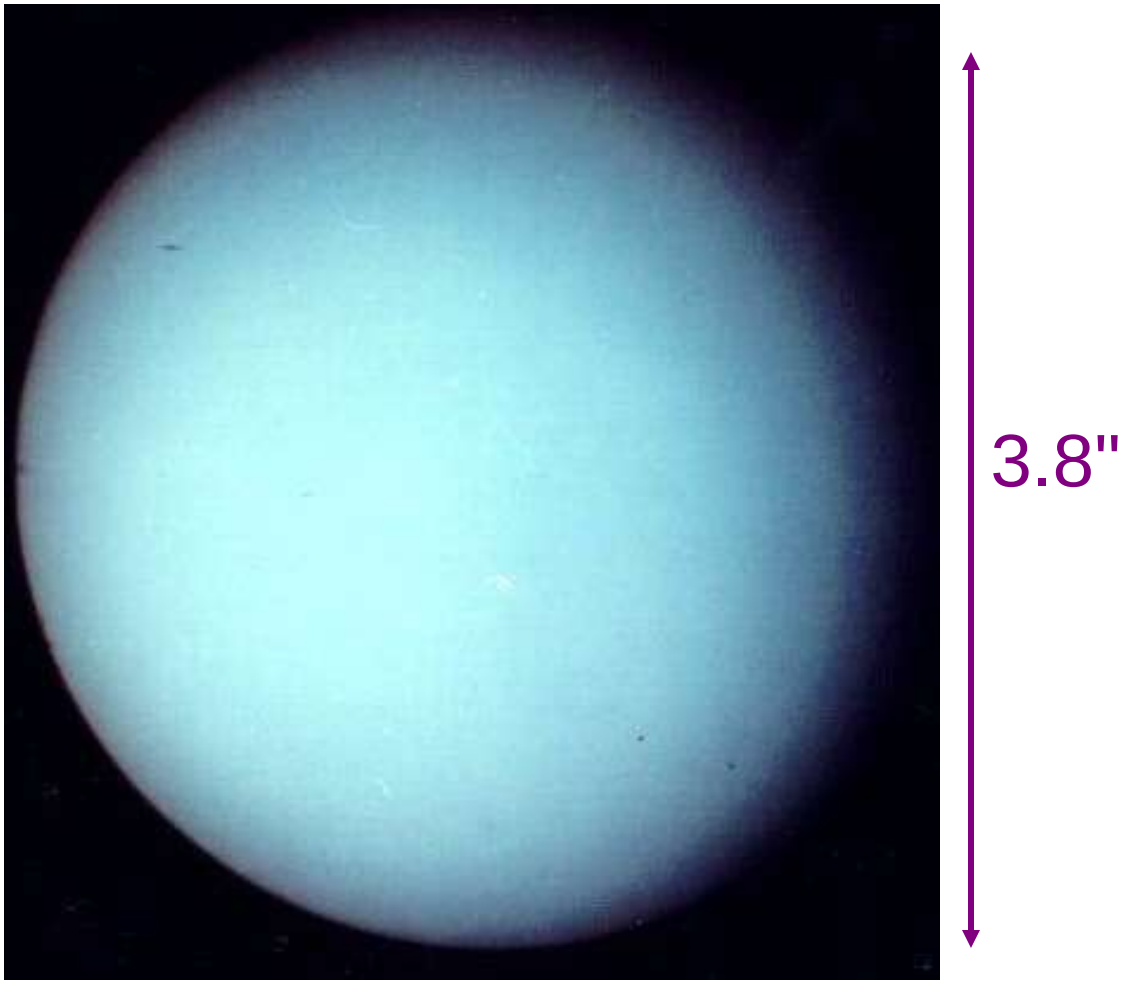


planetary evolution science and social networking

