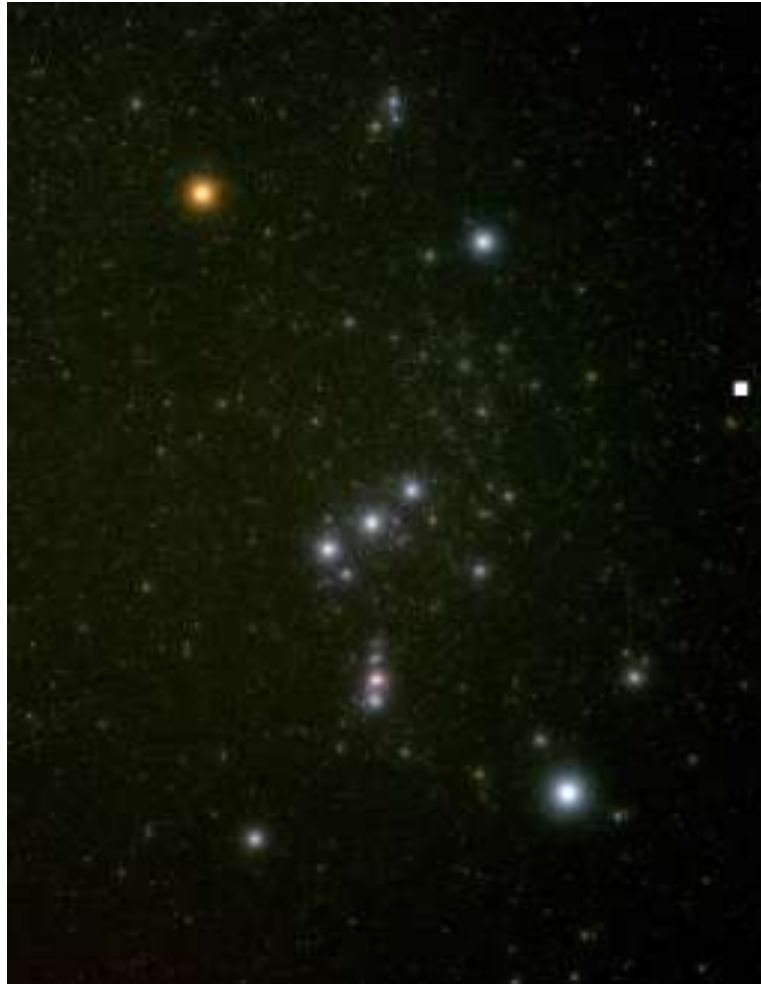


Understanding the Solar System

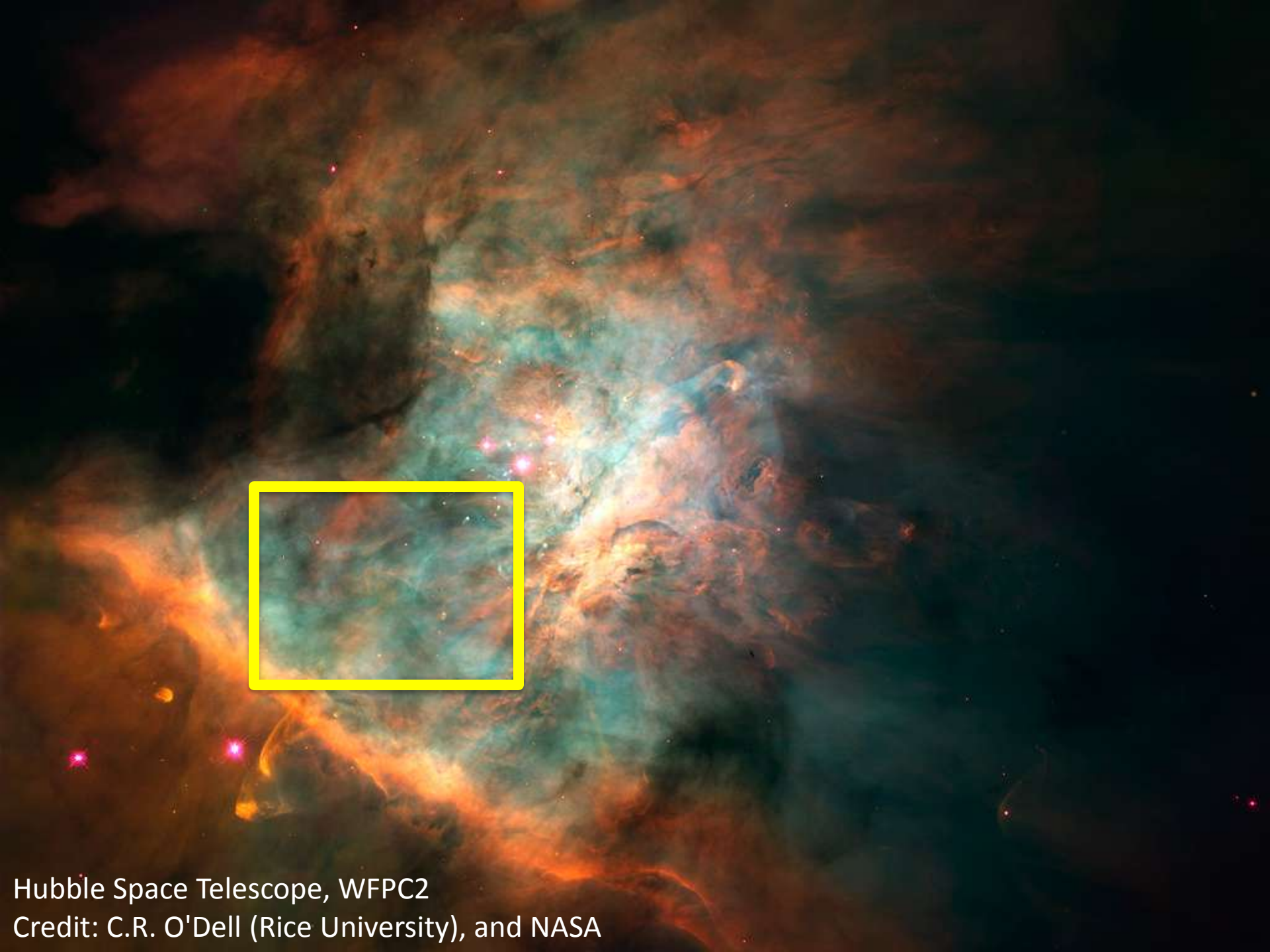
How did it begin? How is it evolving?

Heidi B. Hammel
Space Science Institute
Boulder, CO

hunting for answers

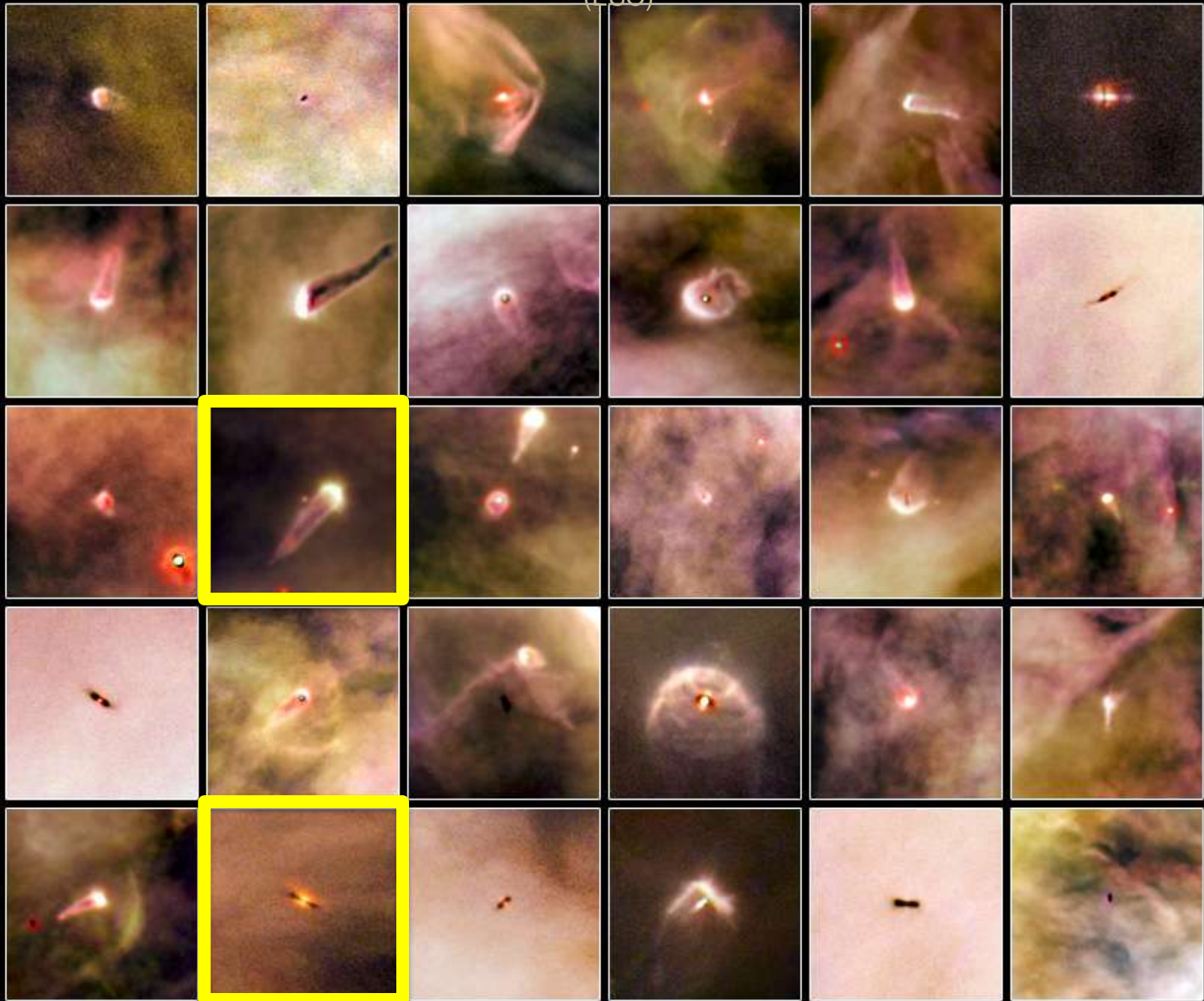


Constellation of Orion the Hunter, by John Gavreau



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





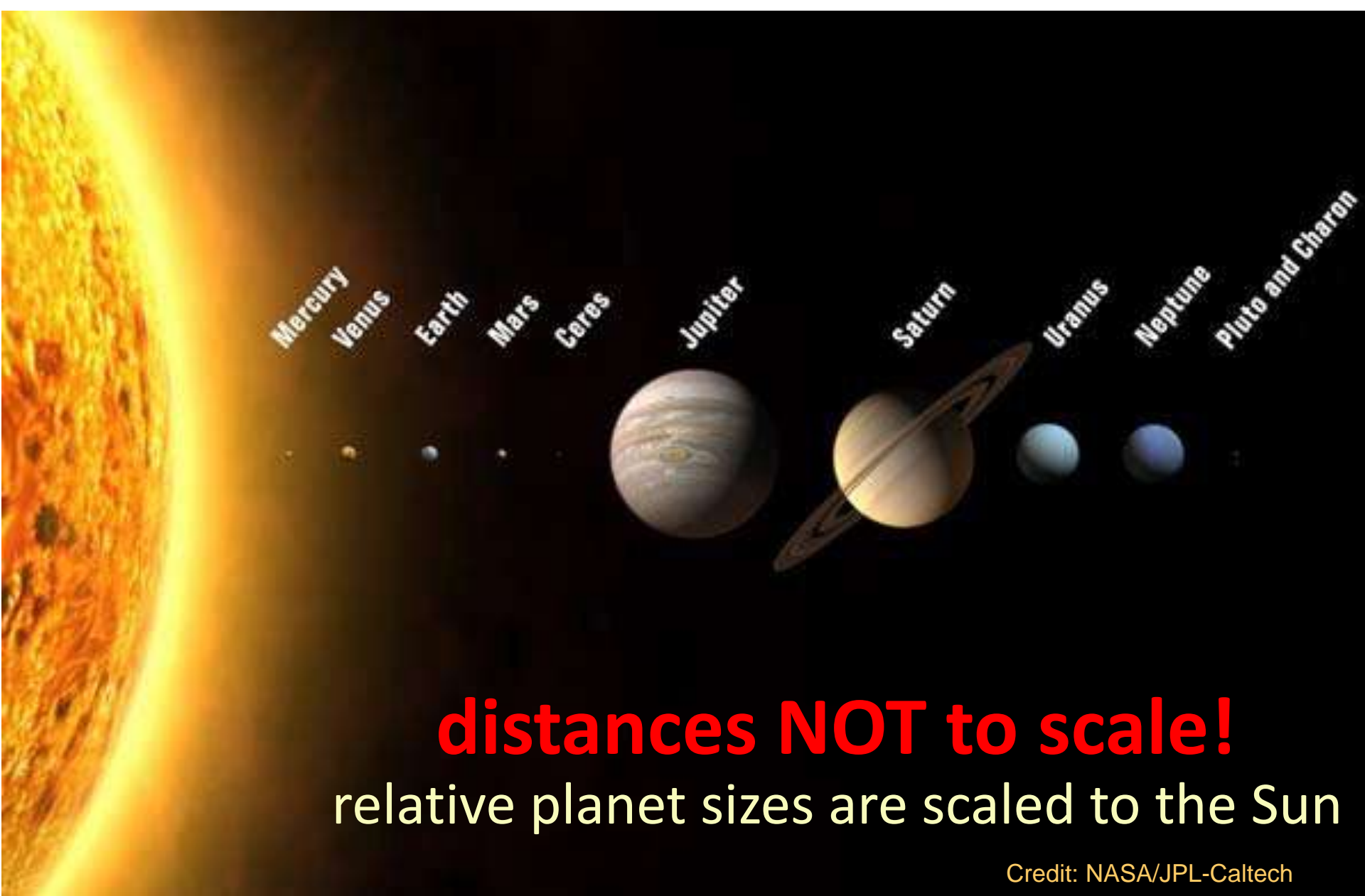
Orion's **proto-planetary disks (proplyds)**

how do you get from this...



