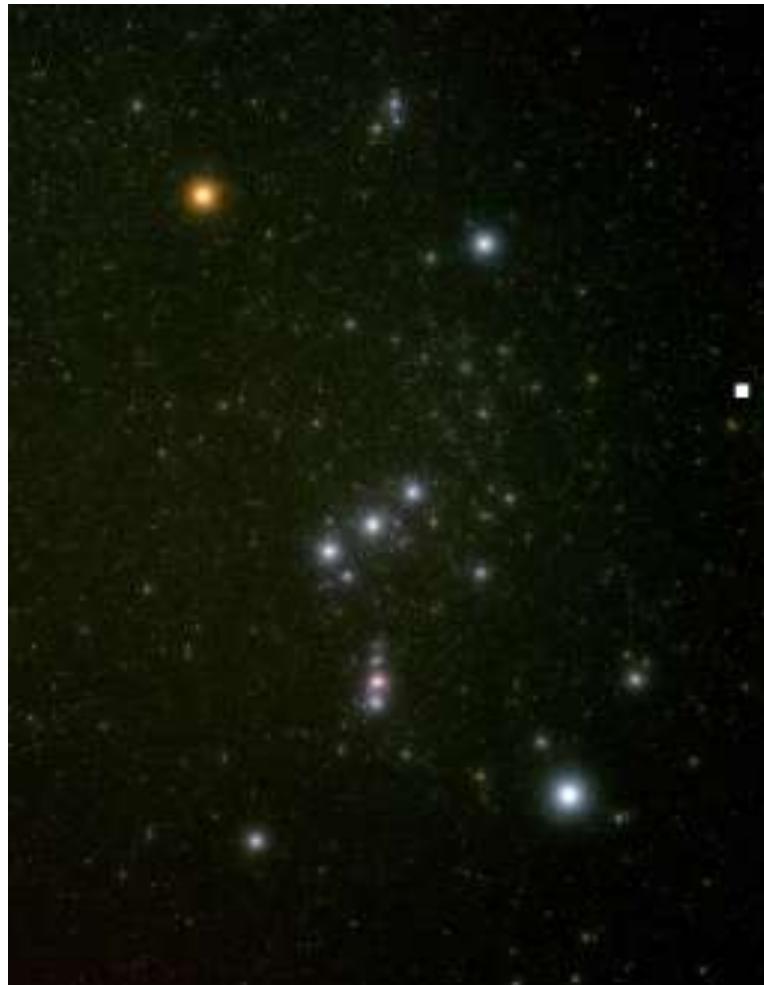


Understanding the Solar System

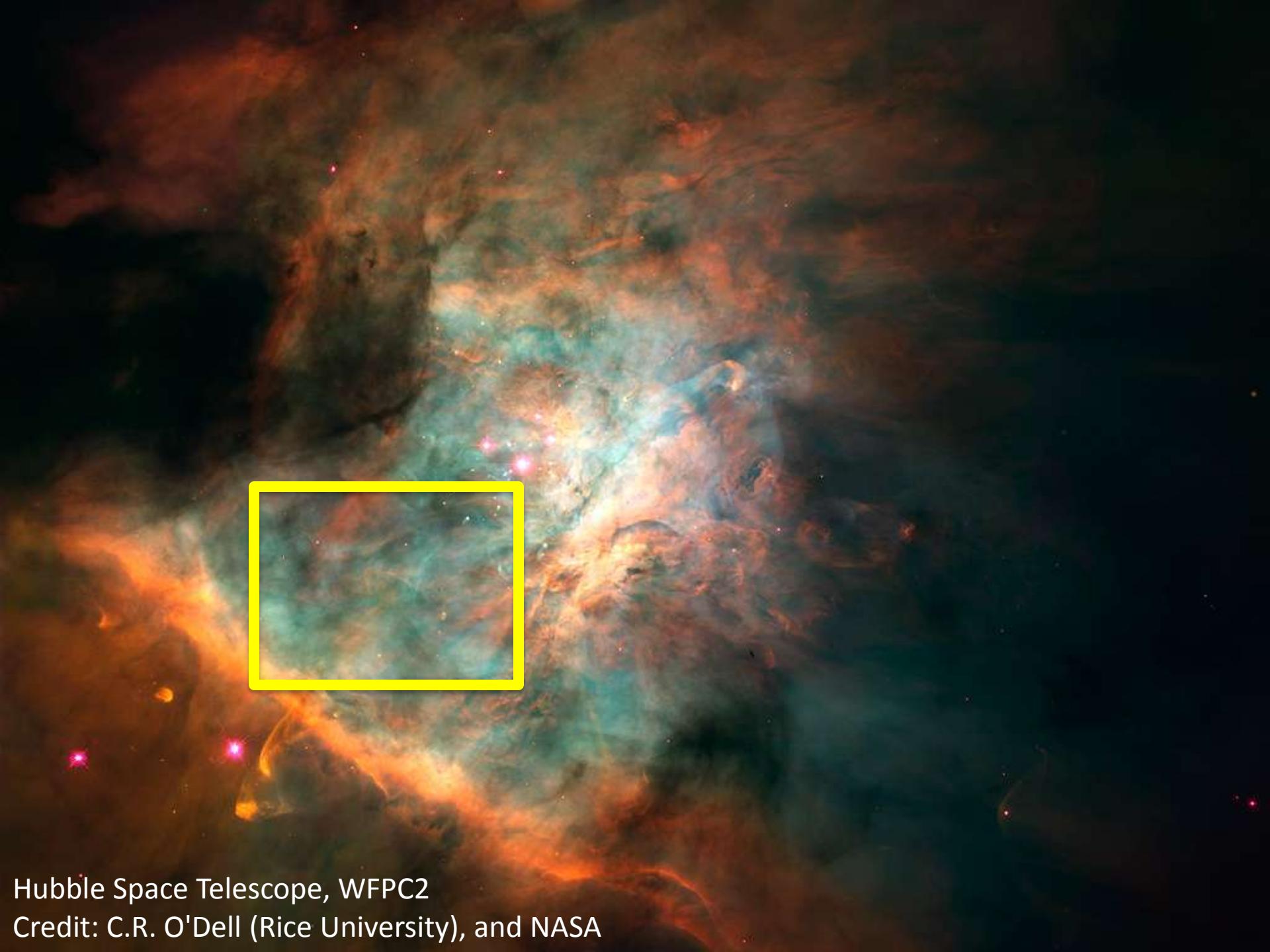
How did it begin? How is it evolving?

Heidi B. Hammel
Space Science Institute
Boulder, CO

hunting for answers



Constellation of Orion the Hunter, by John Gavreau

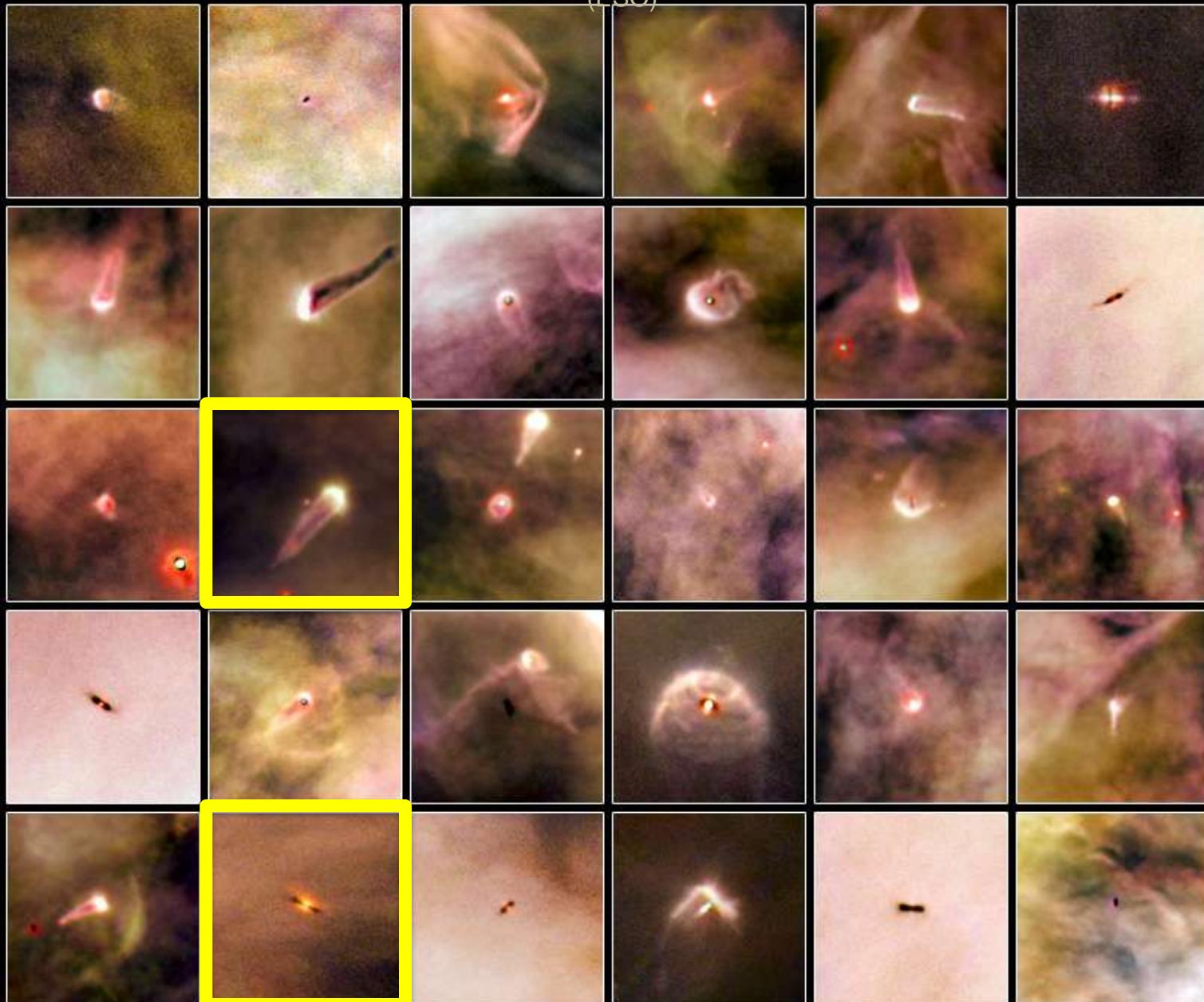


Hubble Space Telescope, WFPC2

Credit: C.R. O'Dell (Rice University), and NASA



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



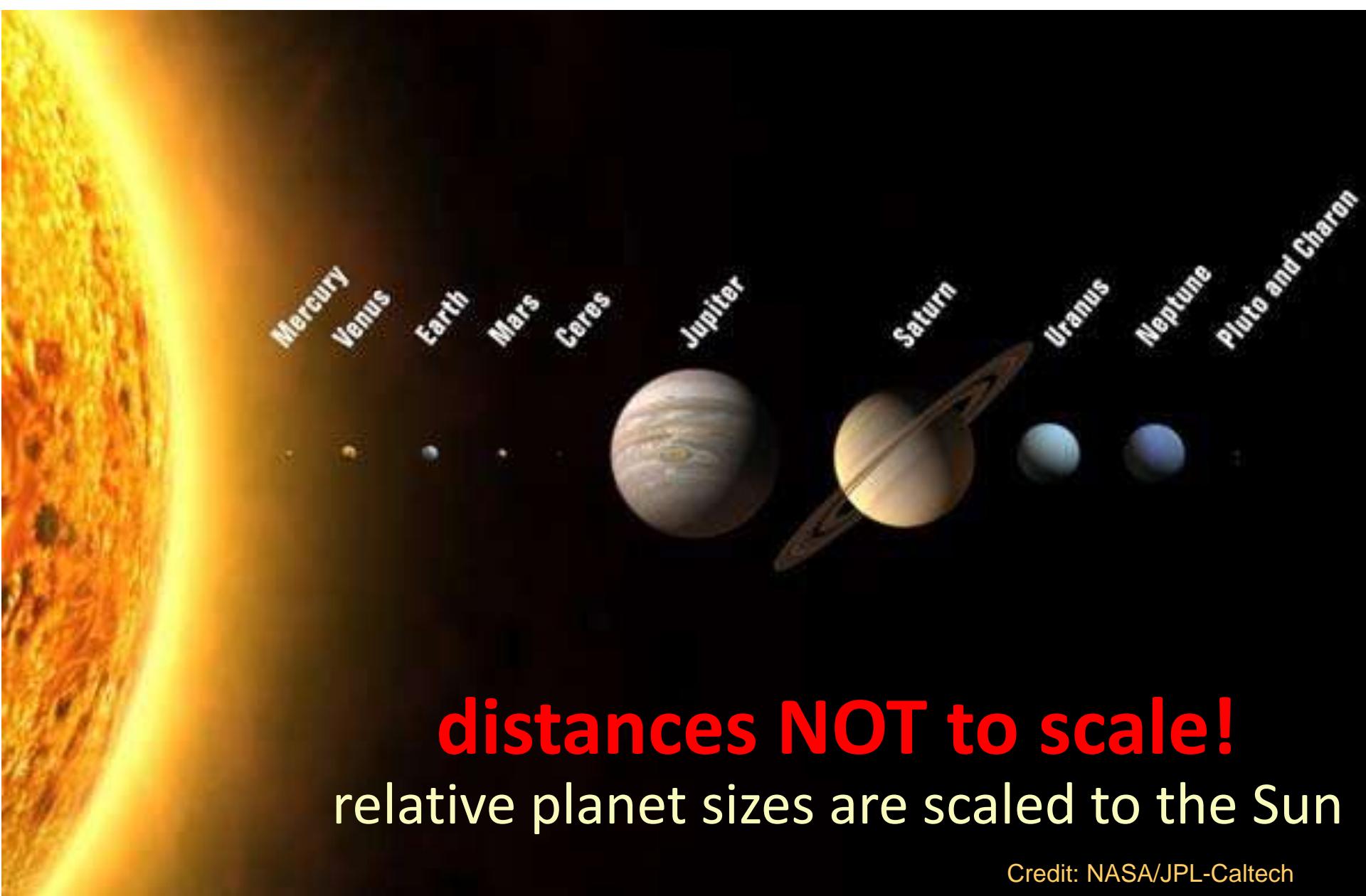
Orion's **proto-planetary disks (proplyds)**

how do you get from this...