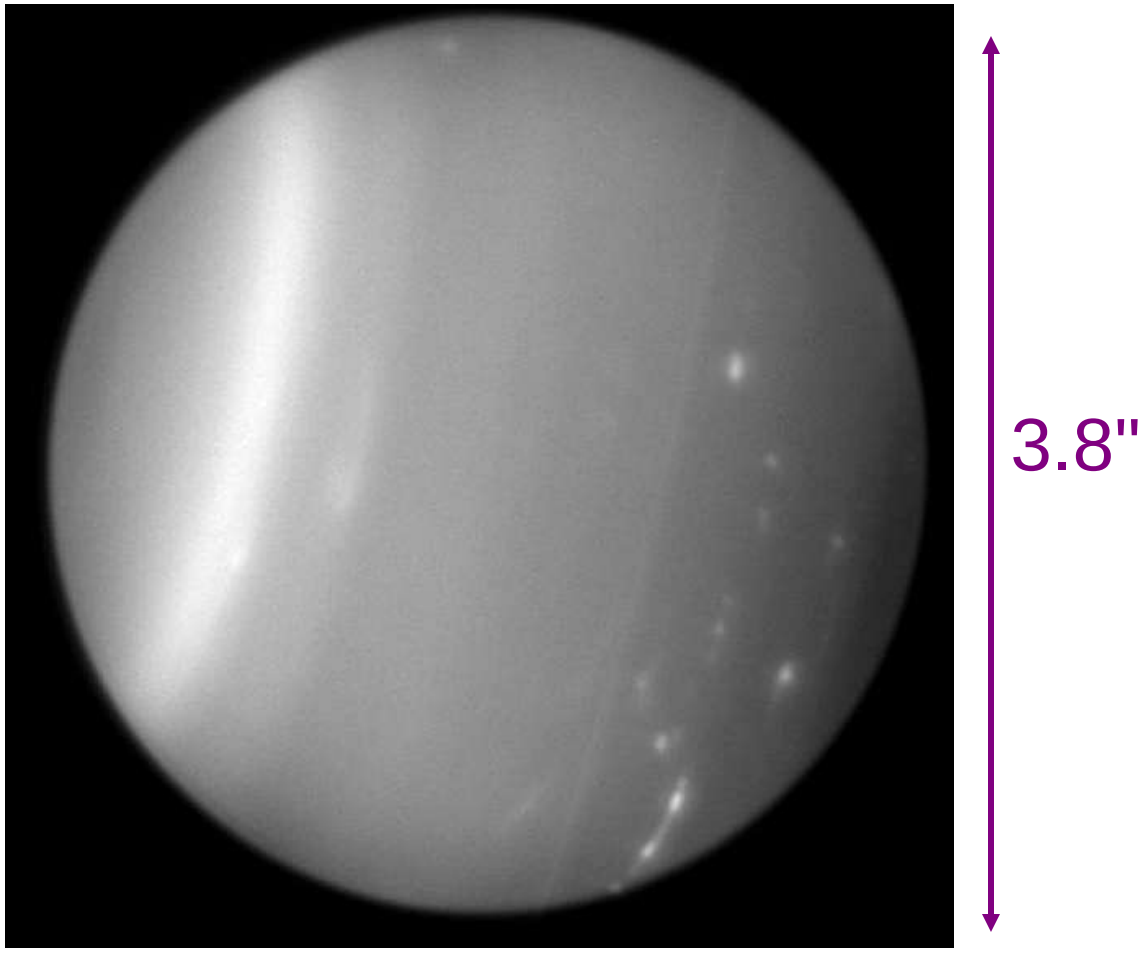
atmospheric change on uranus



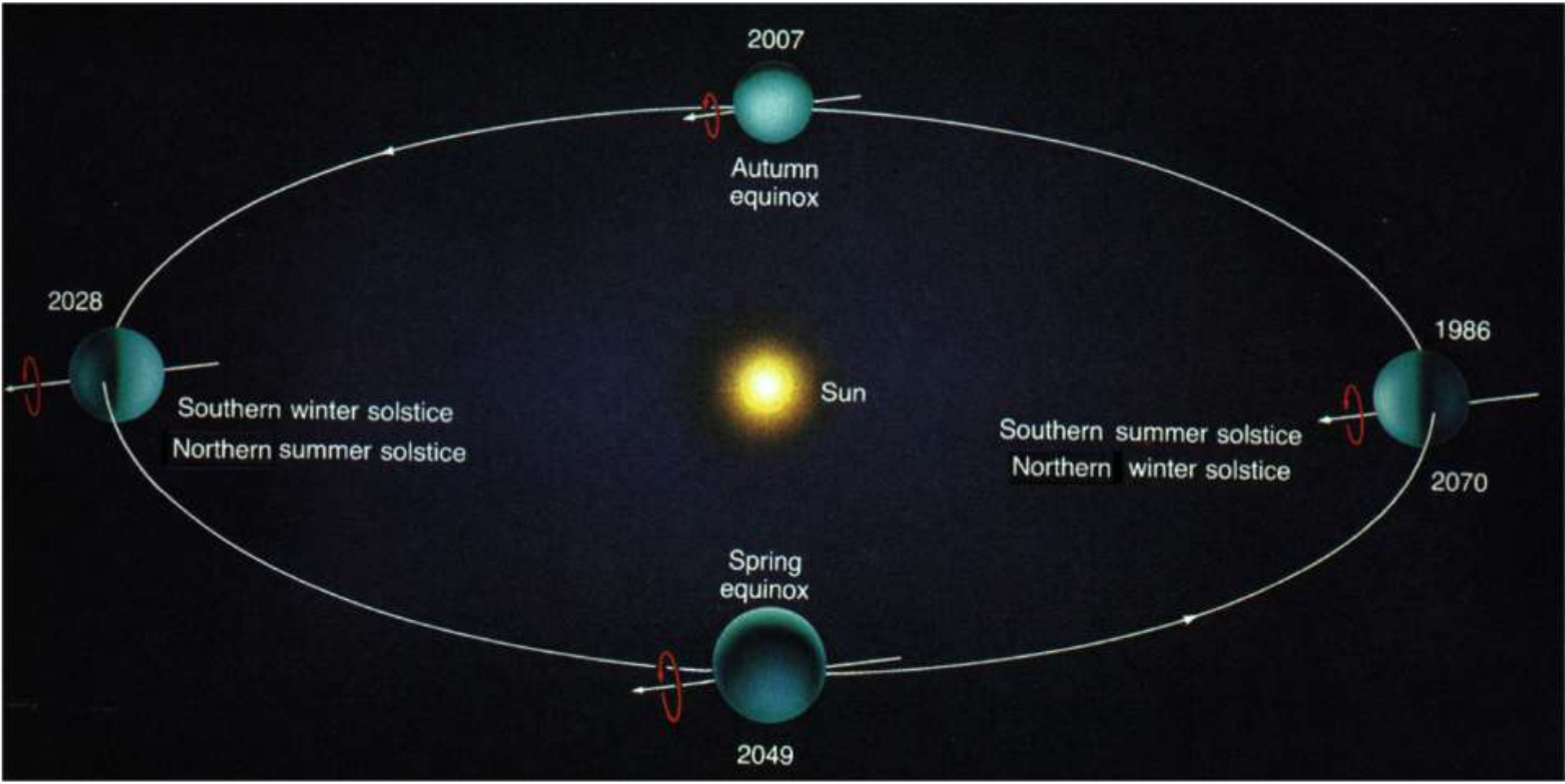