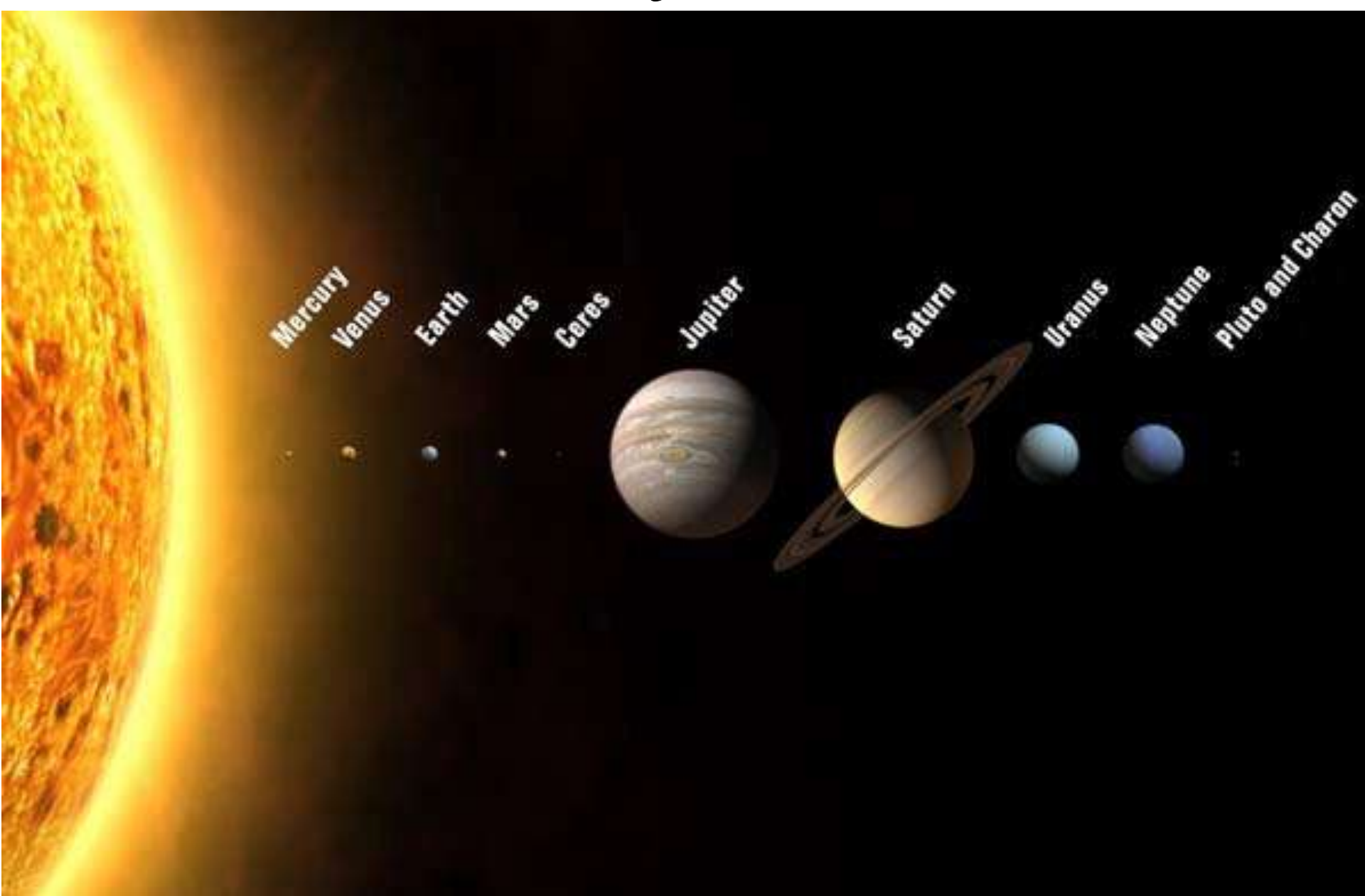
Proplyd in Orion
Hubble Space Telescope ACS
Credit: NASA/ESA and L. Ricci (ESO)

... to this?