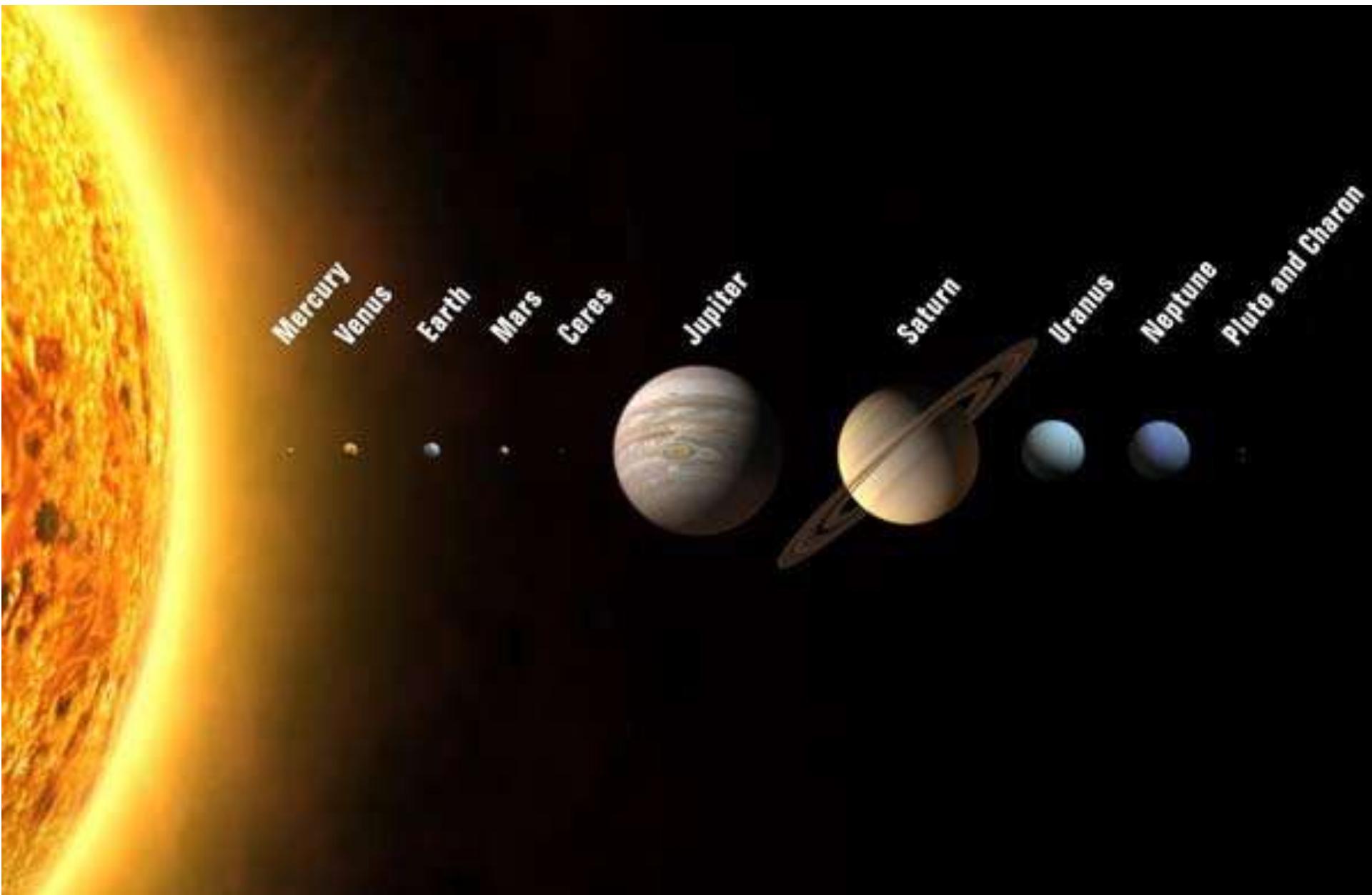


Proplyd in Orion
Hubble Space Telescope ACS
Credit: NASA/ESA and L. Ricci (ESO)

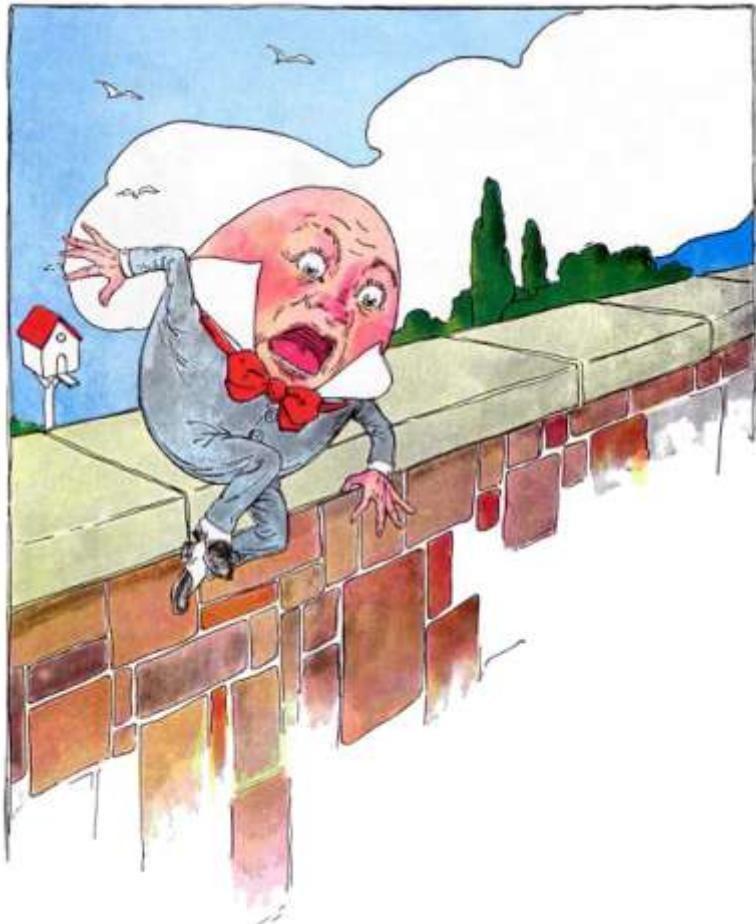
... to this?



the story in 1988



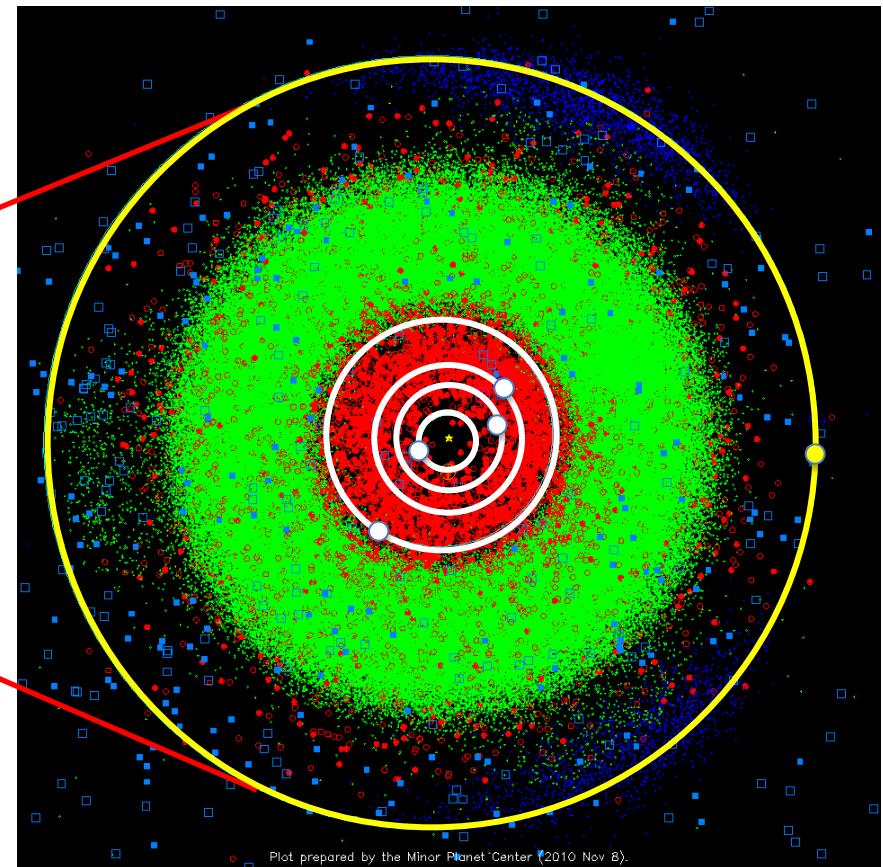
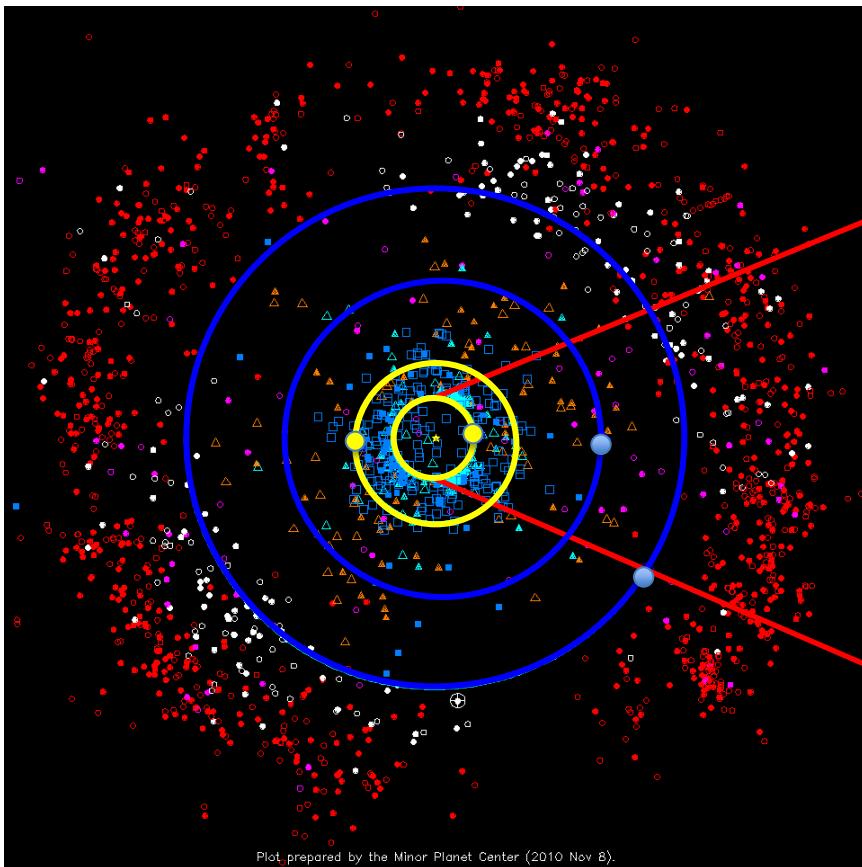
humpty dumpty pushed in
1992