voyager uranus in 1986



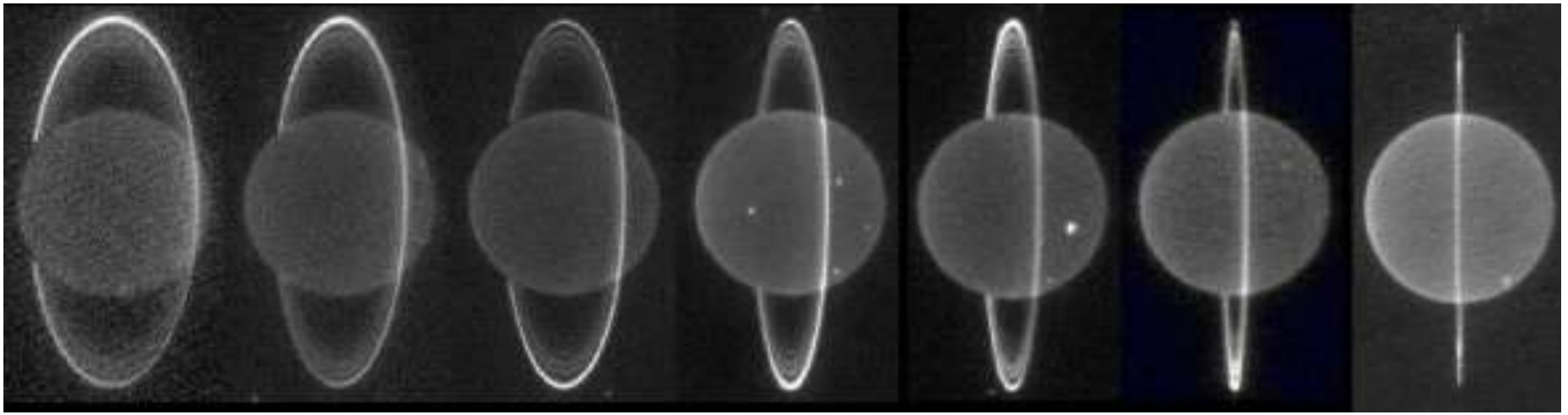
keck uranus in 2004



seasonal change