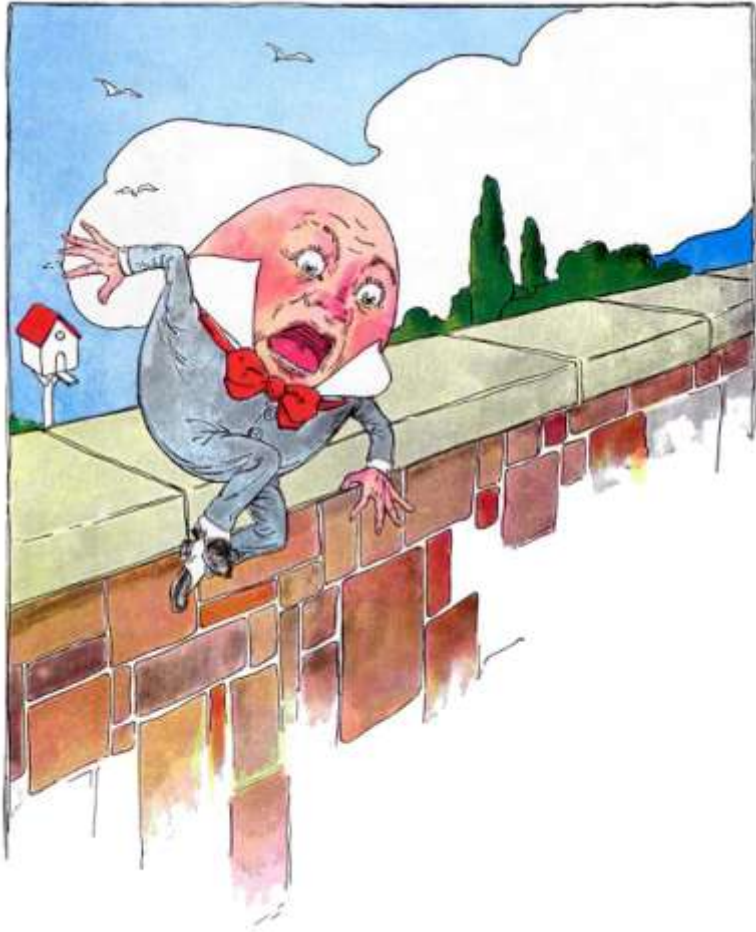


distances NOT to scale!
relative planet sizes are scaled to the Sun

the story in 1988



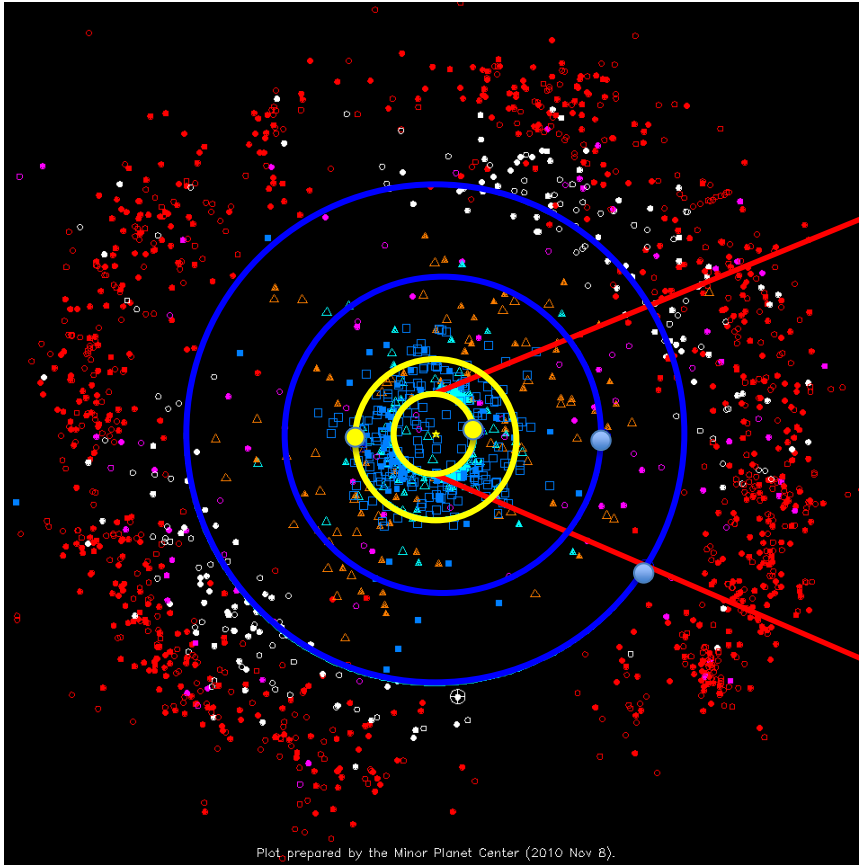
humpty dumpty pushed in
1992



1992 QB1
kuiper belt detected

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

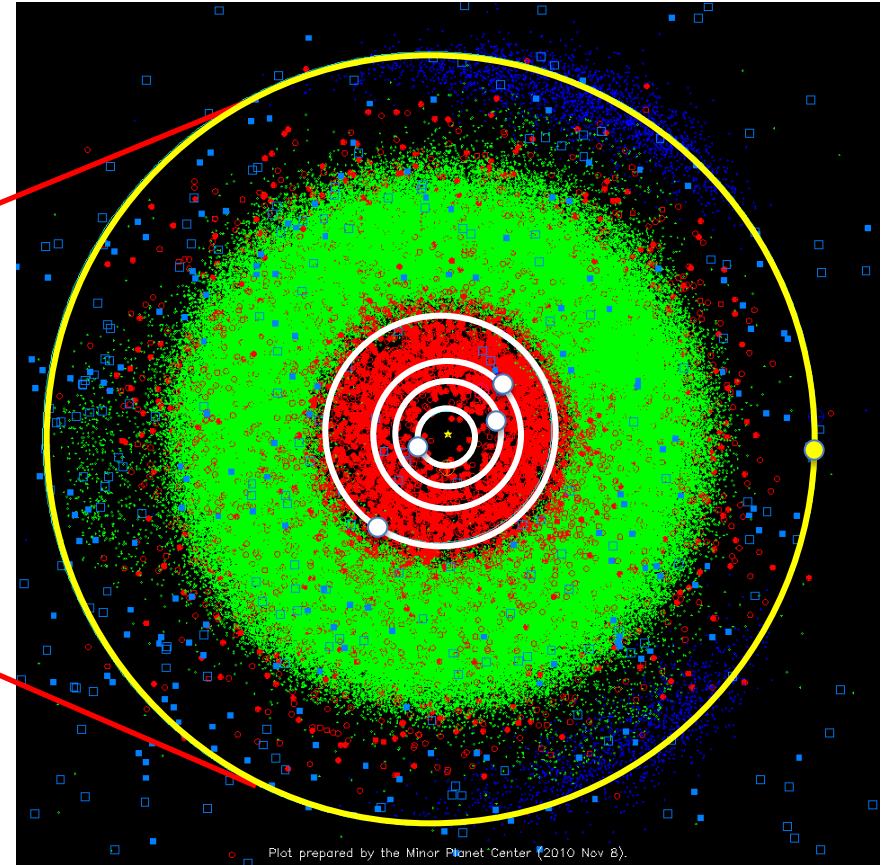
the REAL solar system



Outer Solar System

8 November 2010

Data: Minor Planet Center

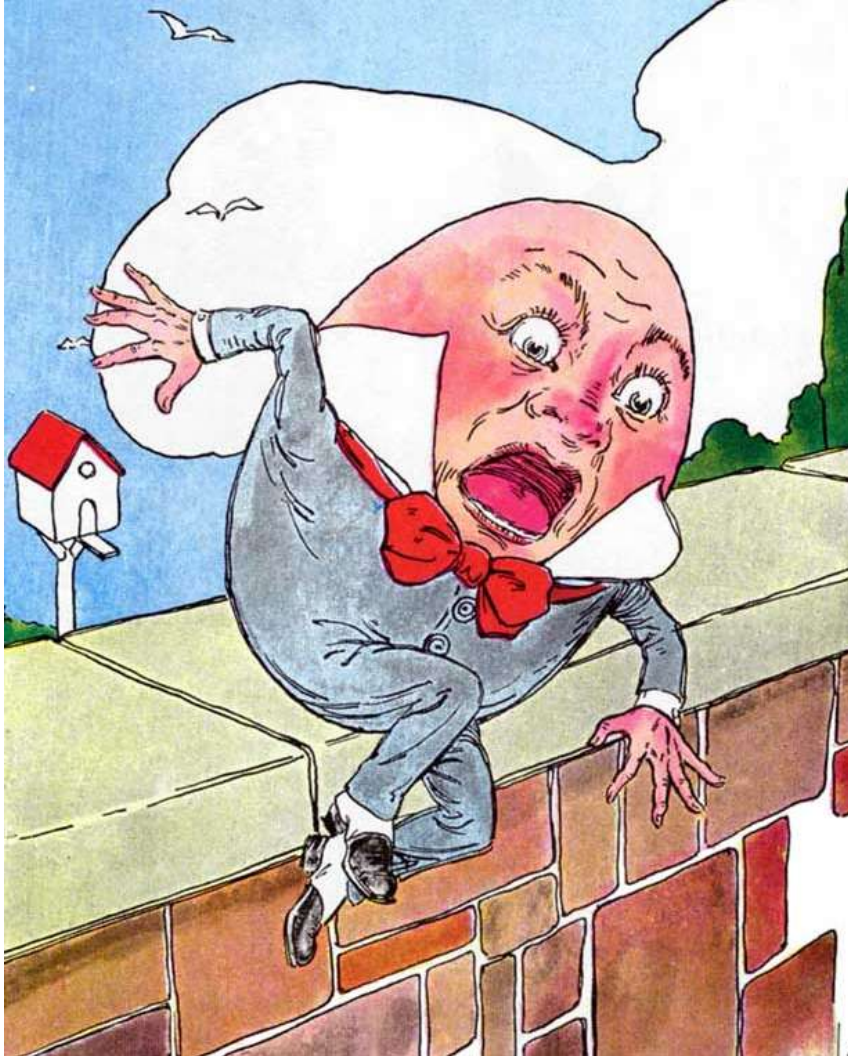


Inner Solar System

8 November 2010

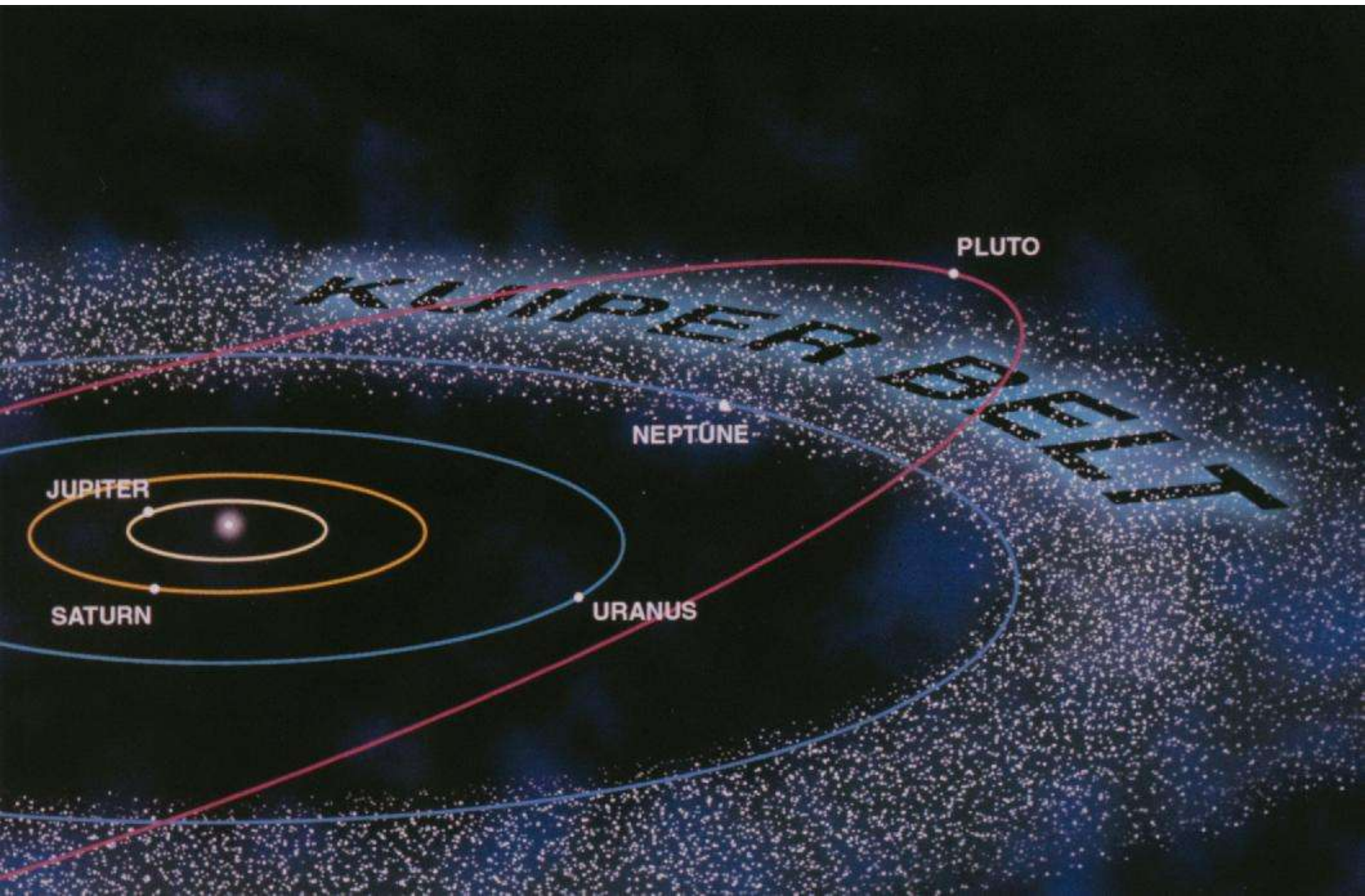
Data: Minor Planet Center

humpty dumpty **shoved** in mid
1990s

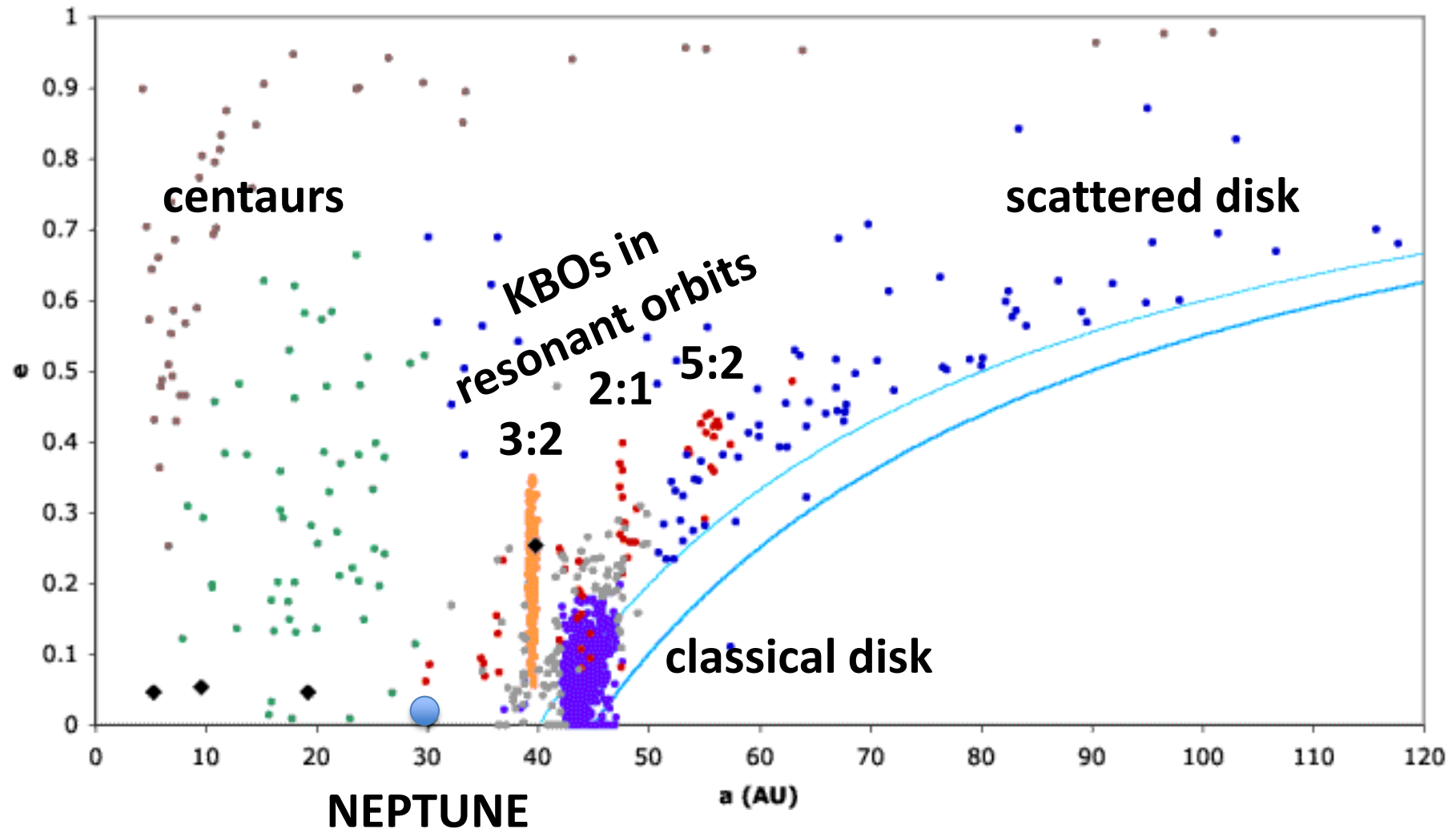


planetary
migration
theory

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

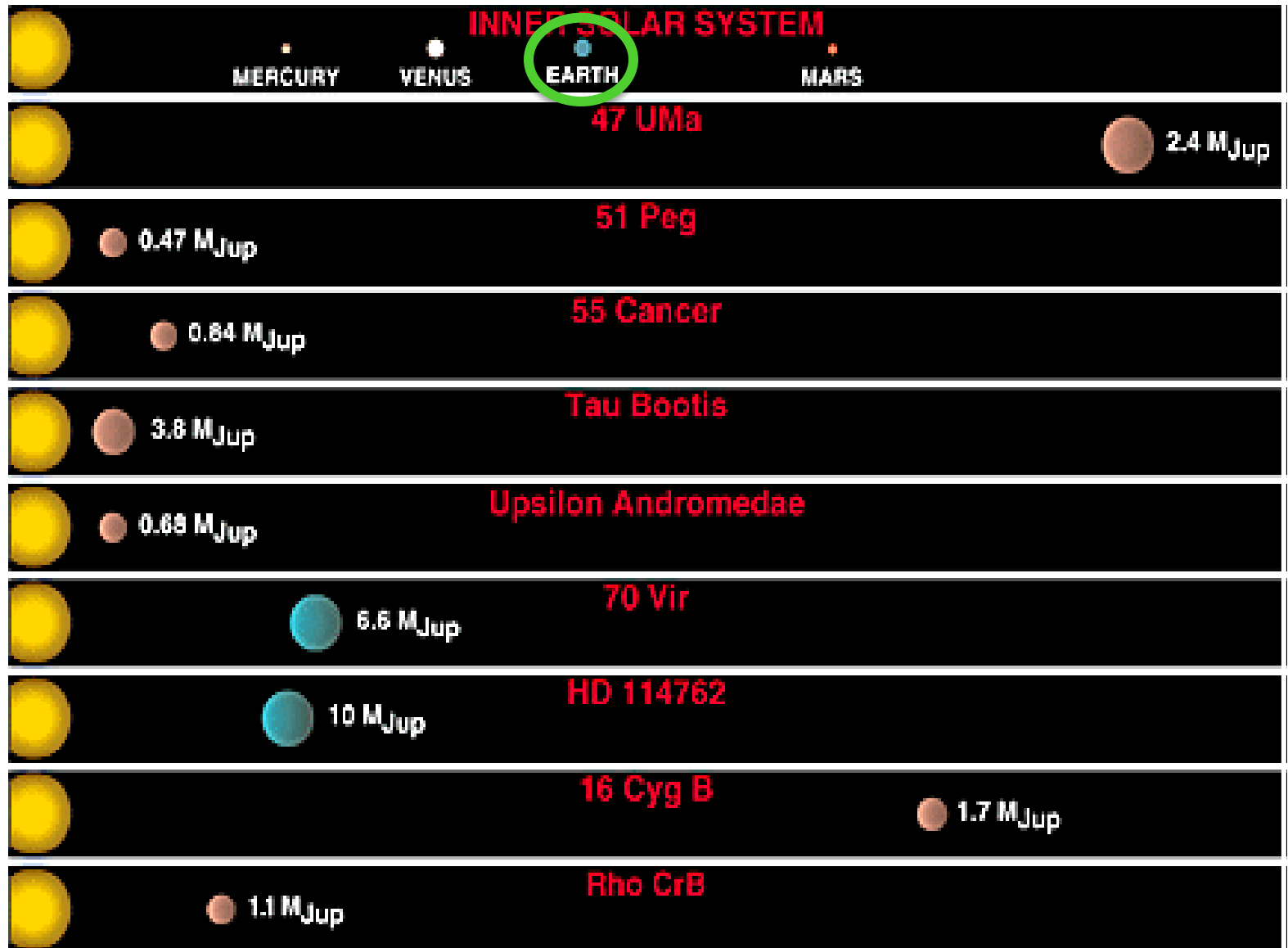
490 planets around other stars

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

STAR

INCREASING DISTANCE FROM STAR →
you are here