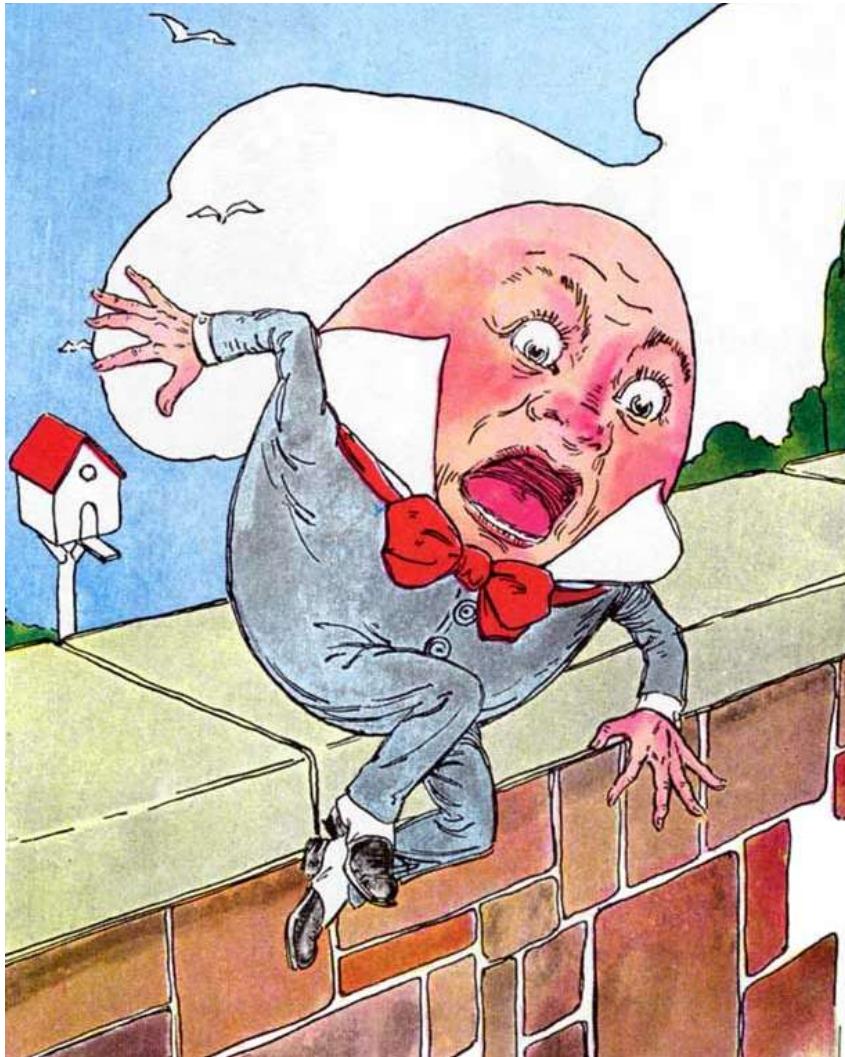
1992 QB1
kuiper belt detected

*(beginning of the end of Pluto's
planethood)*

the REAL solar system

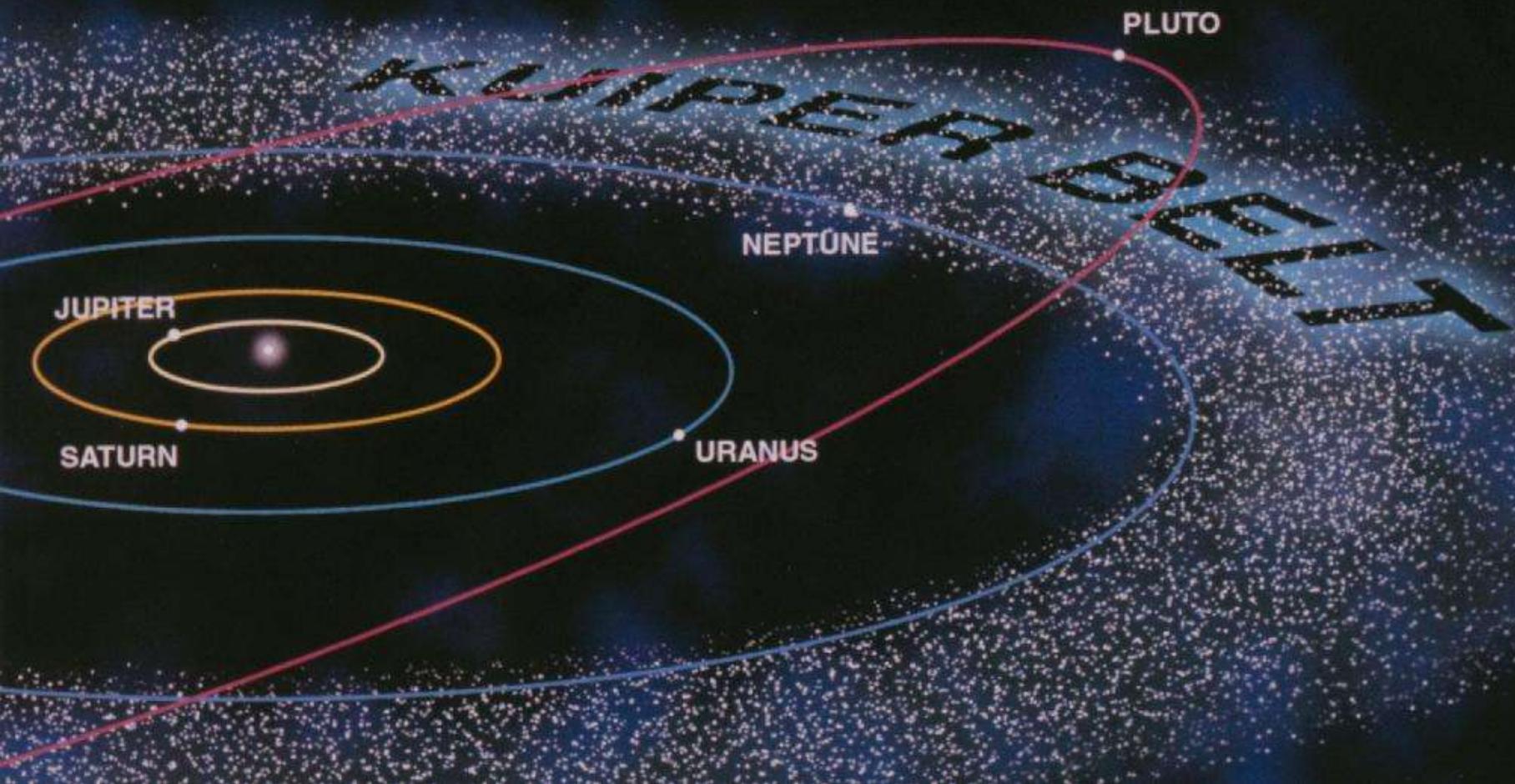


humpty dumpty **shoved** in mid
1990s

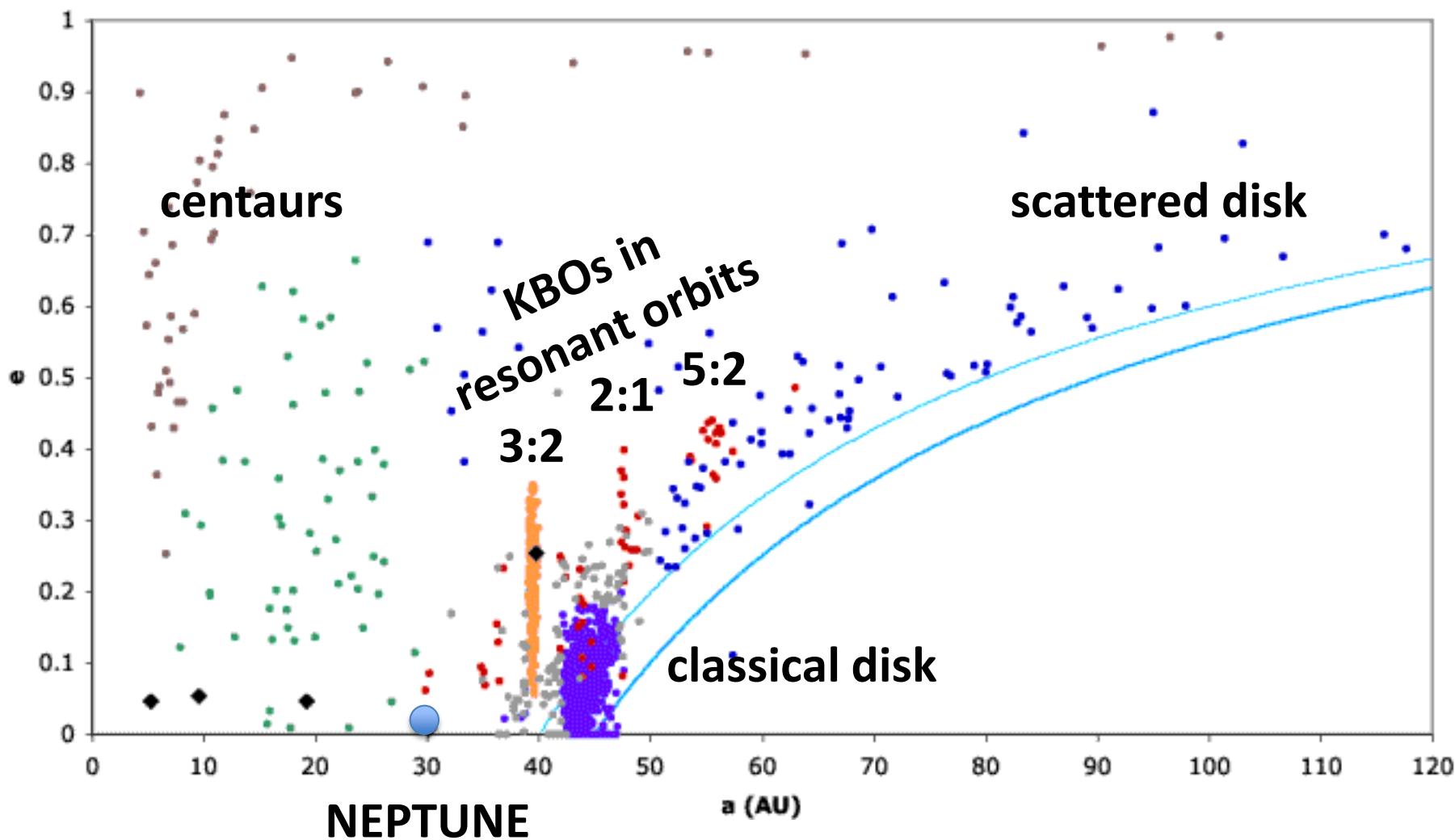


planetary
migration
theory

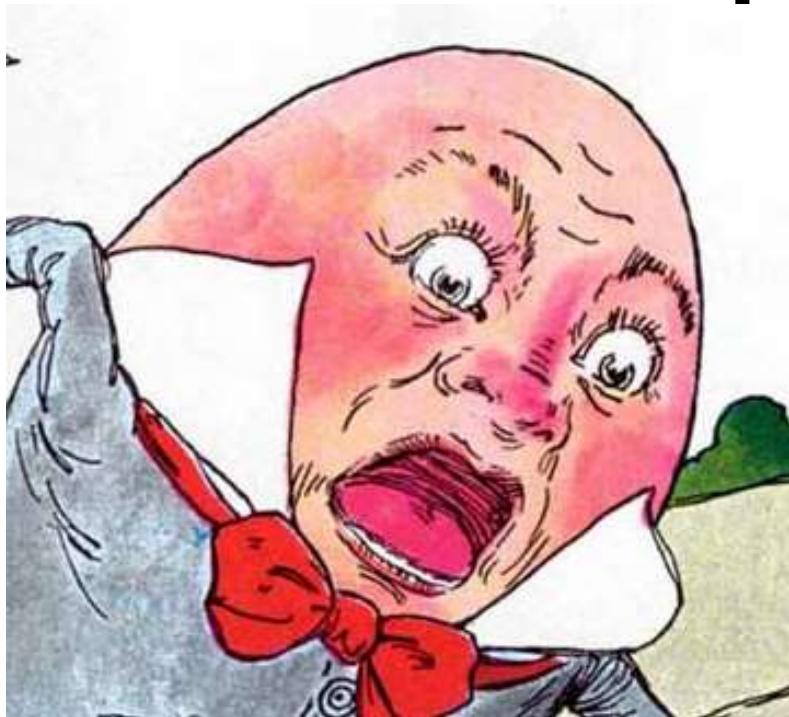
kuiper belt - pluto and his 10,000 closest friends and relations