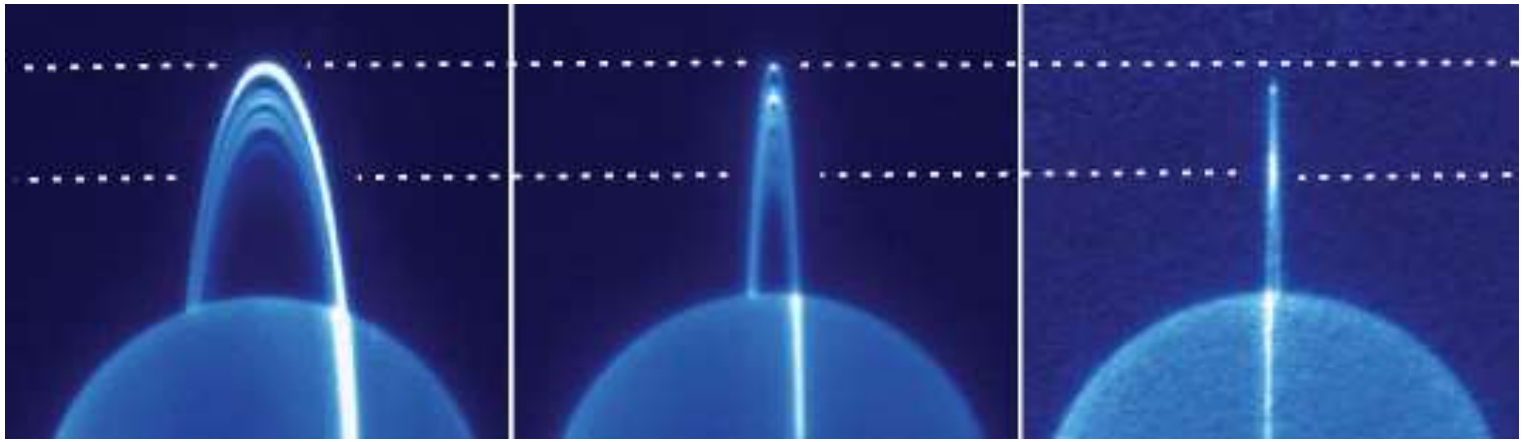
evolving rings



2001 2002 2003 2004 2005 2006 2007

ε (epsilon)