Solar
System



other
planetary
systems

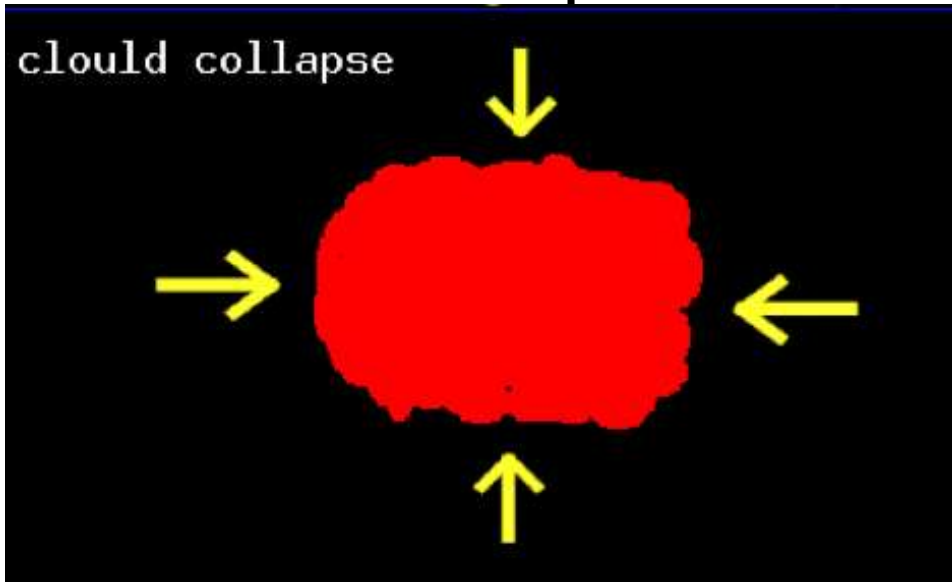
how do we put humpty dumpty
together again?

how to build a solar system I of 7

according to Hal Levison et al.

Stage 1

cloud
collapse

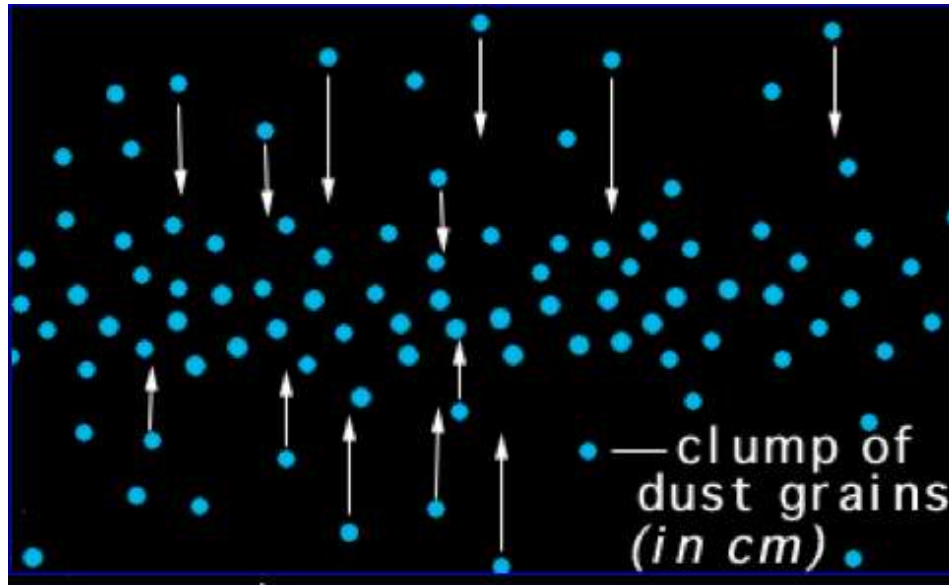


how to build a solar system 2 of 7

according to Hal Levison et al.

Stage 2

Disks form

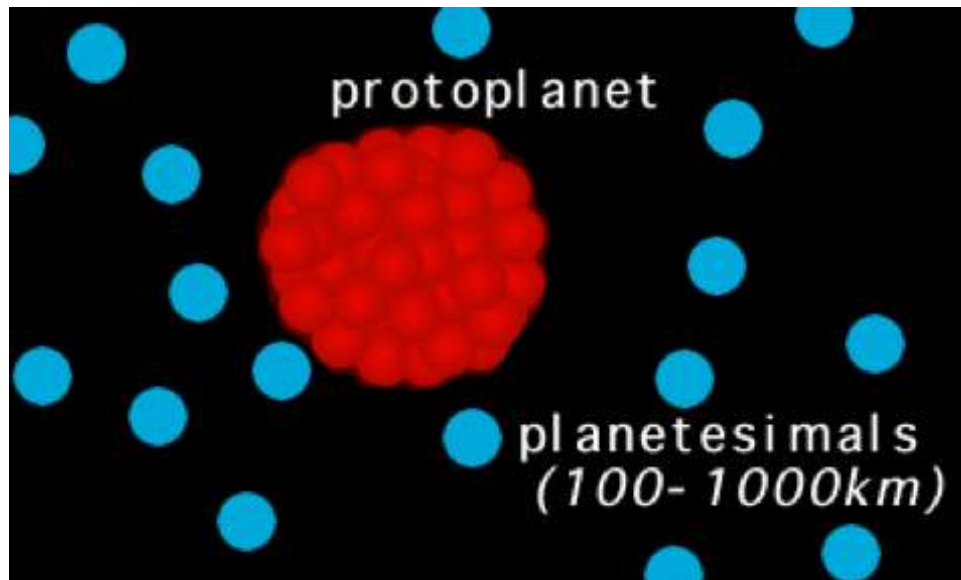


Composite by Emily Lackdawalla
The Planetary Society

how to build a solar system 4 of 7

according to Hal Levison et al.
Stage 4

protoplanets form



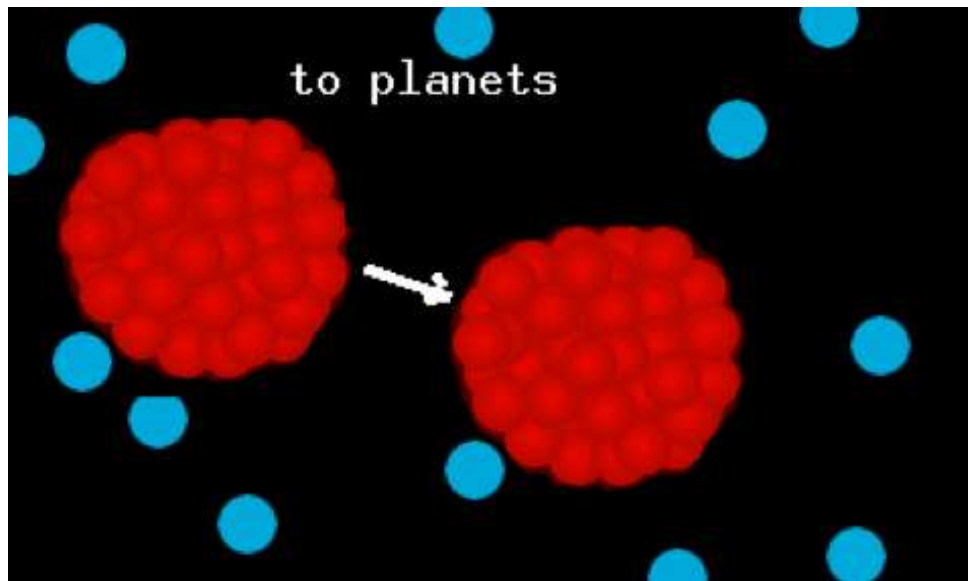
NASA, ESA, JPL, and A. Feild (STScI)

how to build a solar system 5 of 7

according to Hal Levison et al.

Stage 5

planets form



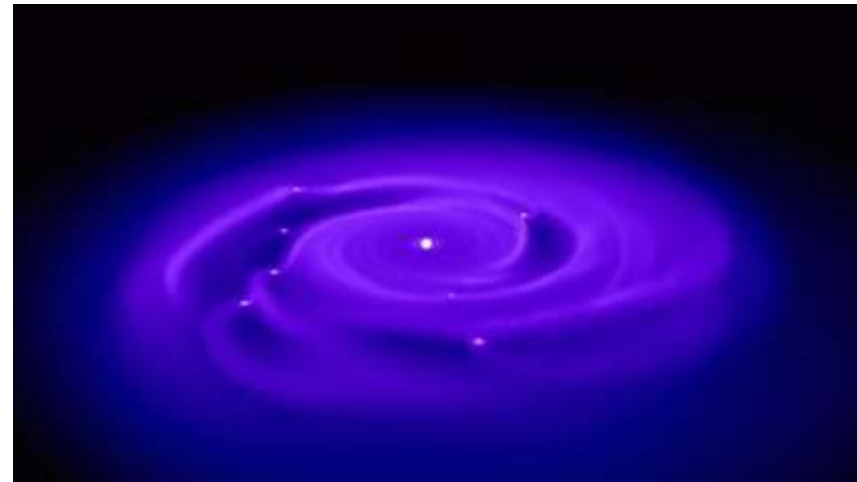
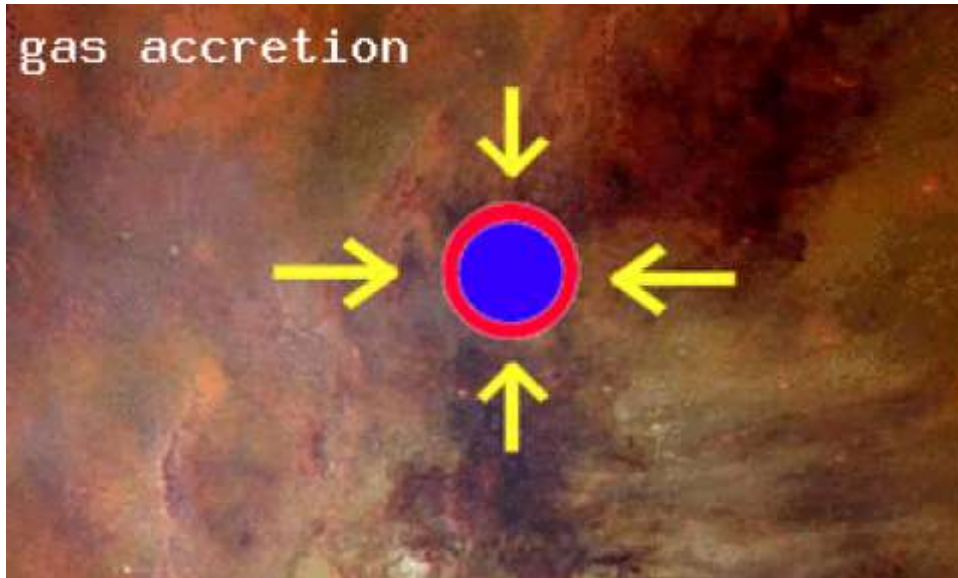
Artist's concept; credit: NASA/JPL-Caltech

how to build a solar system 6 of 7

according to Hal Levison et al.