orbits of Kuiper Belt Objects



humpty dumpty fell in 1995



exoplanets
more exoplanets

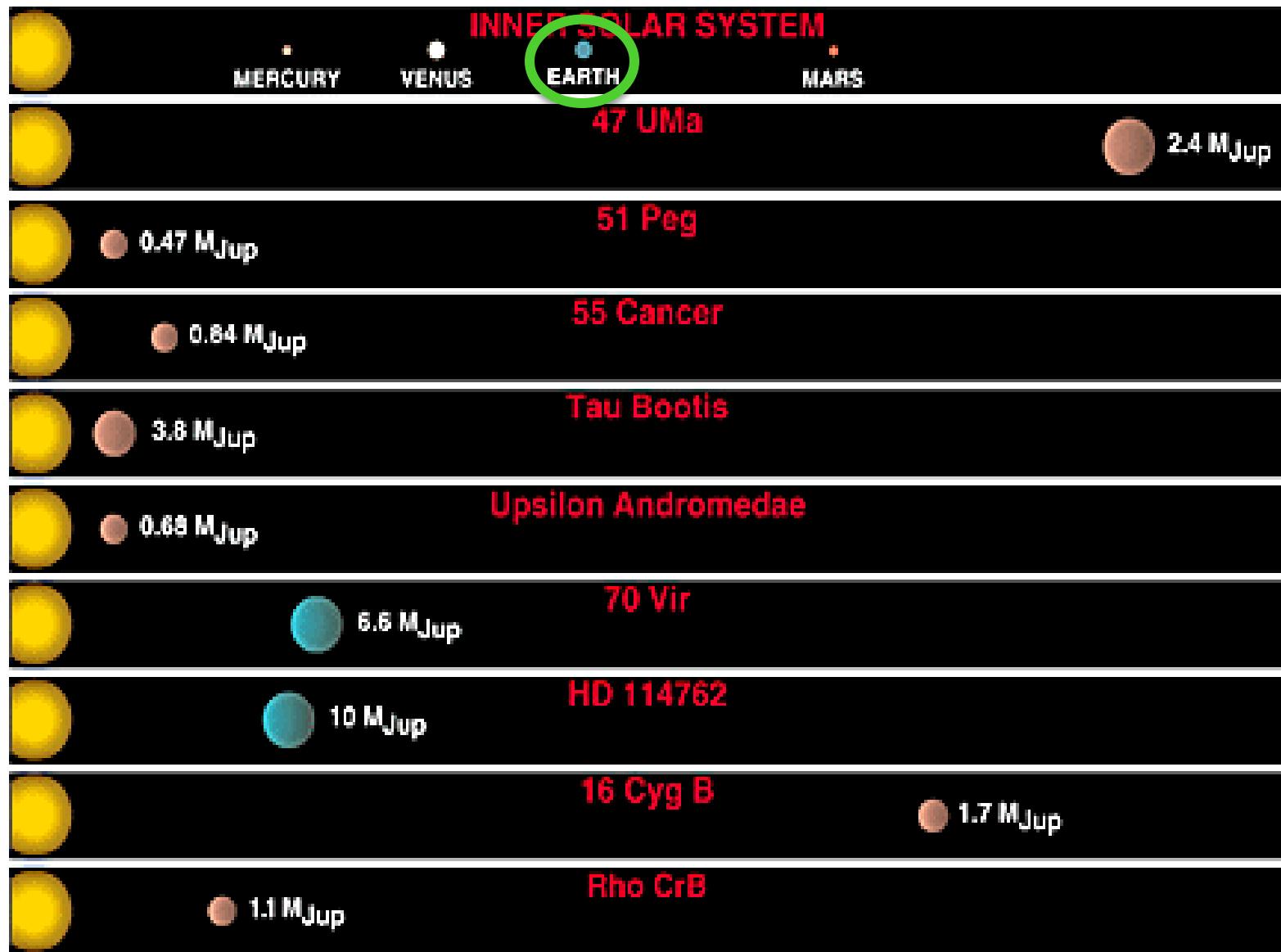
AND MORE EXOPLANETS

490 planets around other stars

STAR

INCREASING DISTANCE FROM STAR →
you are here

Solar
System



other
planetary
systems

how do we put humpty dumpty
together again?

how to build a solar system I of

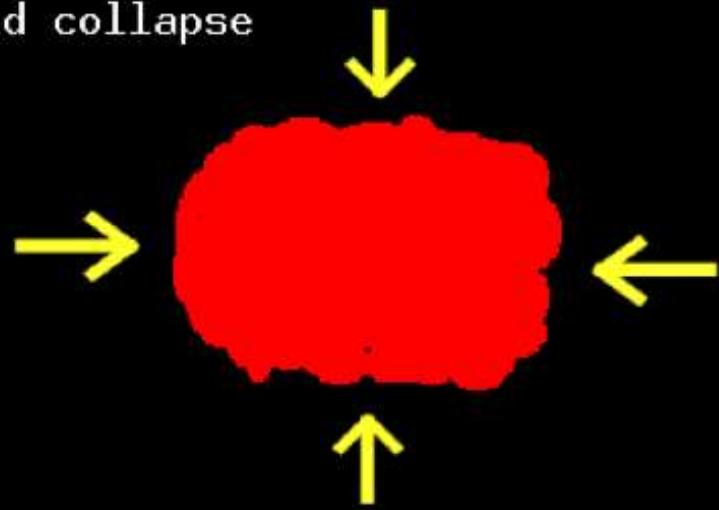
7

according to Hal Levison et al.

Stage 1

cloud
collapse

cloud collapse



Star-Birth Clouds • M16

PRC95-44b • ST Scl OPO • November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA

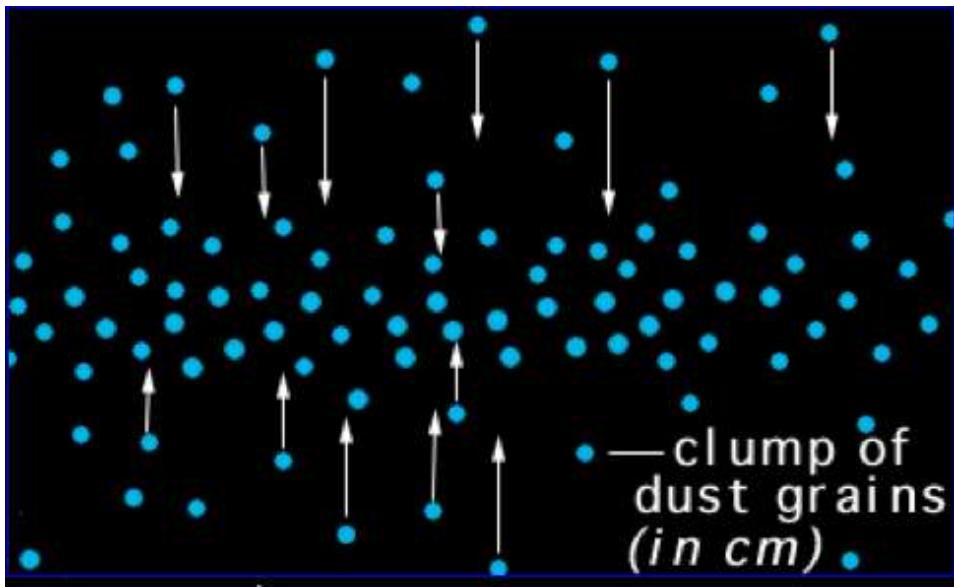
HST • WFPC2

how to build a solar system 2 of

7

according to Hal Levison et al.
Stage 2

Disks form



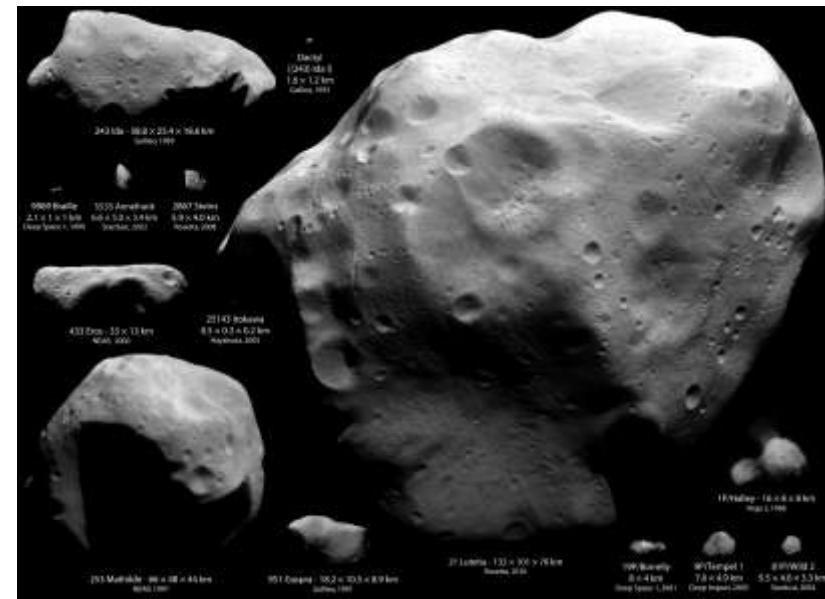
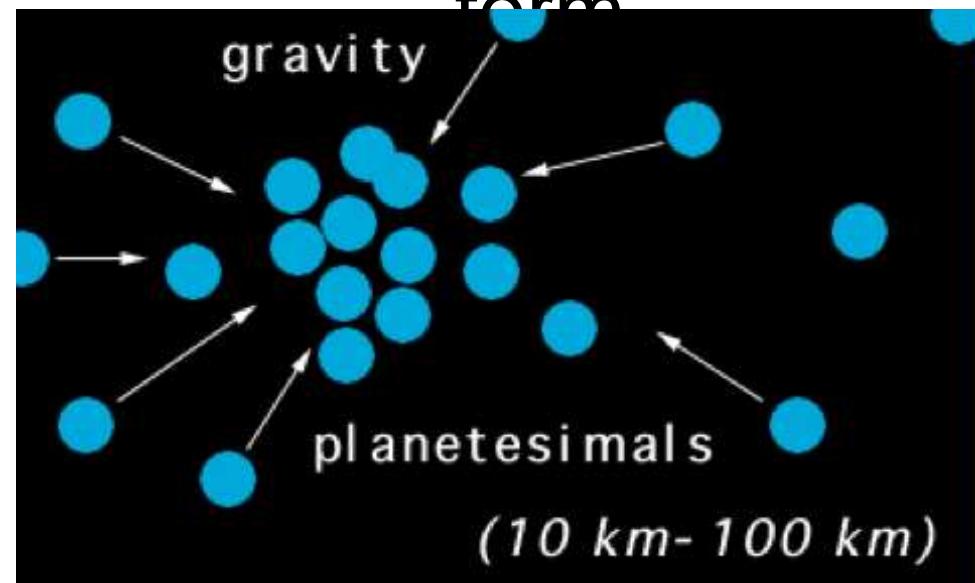
how to build a solar system 3 of

7

according to Hal Levison et al.
Stage 3

planetesimals

form



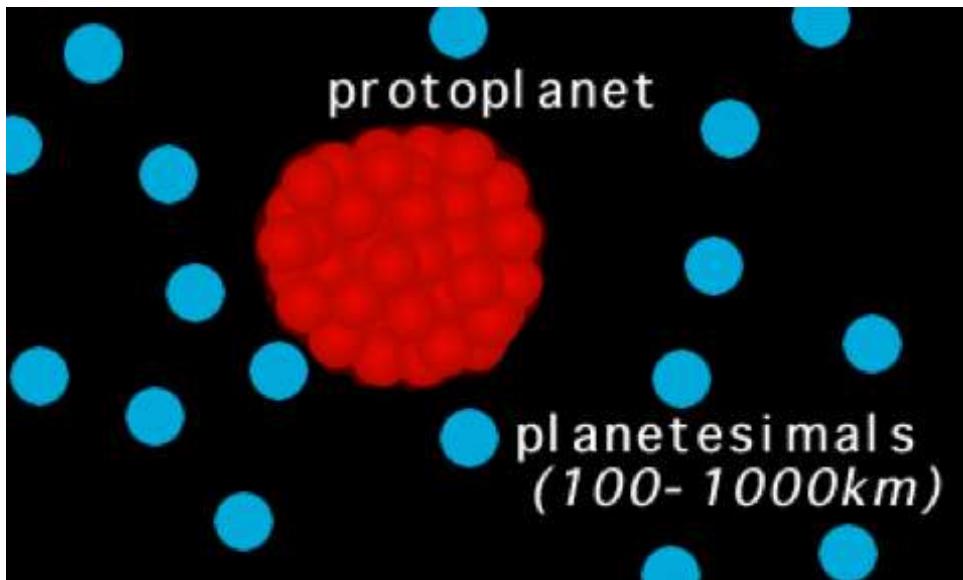
Composite by Emily Lackdawalla
The Planetary Society

how to build a solar system 4 of

7

according to Hal Levison et al.
Stage 4

protoplanets form



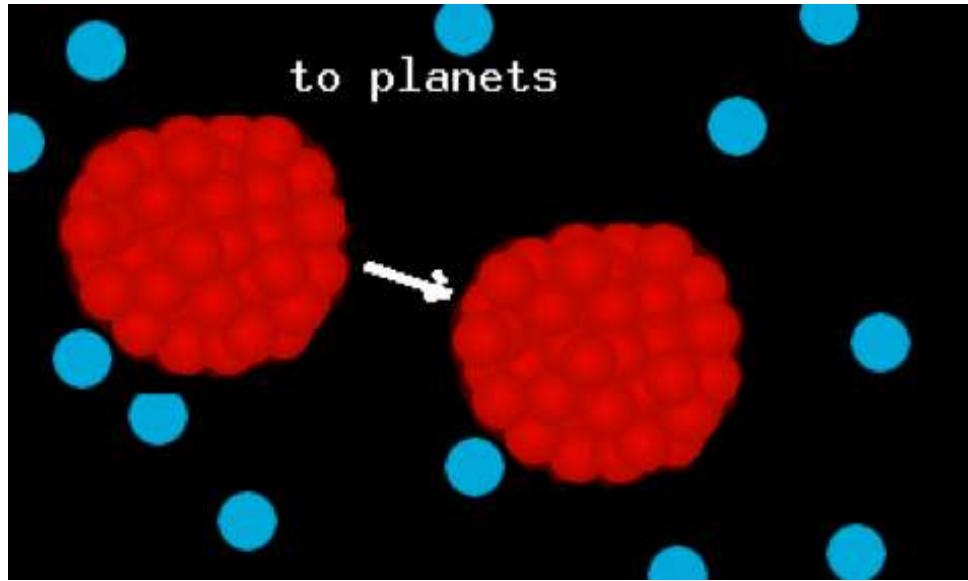
NASA, ESA, JPL, and A. Feild (STScI)