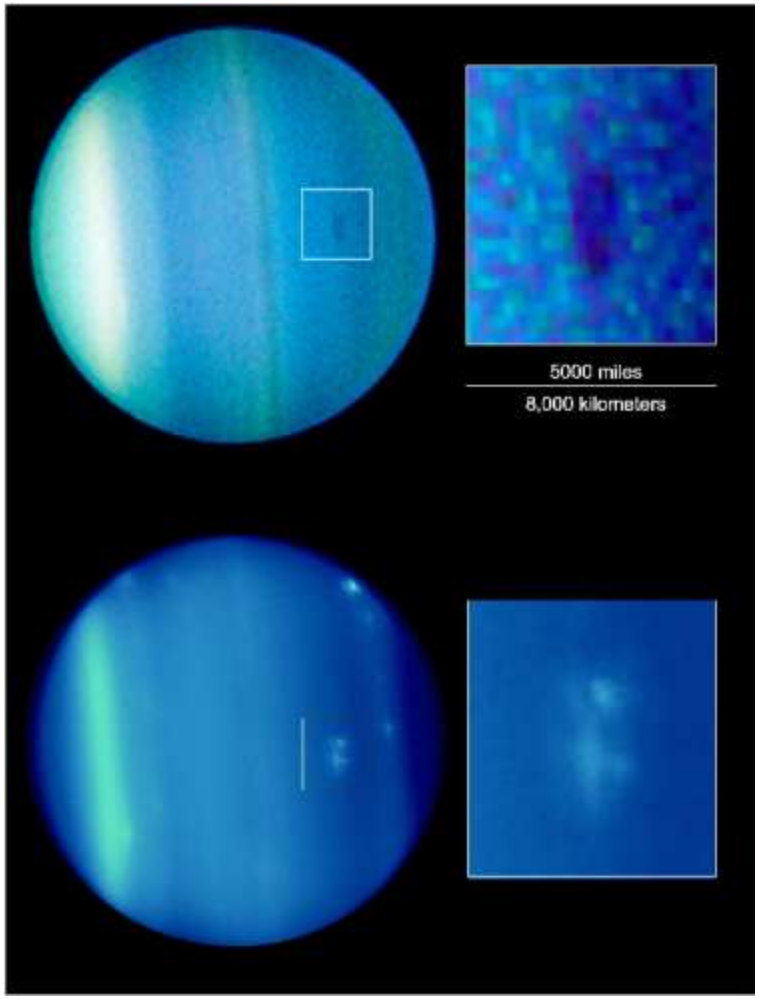
ζ (zeta)



2004 2006 2007

Published in *Science* (23 August 2007), *"The Dark Side of the Rings of Uranus,"* by I. de Pater, H. B. Hammel, M. Showalter, and M. van Dam

uranus turns “neptunish”



there ain’t no such thing as a static planet...

immediate future for solar system

The New York Times

Tuesday, November 9, 2010

nytimes.com/pages/science

me

Immediate future for solar system

Voices: What's Next in Science

BY CARL ZIMMER

Scientists can't say what they'll be discovering 10 years from now. But they do pay careful attention to the direction in which their fields are moving, and they have some strong hunches about where they are headed in the year ahead. Here are prognostications for science in 2011 from 10 leading figures in 10 widely scattered disciplines, from genomics to mathematics to earth science. Regardless of whether they prove true next year, they offer a glimpse into the kinds of possibilities that get scientists excited. Post a Comment

Heidi B. Hammel
Senior research scientist, Space Science Institute

« Previous 1 of 11

Christopher Capozziello for The New York Times

Space Science

"The Dawn spacecraft will get to orbit around a very large asteroid called Vesta in July. It's going to be fascinating to see what it looks like up close. We're going to be able to start answering very broad questions about the history of asteroids."

Heidi B. Hammel 1:28

Asteroids first formed at the birth of the solar system 4.6 billion years ago, developing into small proto-planets. The biggest asteroids, like the 330-mile-wide Vesta, might have even grown into full-blown planets if not for the pull of Jupiter's powerful gravitational field. Since then, collisions have blasted asteroids apart into smaller bodies. Astronomers want to know just how planetlike asteroids like Vesta became. It's possible, for example, that Vesta developed a heavy core and might even have a magnetic field. Once the Dawn takes a close look at Vesta, it will move on to another giant asteroid, Ceres, which has water-bearing minerals and perhaps even a weak atmosphere. By comparing the two asteroids, astronomers hope to learn about early planet formation.