Stage 6

gas accretion

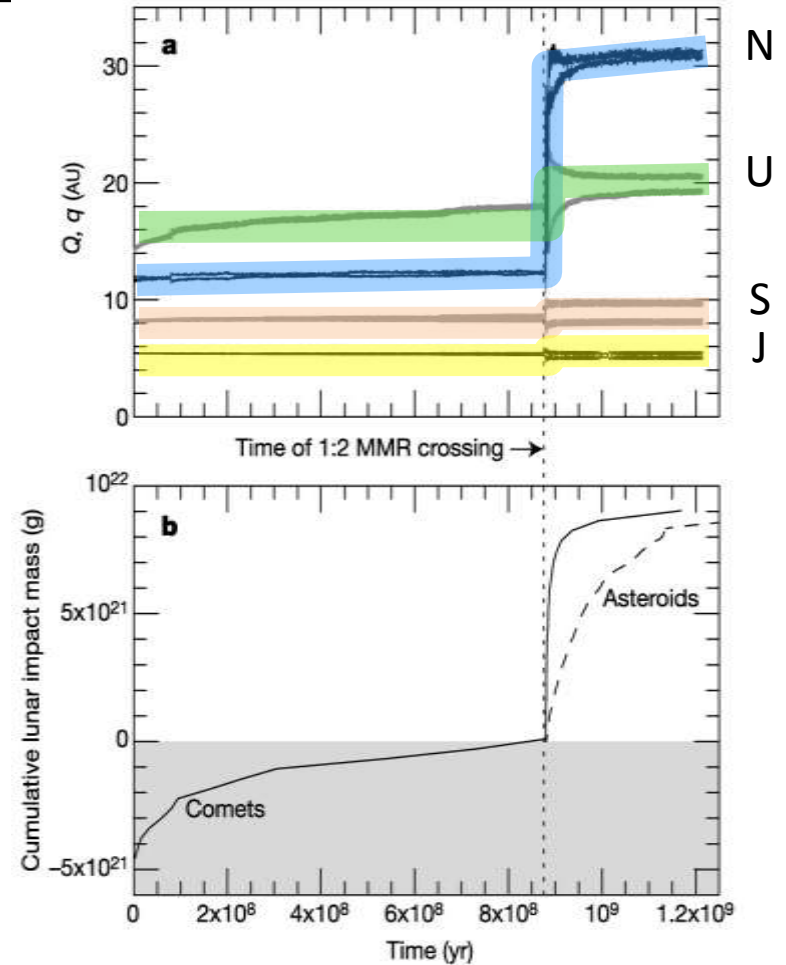
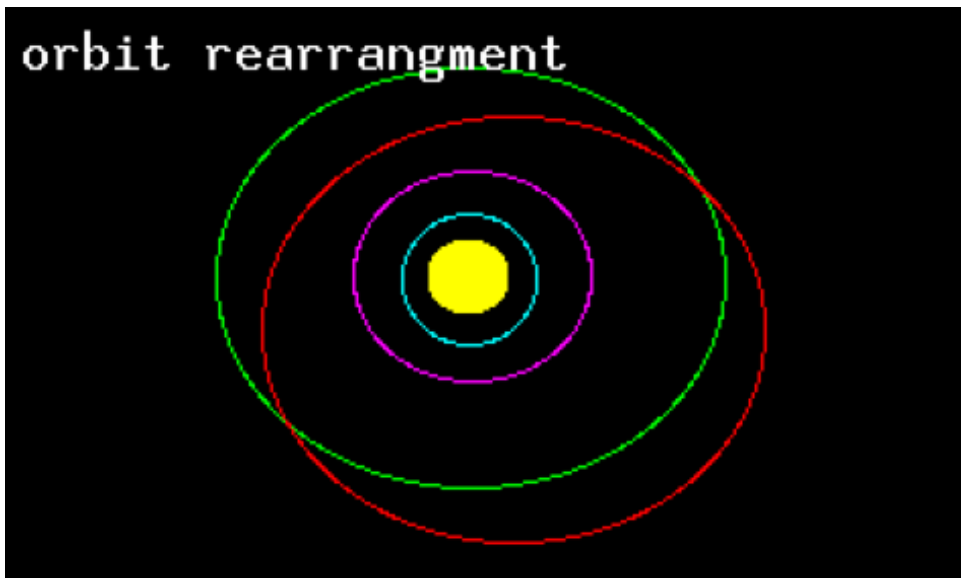


Simulation credit: Thomas Quinn, U. Washington

how to build a solar system 7 of 7

according to Hal Levison et al

Stage 7 dynamical



solar system formation is
complex and messy

smooshing and smashing!
whooshing and crashing!

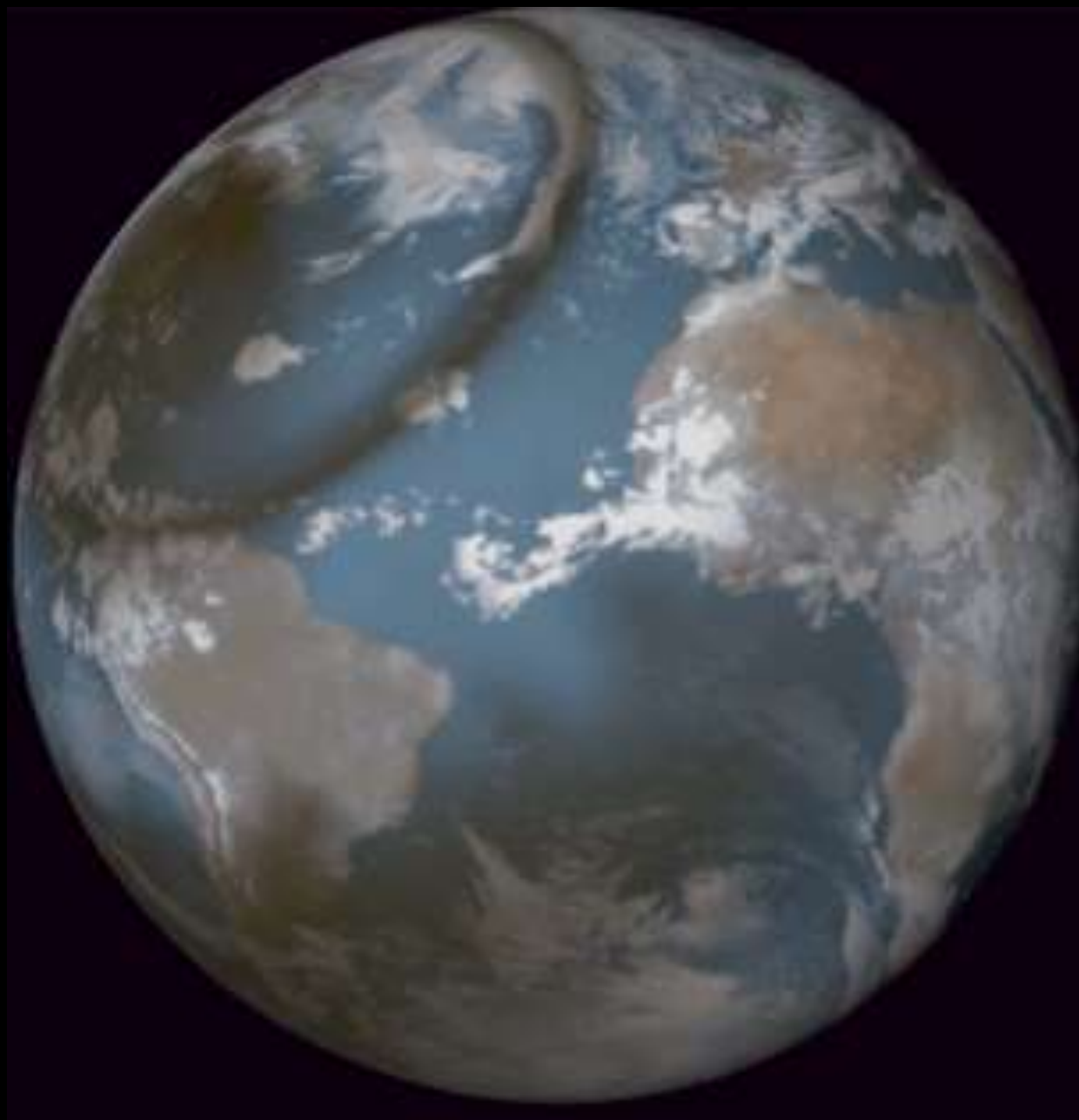
understanding solar system
formation very much a work in
progress

AND FURTHERMORE...