how to build a solar system 5 of

7

according to Hal Levison et al.
Stage 5

planets form



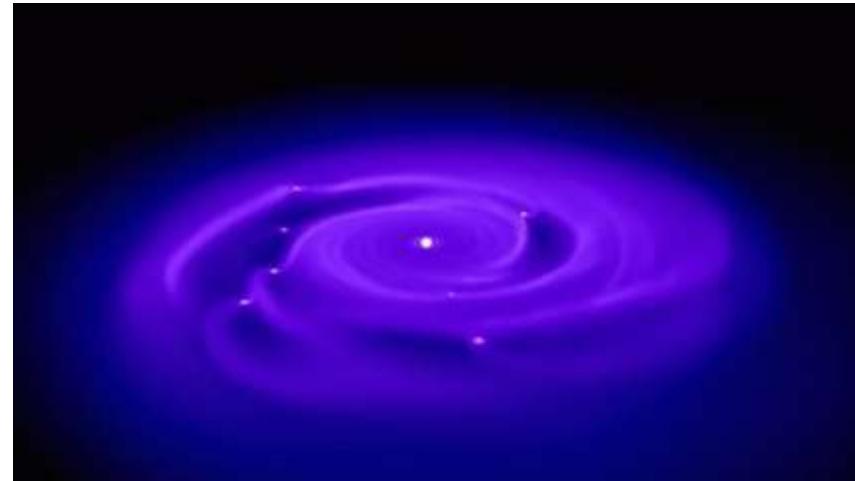
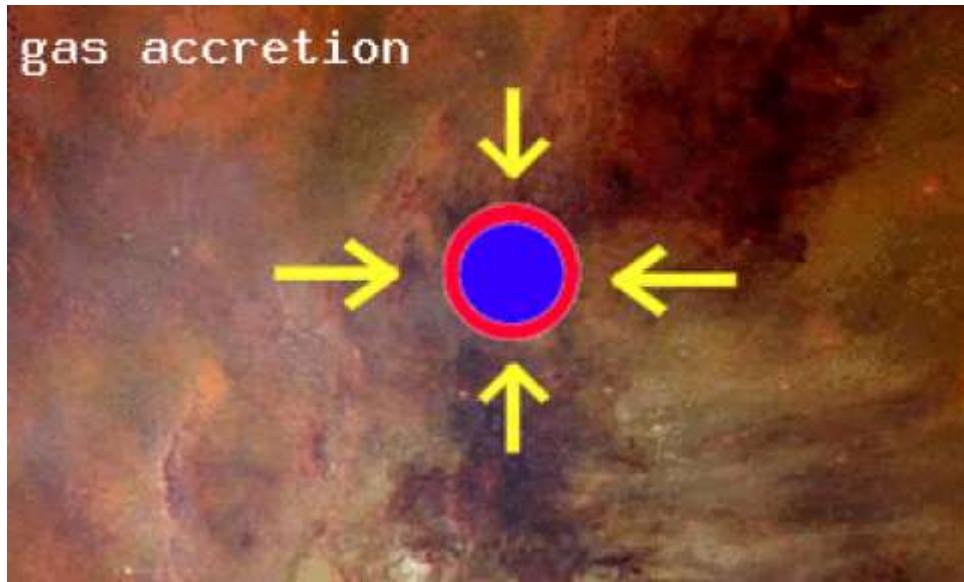
Artist's concept; credit: NASA/JPL-Caltech

how to build a solar system 6 of

7

according to Hal Levison et al.
Stage 6

gas accretion



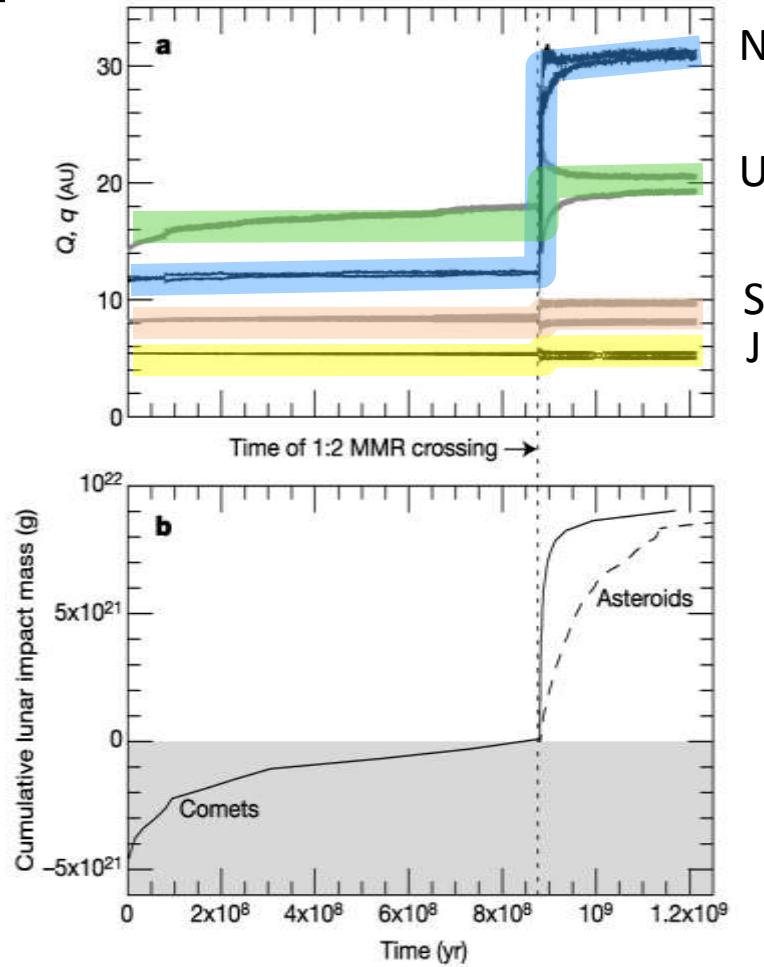
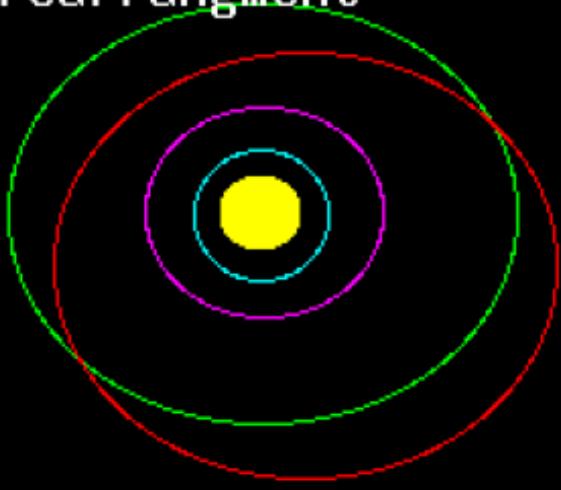
Simulation credit: Thomas Quinn, U. Washington

how to build a solar system 7 of 7

according to Hal Levison et al

Stage 7 dynamical

orbit rearrangement



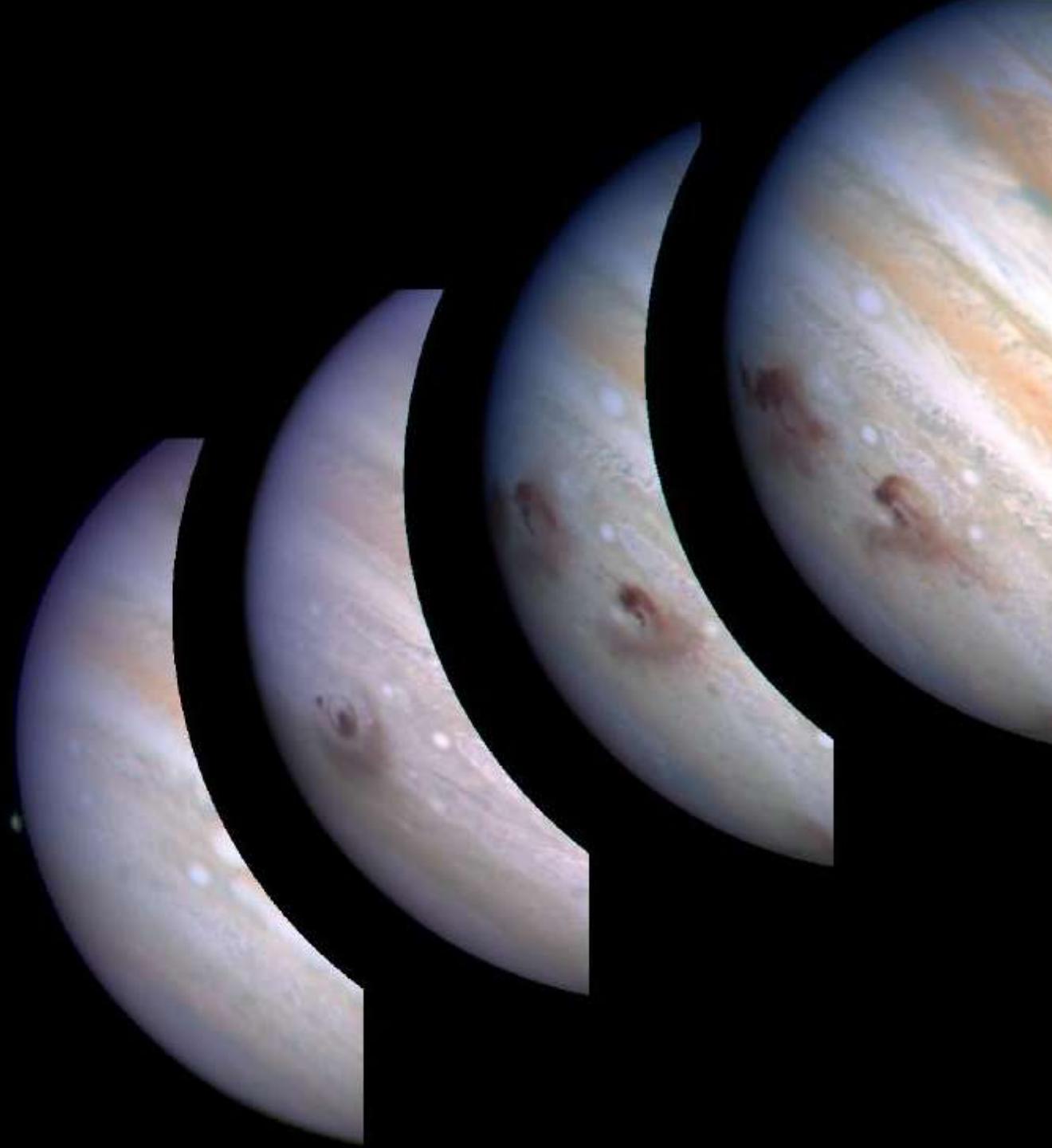
solar system formation is
complex and messy

smooshing and smashing!
whooshing and crashing!

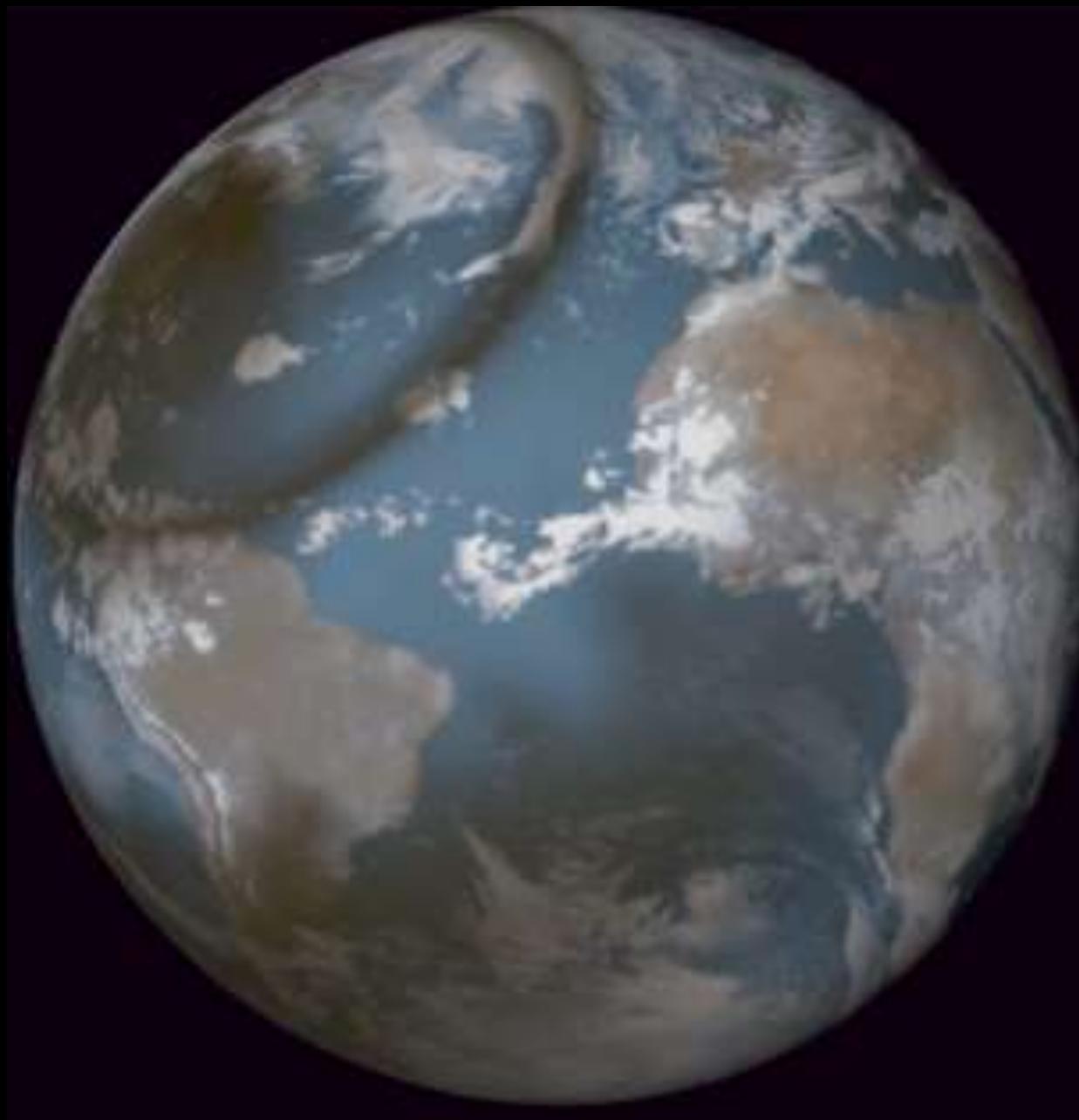
understanding solar system
formation very much a work in
progress

AND FURTHERMORE...