Upcoming Planetary Science Missions

2010

Nov 04 - EPOXI encounters Comet Hartley 2
Nov 19 - Launch of O/OREOS
Dec 07 - Venus Climate Orbiter (JAXA) arrives at Venus

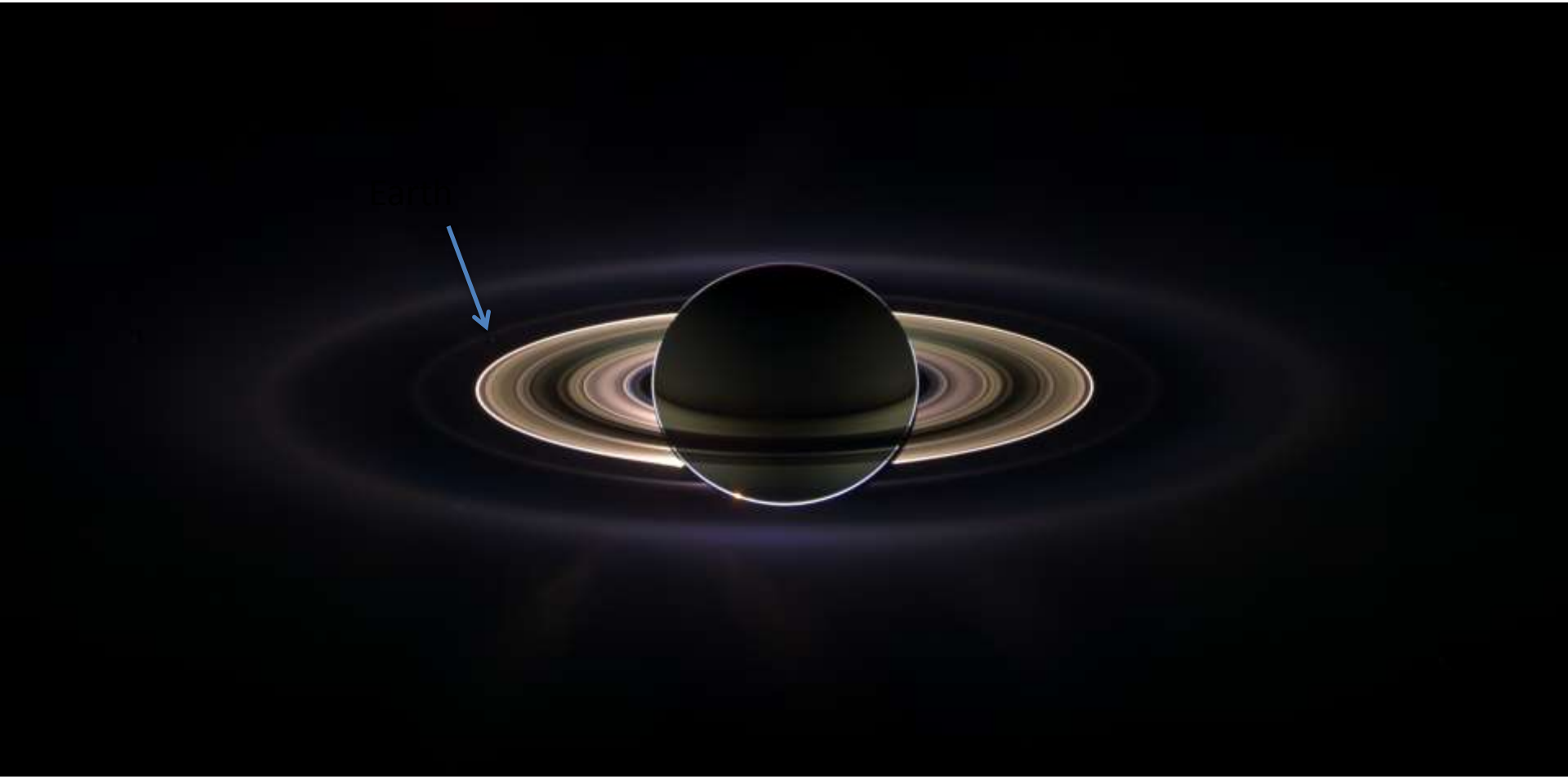
2011

Feb 14 - Stardust NExT encounters comet Tempel 1
Mar 07 - Planetary Decadal Survey released
Mar 18 - MESSENGER orbit insertion at Mercury
July - Dawn reaches asteroid Vesta
Aug 05 - Juno launch to Jupiter
Sep 08 -GRAIL launch to the Moon
Nov 25 -MSL launch to Mars