THE SOLAR SYSTEM
ITSELF IS A WORK IN
PROGRESS



impacts
happen
NOW





First
Hubble
science
image
with
WFC3

July 2009

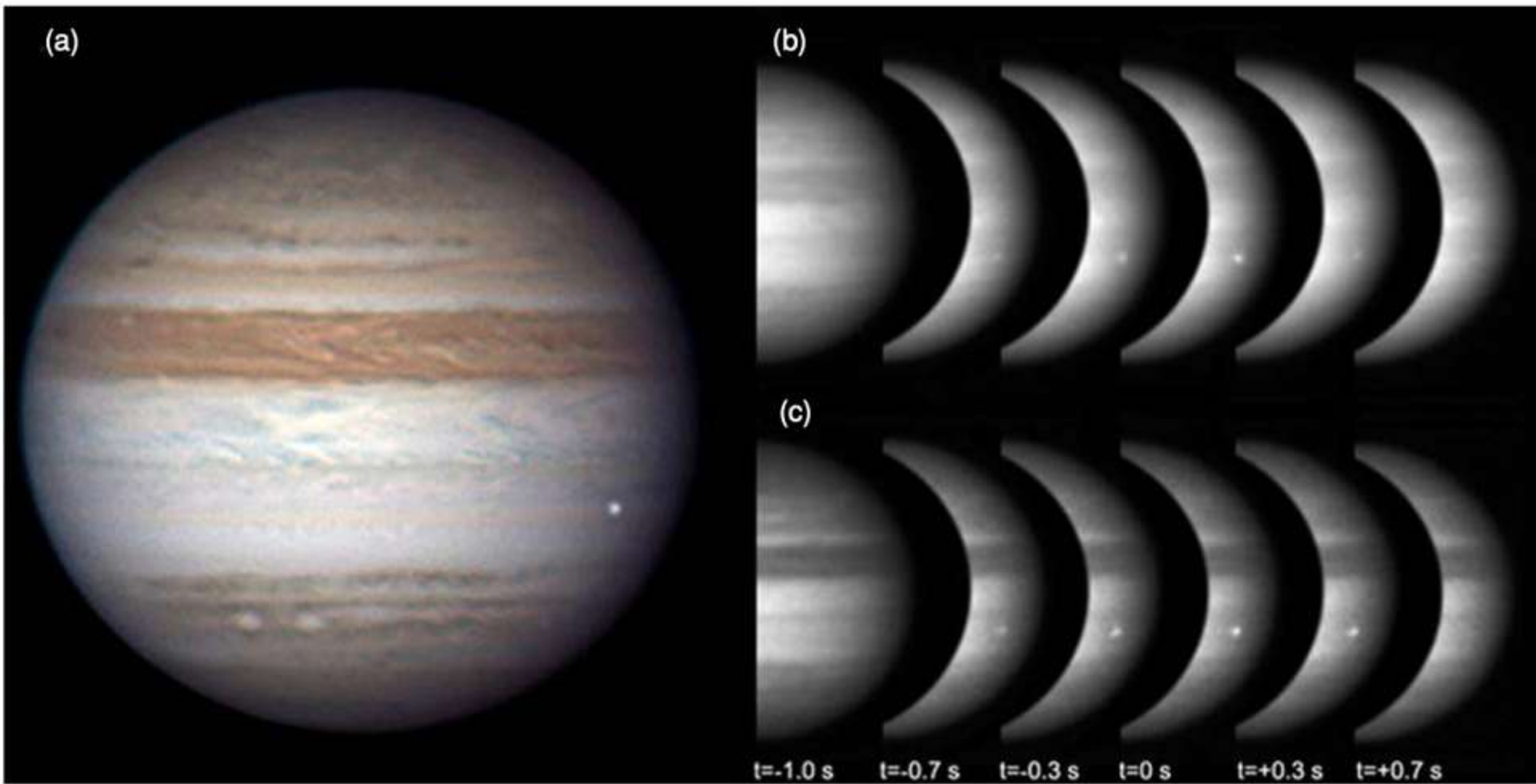


10,000 mi

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

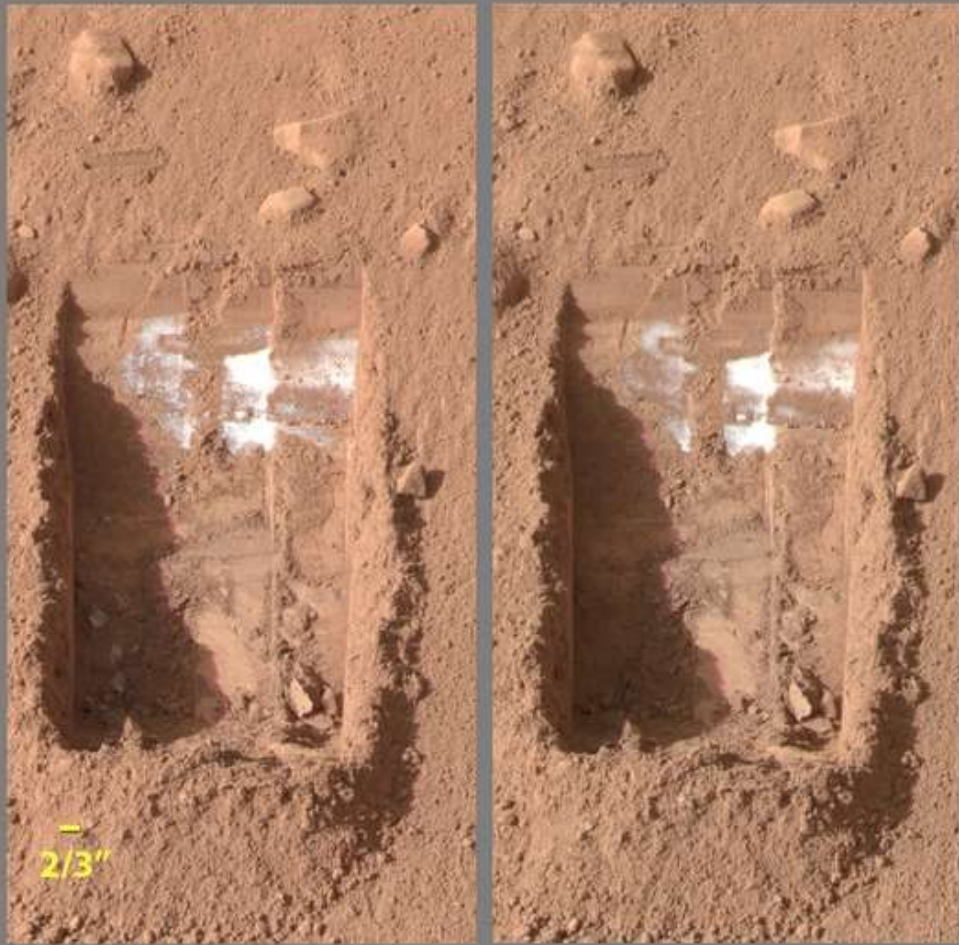


81P/Wild 2
 $5.5 \times 4.0 \times 3.3$ km
Stardust, 2004

delivering water, everywhere

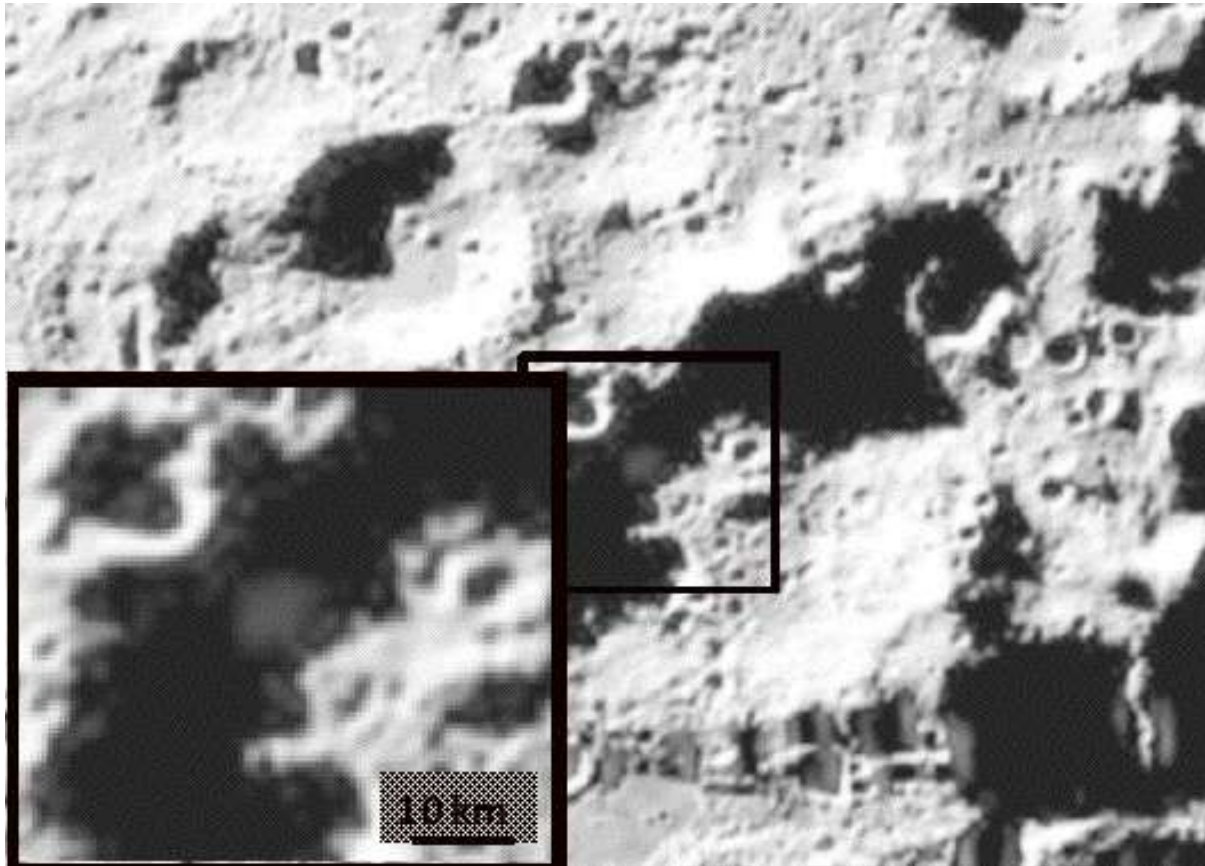
Sol 20

Sol 24

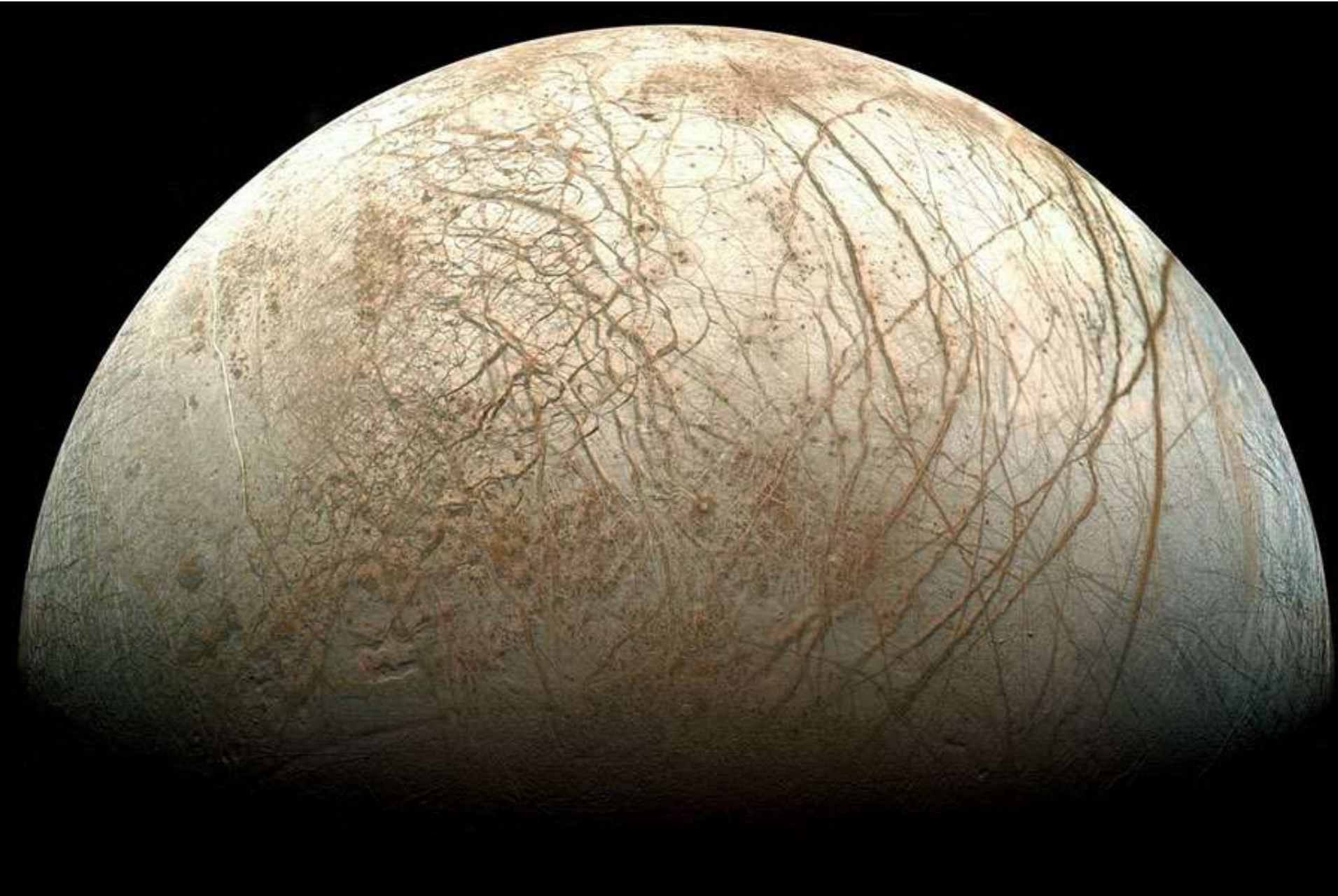


Phoenix Lander on Mars

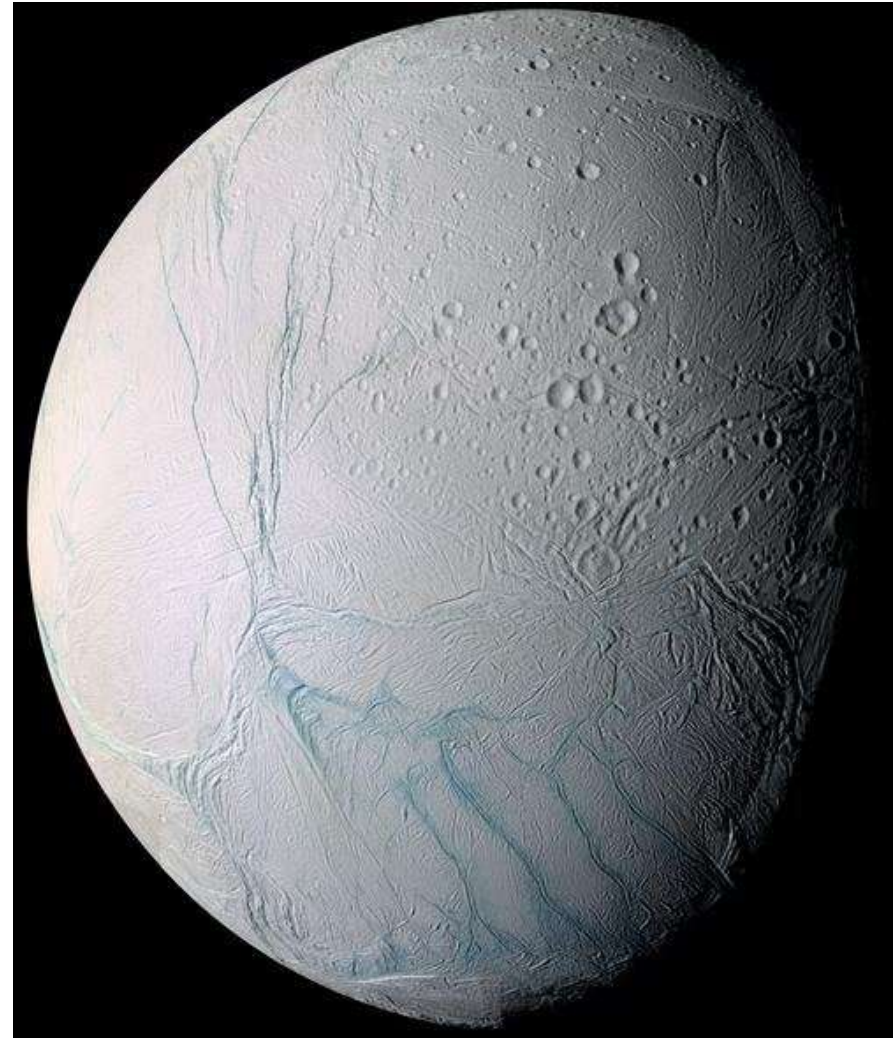
water on the moon



speaking of WATER



we *were* talking about
WATER, right?