THE SOLAR SYSTEM
ITSELF IS A WORK IN
PROGRESS



impacts
happen
NOW





First
Hubble
science
image
with
WFC3

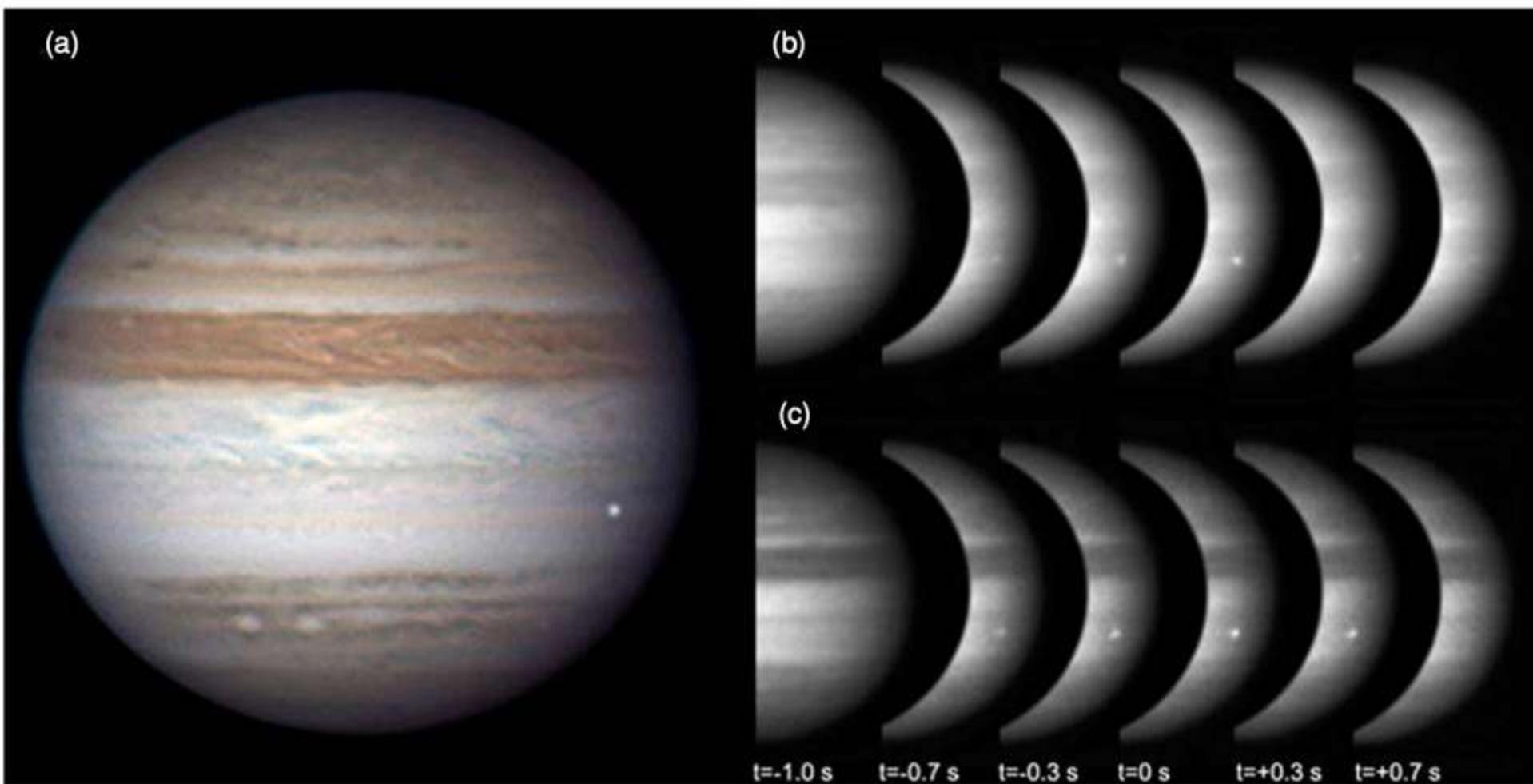
July 2009



10,000 mi

16,100 km
3.4"