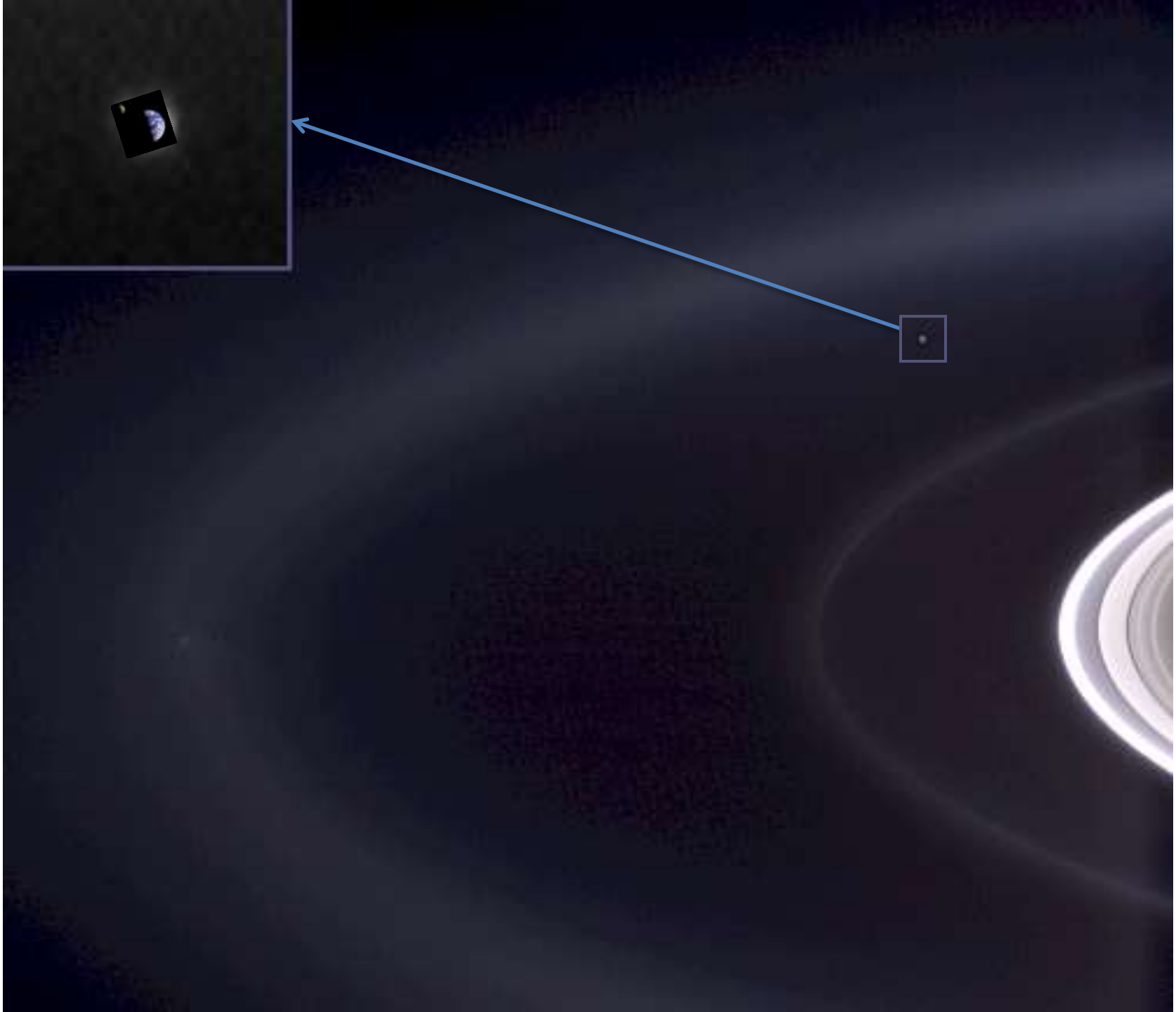
2012

Mid 2012 - Mars Opportunity Rover at Endeavour Crater!
Mid 2012 - Dawn leaves Vesta for its journey to Ceres
August - MSL lands on Mars


far future?
solarsystem.nasa.gov



Saturn in backlit beauty




Earth, as seen by Voyager
from 4 billion miles away
We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.
- T. S. Eliot , Little Gidding, No. 4 of 'Four Quartets'