planetary evolution

Jupiter ■ *Hubble Space Telescope WFC3/UVIS*



July 23, 2009



June 7, 2010

NASA, ESA, M. H. Wong (University of California, Berkeley), A. A. Simon-Miller (Goddard Space Flight Center),
H. B. Hammel (Space Science Institute, Boulder, Colo.), and the Jupiter Impact Science Team ■ STScI-PRC10-20b

planetary evolution science and social networking



The image is a screenshot of a Facebook profile page. The top navigation bar is blue with the Facebook logo on the left, followed by icons for friends, messages (with a red '3' badge), and events (with a red '20' badge). A search bar is on the right. The left sidebar shows the user's profile picture (a green cartoon character), name 'Heidi B. Hammel', and 'Edit My Profile' link. Below this are links for 'News Feed', 'Messages' (with a '75' badge), 'Events' (with a '31' badge), and 'Friends'. The main content area is titled 'News Feed' with a 'Top News • Most Recent' filter. A text box prompts 'What's on your mind?'. A post by 'Christopher Go' is visible, featuring a photo of him and text about a 'SEB revival' on Jupiter. The post includes a URL: <http://astro.christone.net/jupiter>.

facebook

Search

Heidi B. Hammel
Edit My Profile

News Feed

Messages 75

Events 31

Friends

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

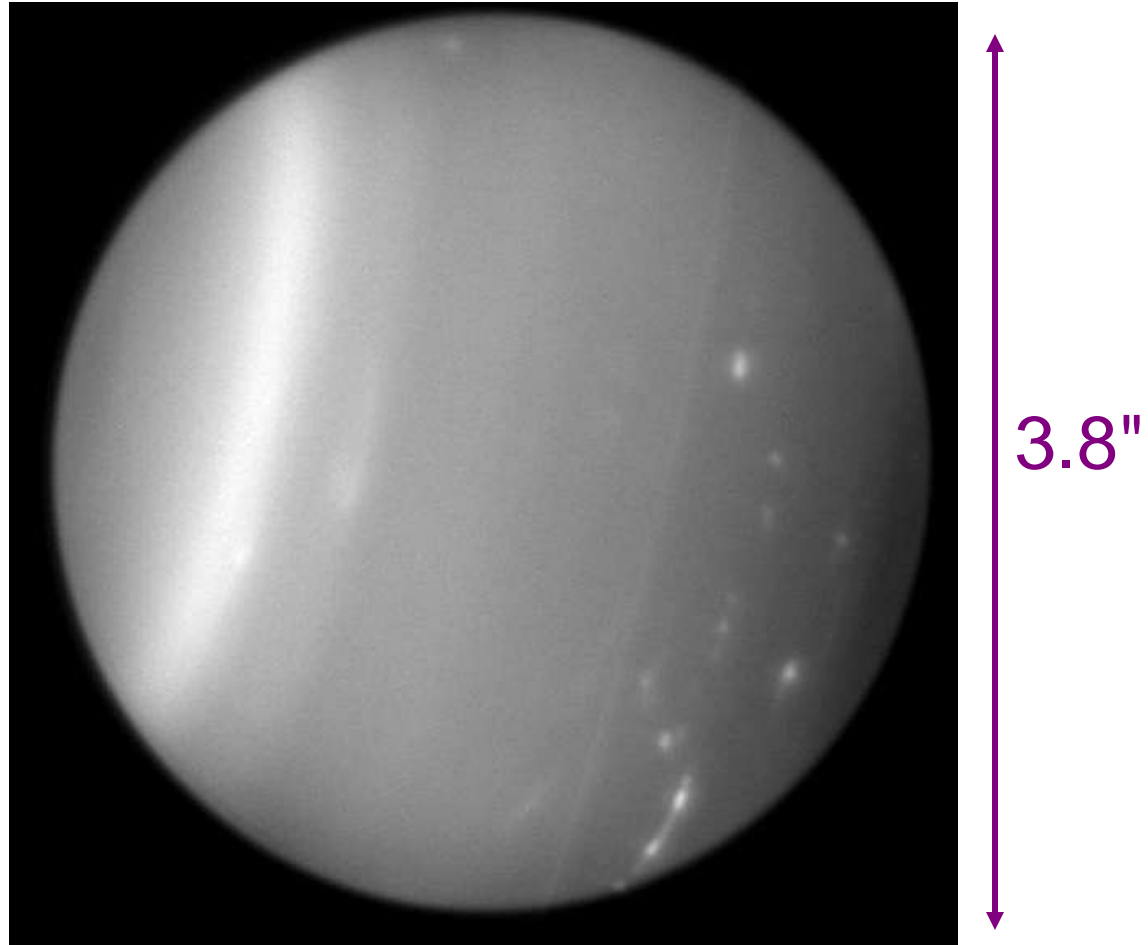


voyager uranus in 1986

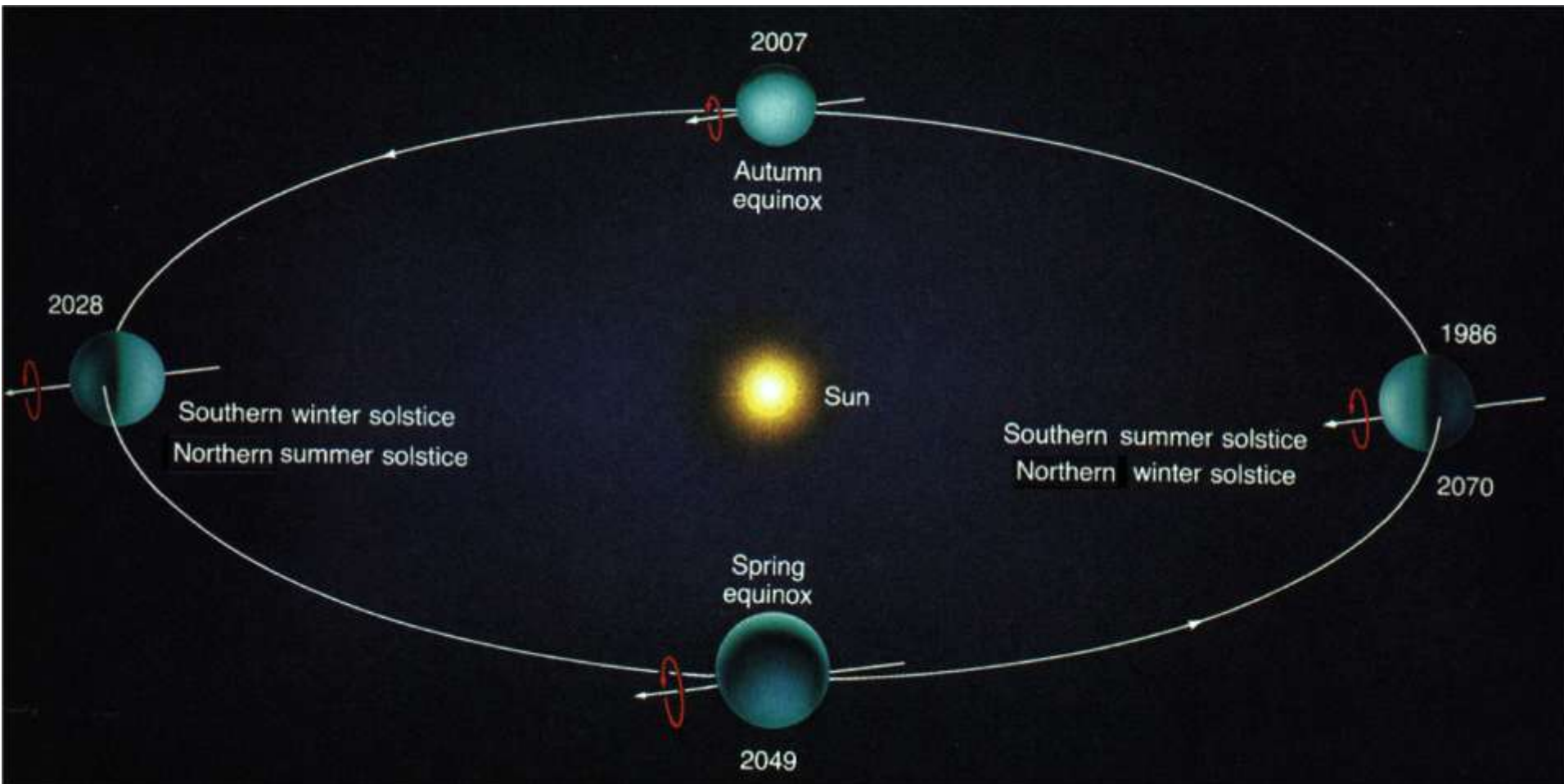


3.8"