Jupiter smashed AGAIN in June 2010

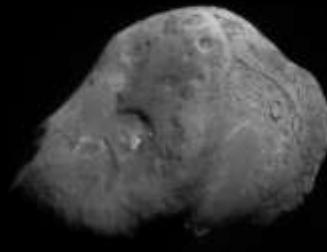


and AGAIN in August 2010

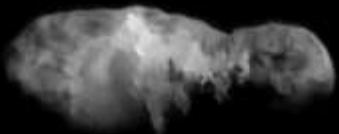
prototype smashers & crashers



1P/Halley - $16 \times 8 \times 8$ km
Vega 2, 1986



9P/Tempel 1
 7.6×4.9 km
Deep Impact, 2005



19P/Borrelly
 8×4 km
Deep Space 1, 2001



103P/Hartley 2
 2.2×0.5 km
Deep Impact, 2010



81P/Wild 2
 $5.5 \times 4.0 \times 3.3$ km
Stardust, 2004

delivering water, everywhere

Sol 20

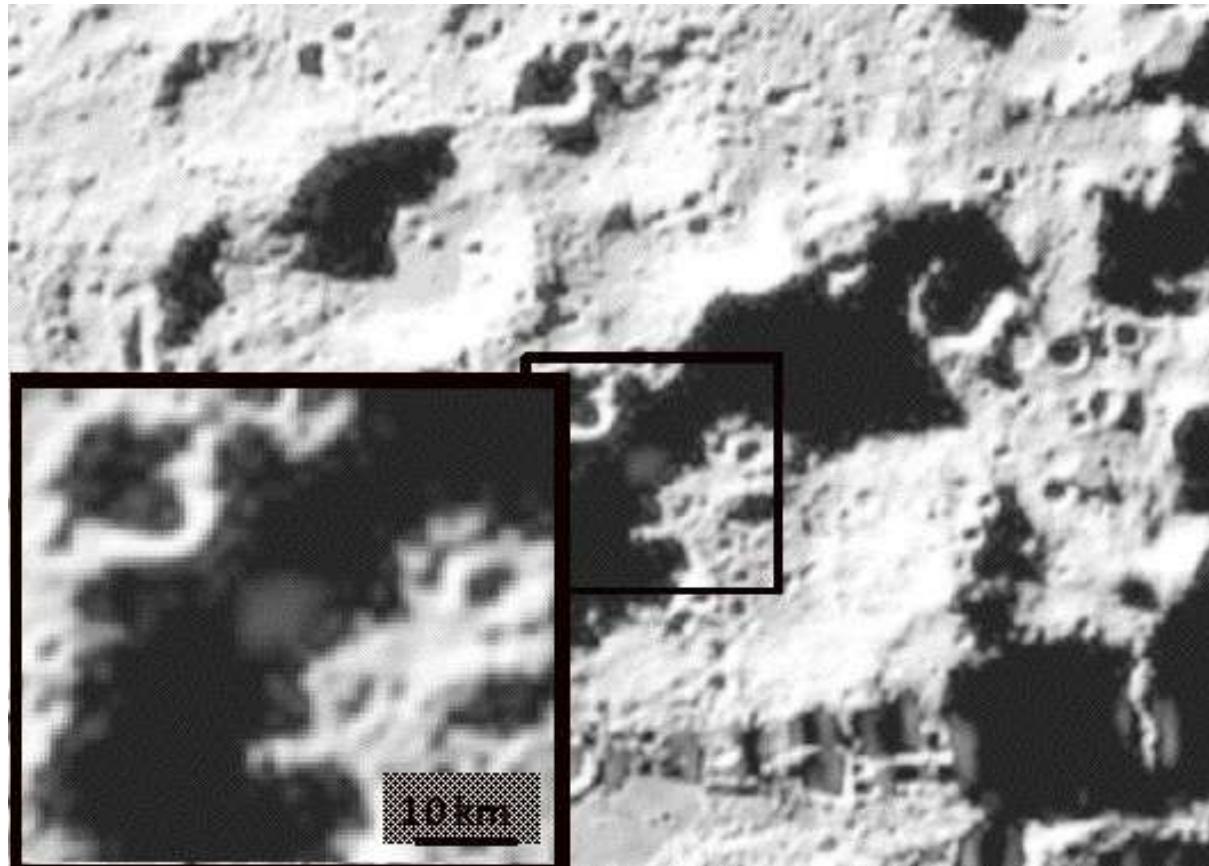


Sol 24

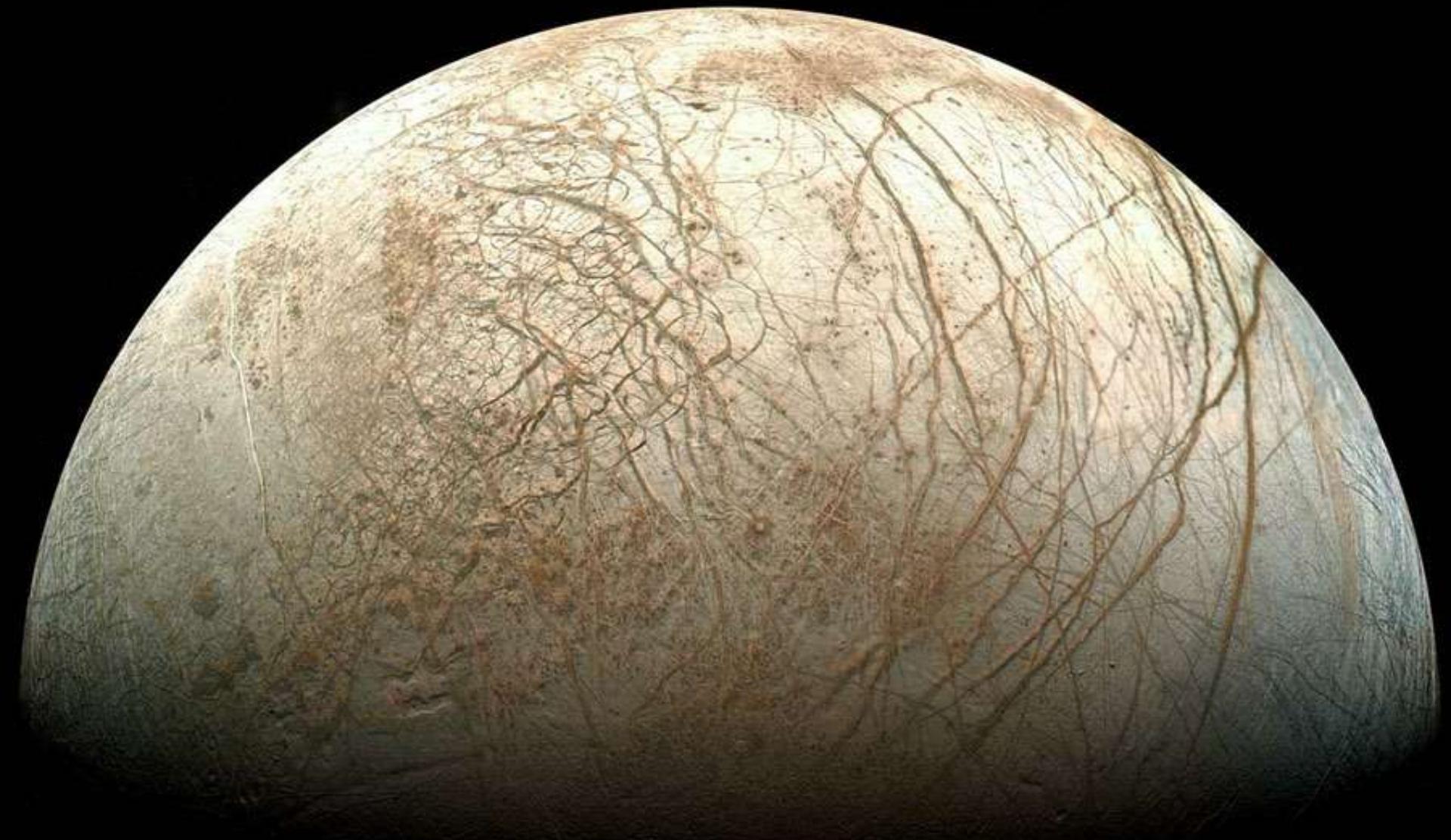


Phoenix Lander on Mars

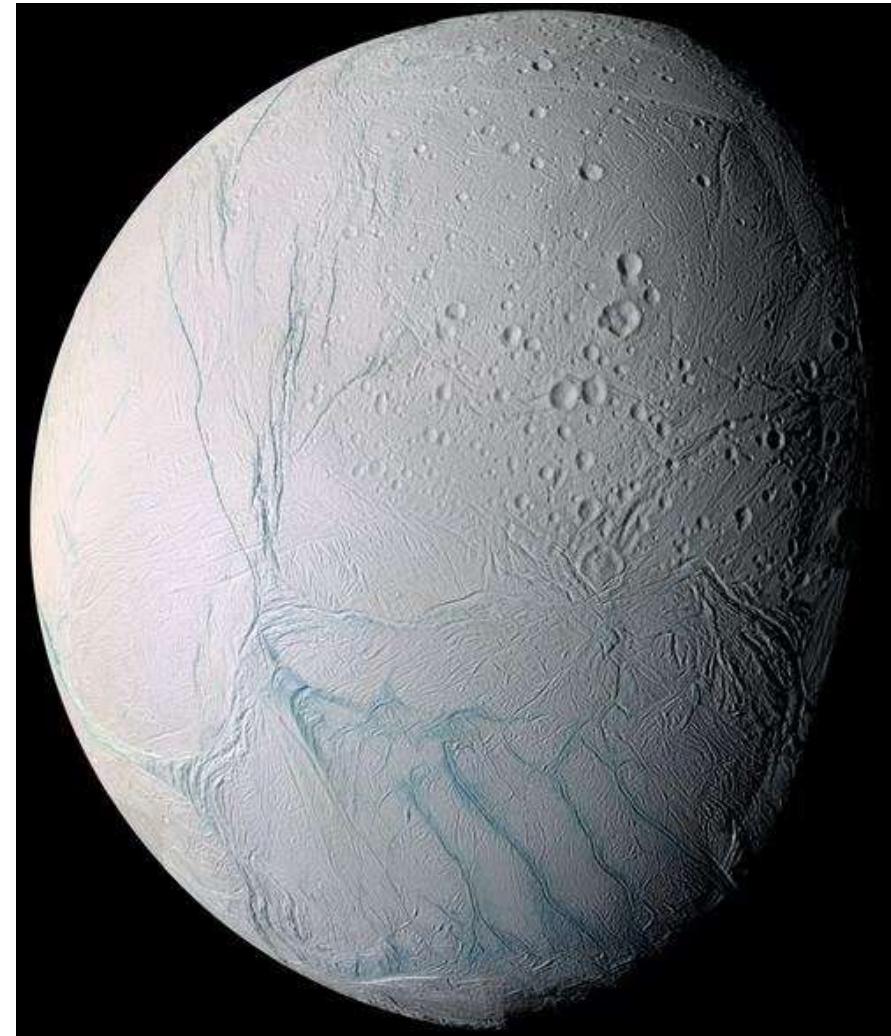
water on the moon



speaking of WATER



we *were* talking about
WATER, right?



planetary evolution

Jupiter • *Hubble Space Telescope WFC3/UVIS*



July 23, 2009



June 7, 2010

planetary evolution science and social networking

facebook 3 20

Heidi B. Hammel
Edit My Profile

News Feed 75

Messages 31

Events 31

Friends

Search

News Feed Top News · Most Recent

What's on your mind?

 Christopher Go

The SEB revival may have begun!! Check my latest Jupiter image with a bright spot on the SEB. This is similar to what happened in 2007 when I discovered the last revival!! Note that there were no bright spot on this area 2 days ago!

<http://astro.christone.net/jupiter>

atmospheric change on uranus

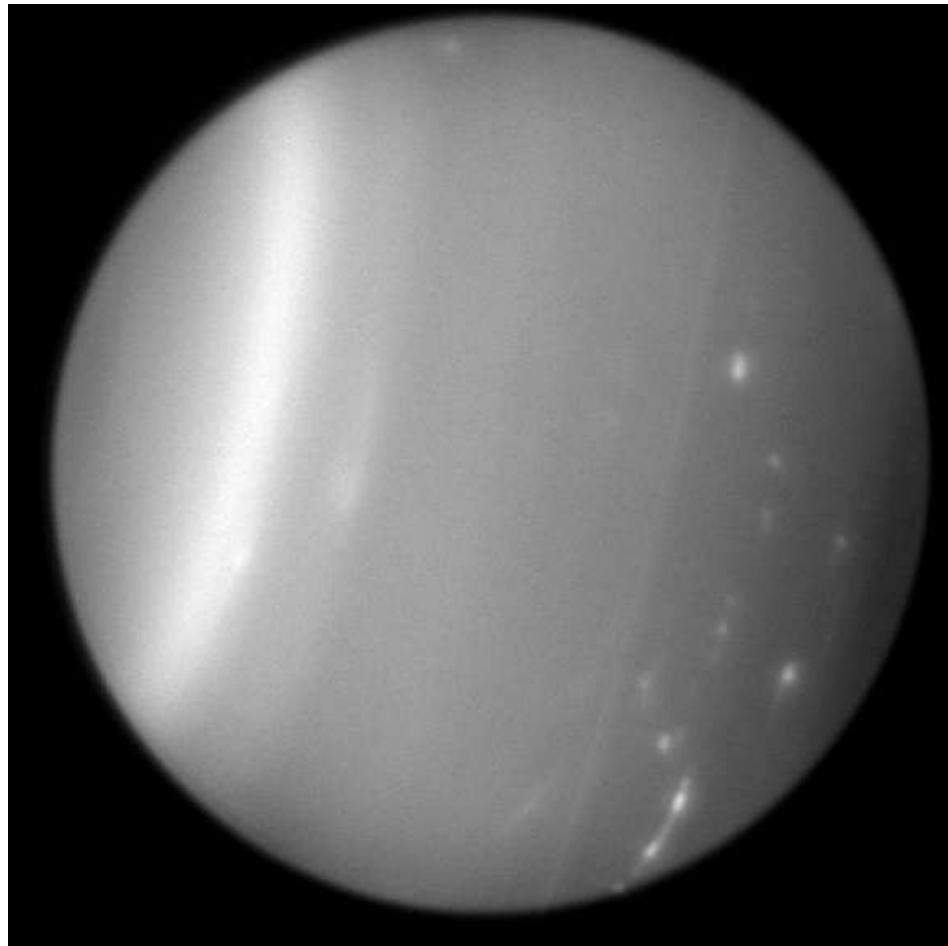


voyager uranus in 1986



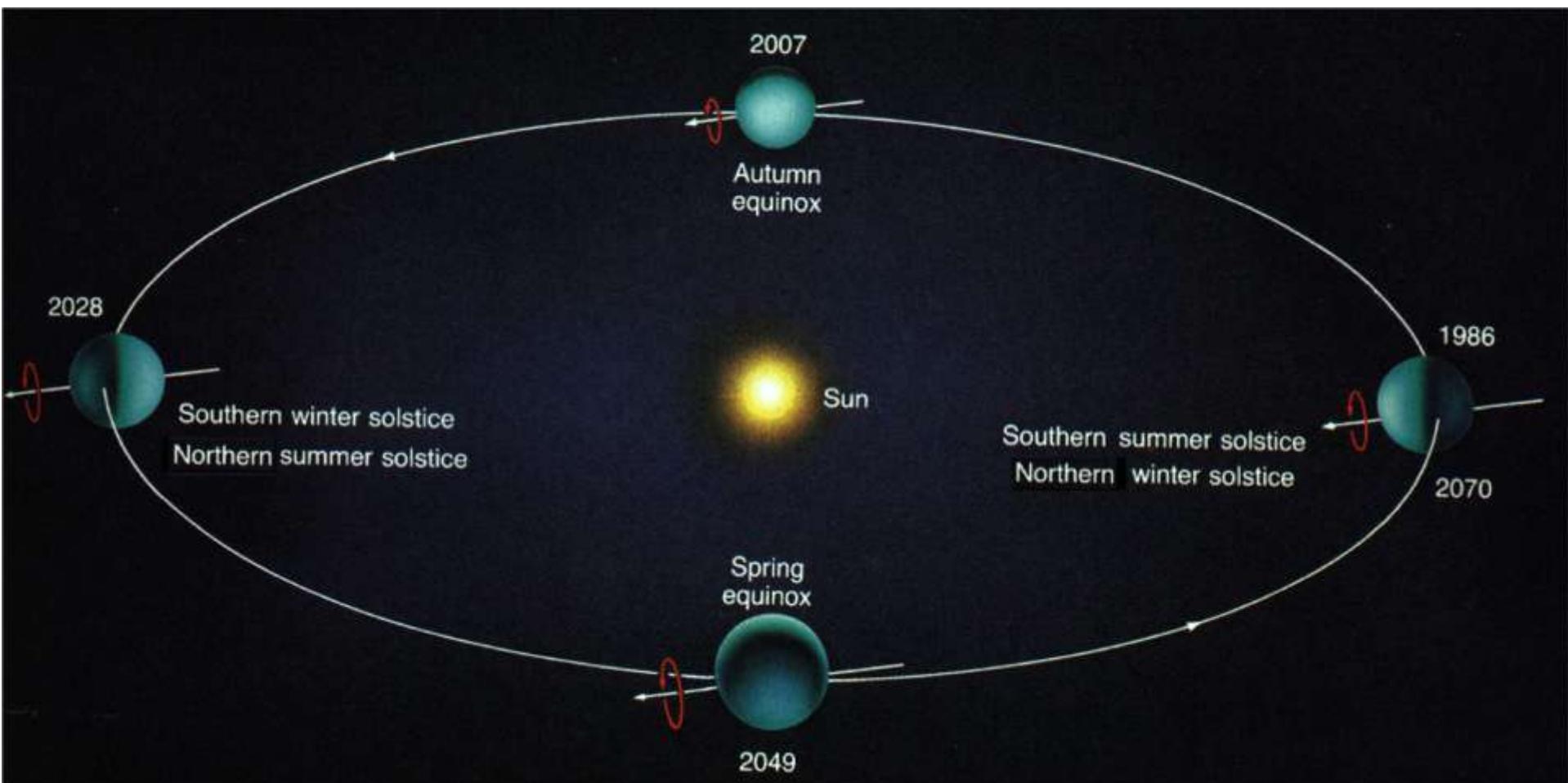
3.8"

keck uranus in 2004

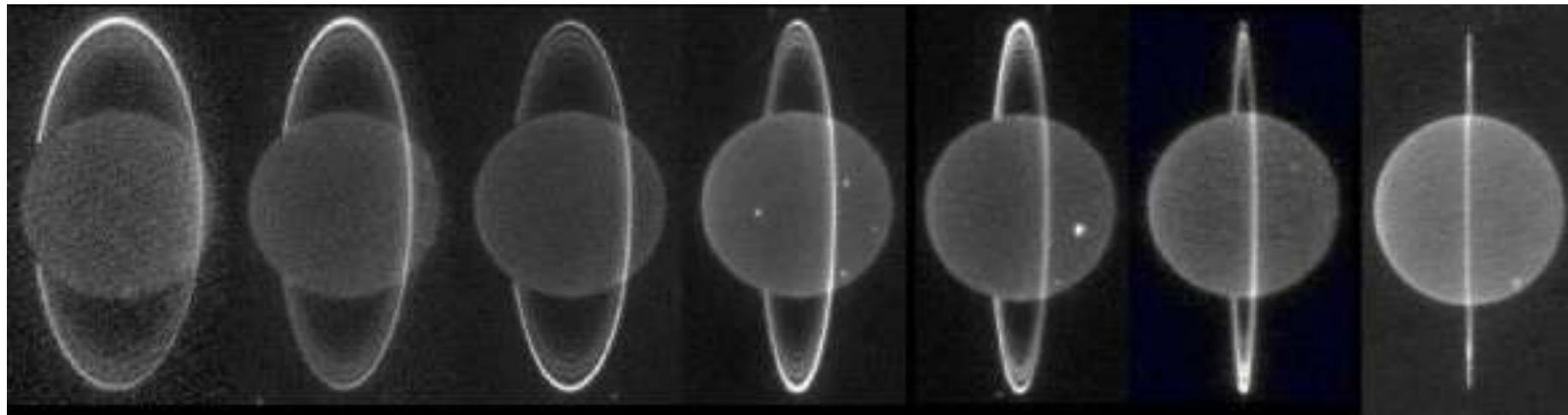


3.8"

seasonal change



evolving rings



2001

2002

2003

2004

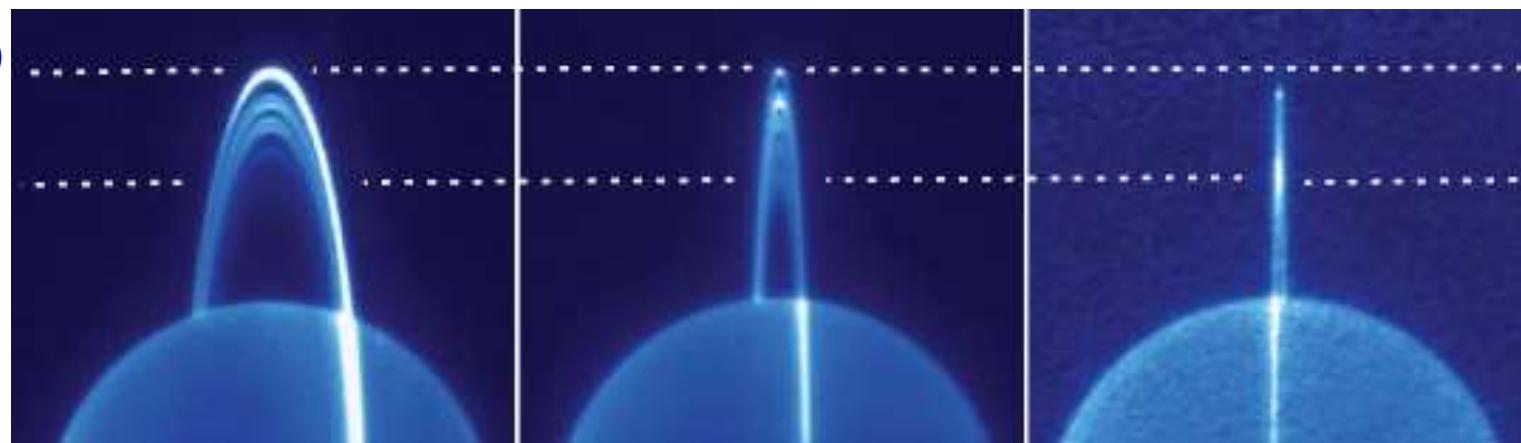
2005

2006

2007

ϵ (epsilon)

ζ (zeta)

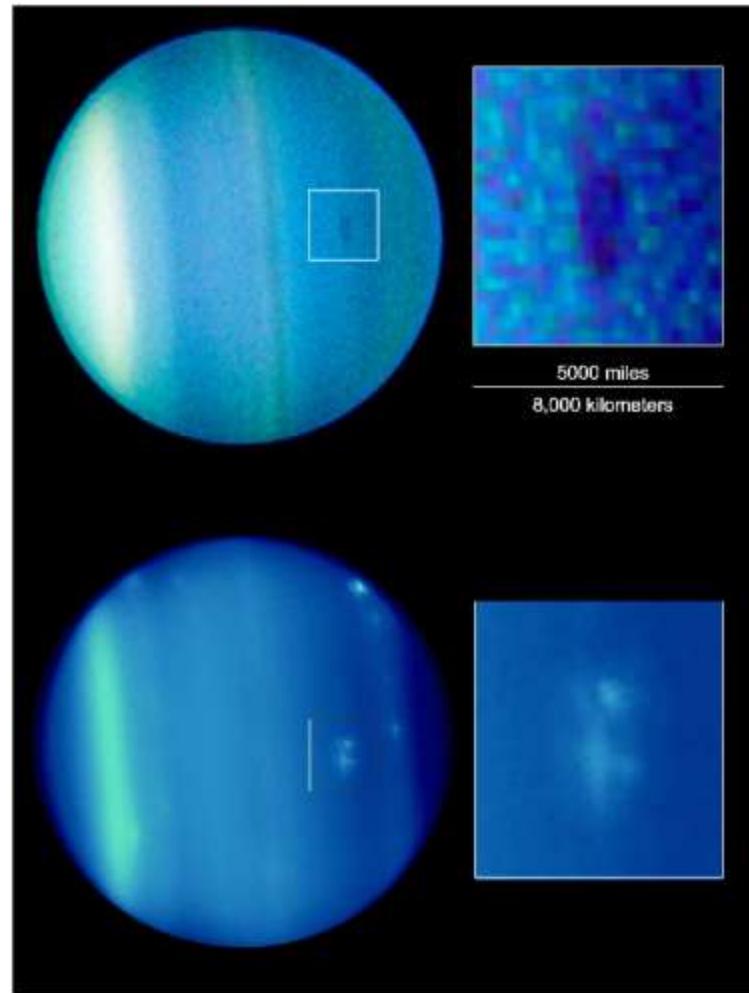


2004

2006

2007

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

Science News – The New York Times

http://www.nytimes.com/pages/science/index.html

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The New York Times

Tuesday, November 9, 2010

Science

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ENVIRONMENT SPACE & COSMOS

nytimes.com/pages/science

me

Science Times: What's Next

MAKING predictions about discoveries is usually to be avoided in the cautious, peer-reviewed world of science: the danger of embarrassment is all too present. But in this anniversary issue of Science Times (the first was published Nov. 14, 1978), we yield to the temptation. We asked science reporters and top researchers to identify which fields are hot — in other words, where talent, money and circumstance are converging. Their watch list for noteworthy advances in 2011 touches areas as varied as dark matter, brain science, quantum computing and the fight against AIDS.



John Hensley

Voices: What's Next

Here are prognostications for science in 2011 from 10 leading figures in 10 widely scattered disciplines, from genomics to mathematics to earth science.

Podcast: Science Times

This week: The long view of the year

NYTIMES.COM SCIENCE TIMES

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CUBIST

PHARMACEUTICALS

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



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



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

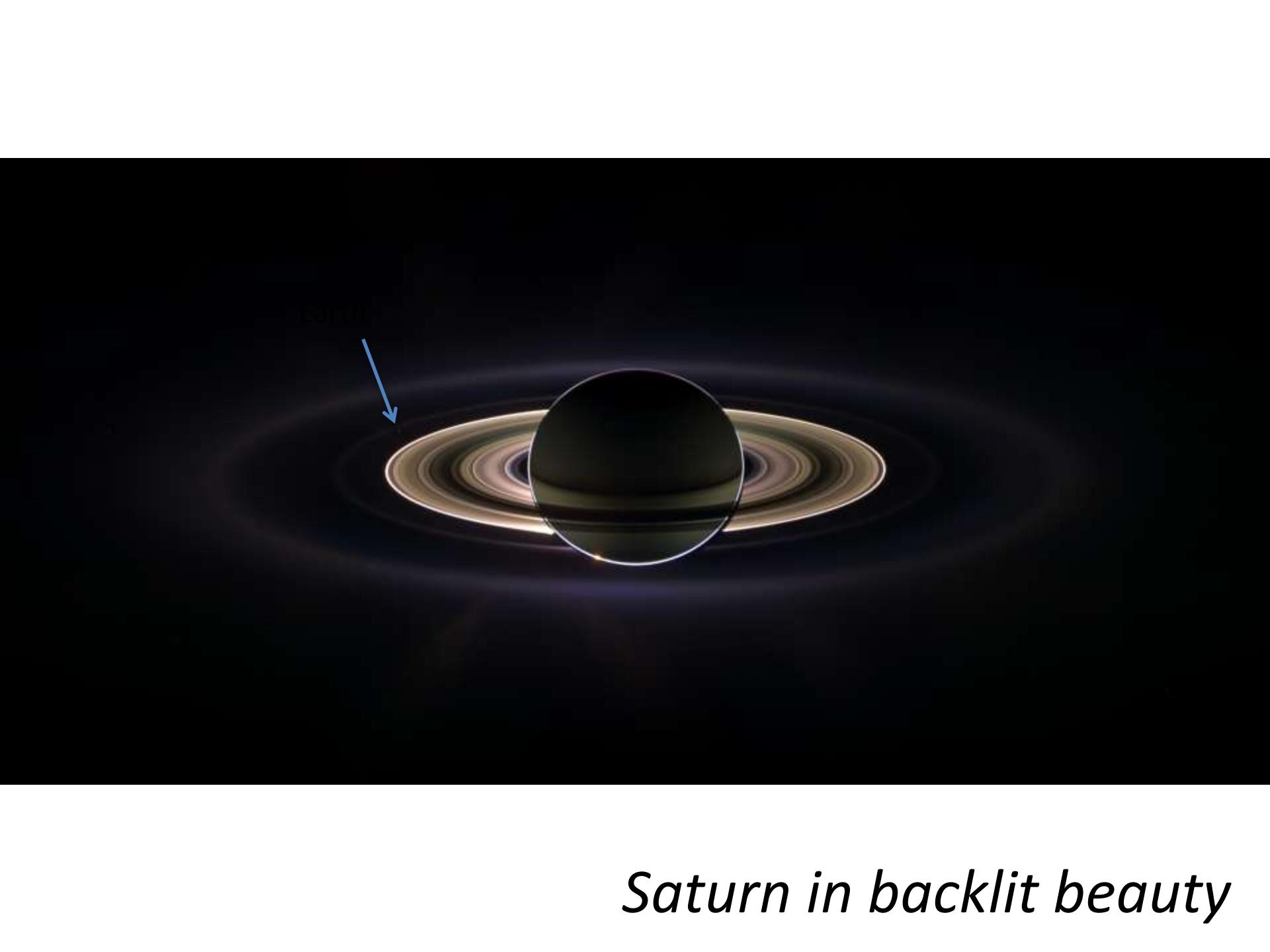
- Aug 05 - Juno launch to Jupiter
- Sep 08 - GRAIL launch to the Moon
- Nov 25 - MSL launch to Mars

2012

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

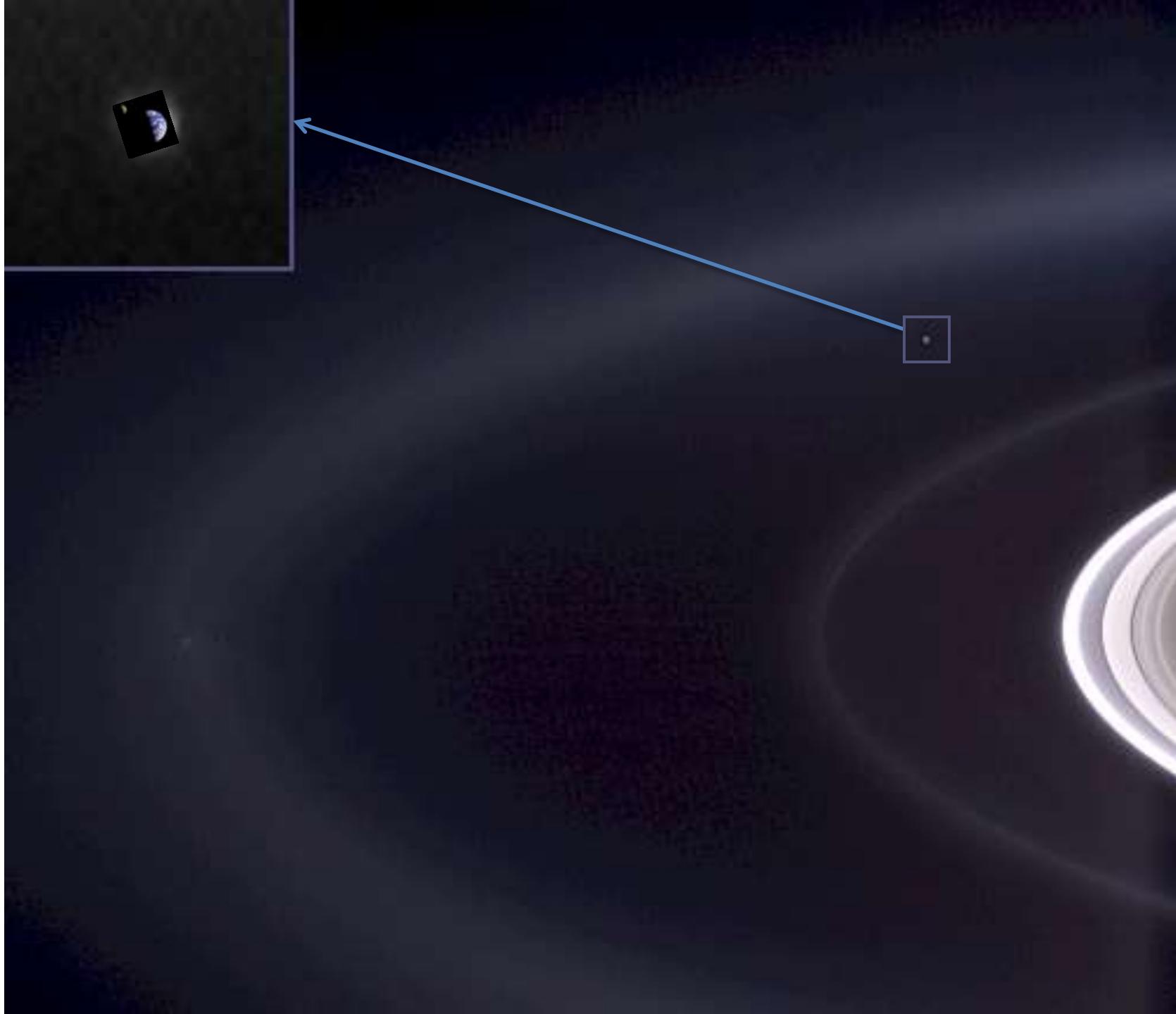
far future?





Earth

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'