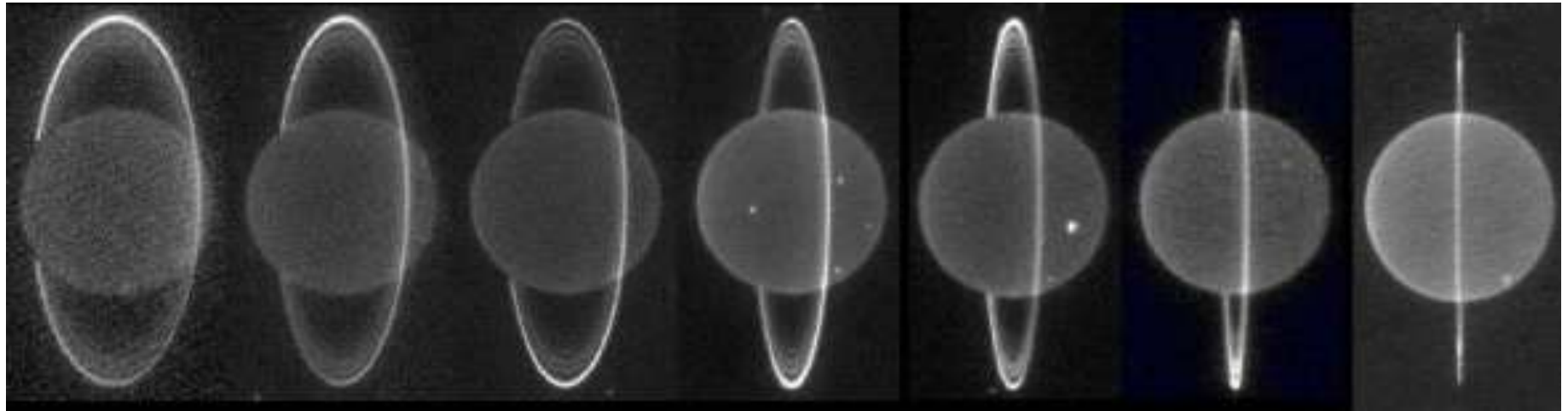
keck uranus in 2004



seasonal change



evolving rings



2001

2002

2003

2004

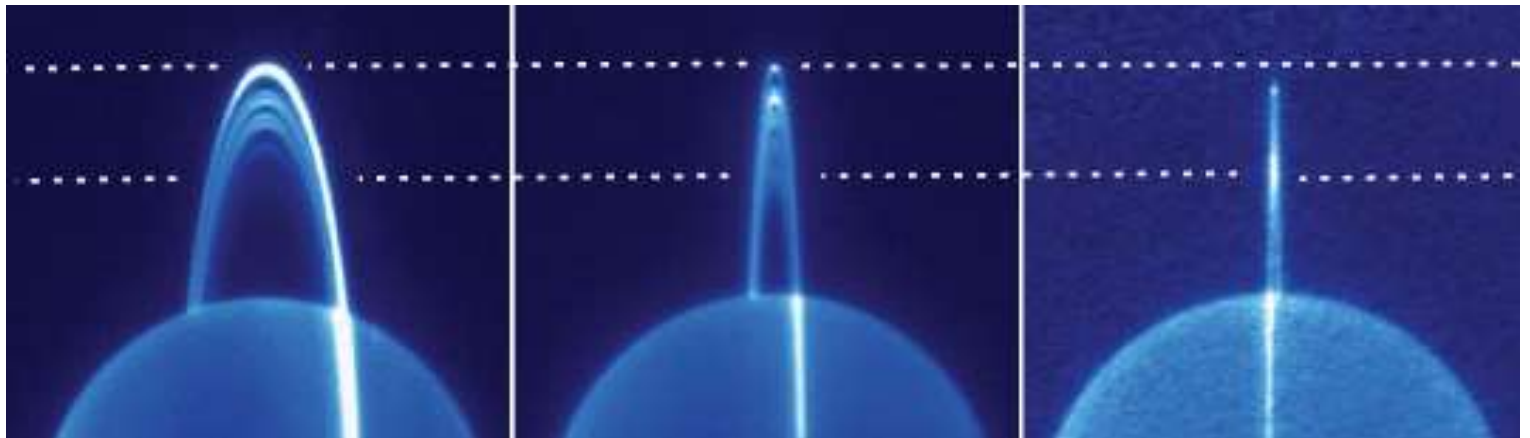
2005

2006

2007

ϵ (epsilon)

ζ (zeta)

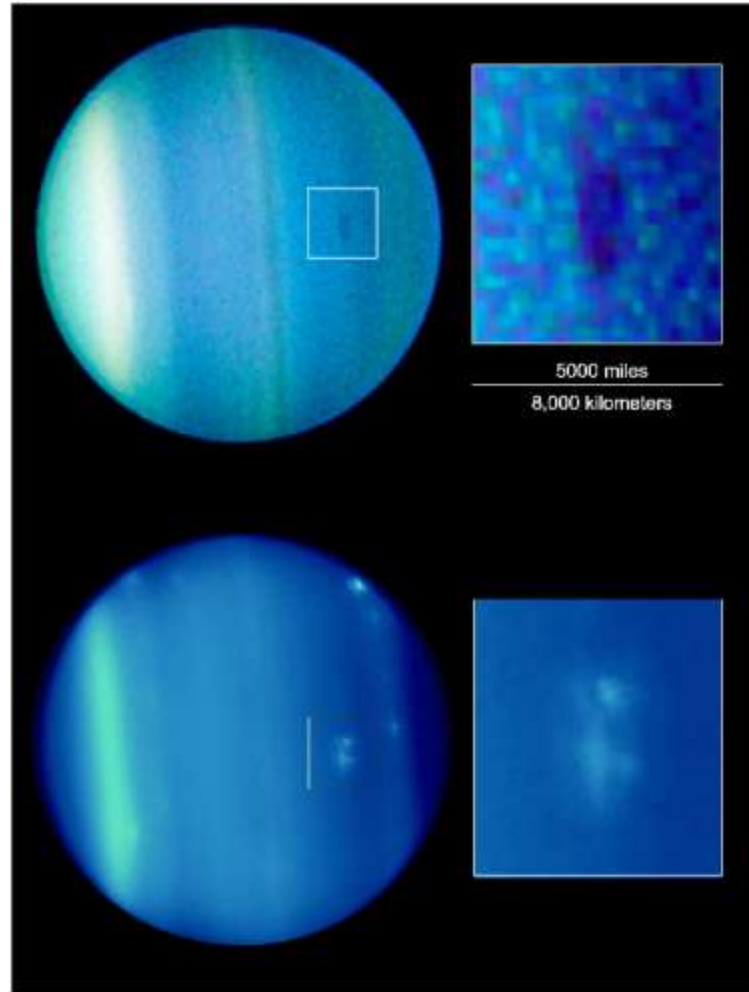


2004

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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Science News - The New York Times

HOMEPAGE TODAY'S PAPER VIDEO MOST POPULAR TIMES TOPICS

The New York Times
Tuesday, November 9, 2010

Science

Search All NYTimes.com

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ENVIRONMENT SPACE & COSMOS

nytimes.com/pages/science

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.

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

BROWSE TOPICS
Pick a Topic

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CUBIST
PHARMACEUTICALS

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



Christopher Cappozzello 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

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

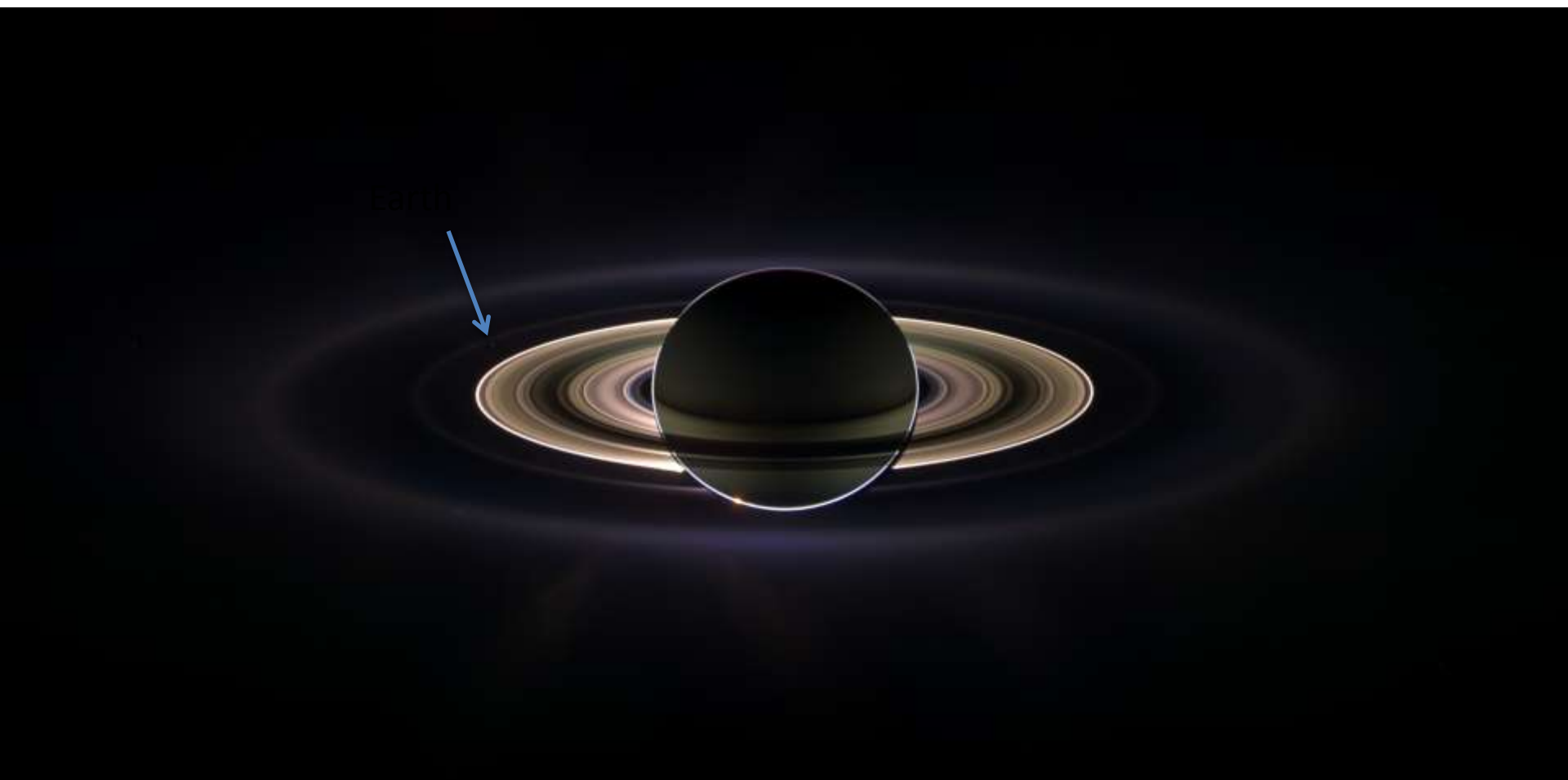
Mid 2012 - Mars Opportunity Rover at Endeavour Crater!

Mid 2012 - Dawn leaves Vesta for its journey to Ceres

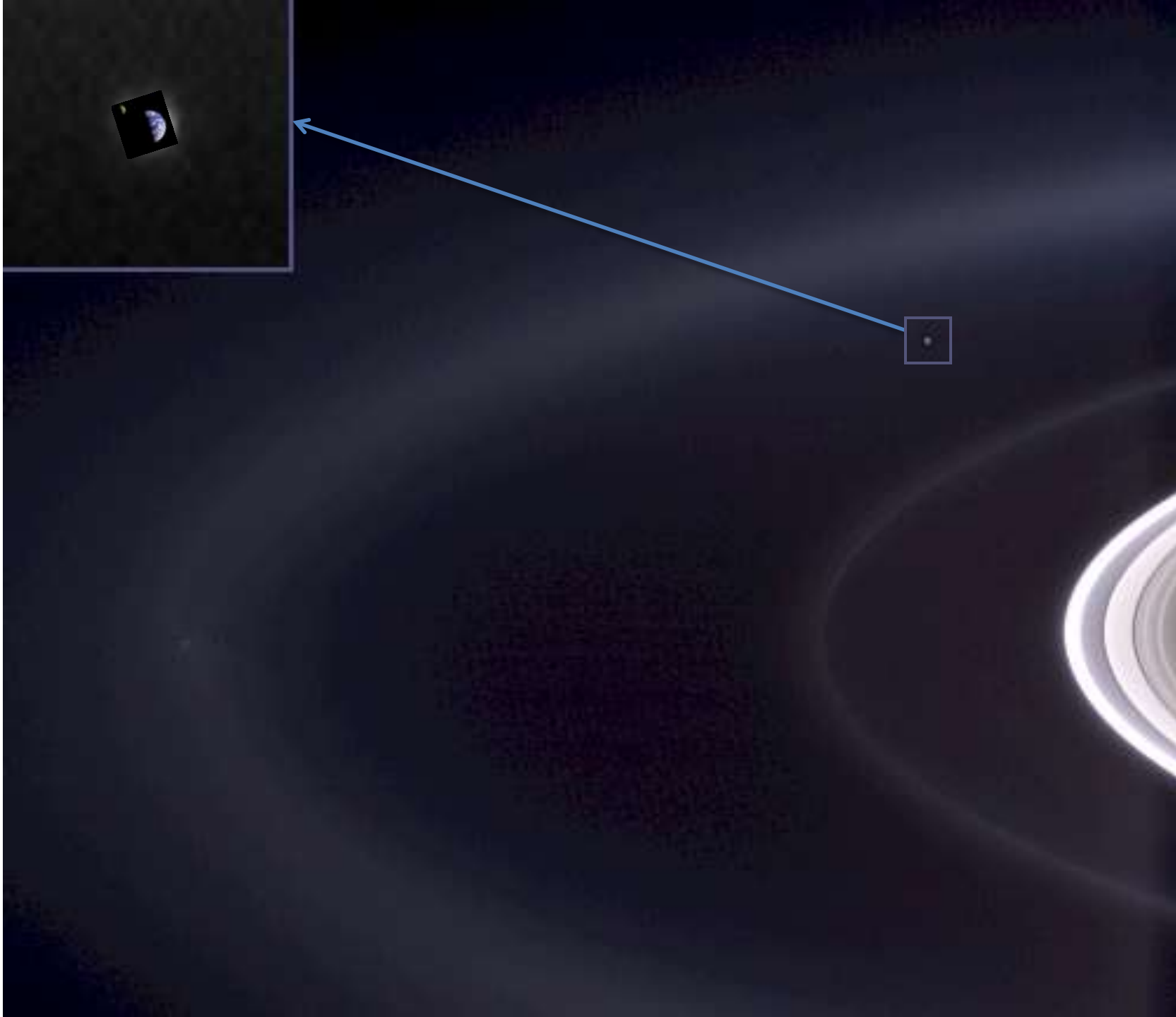
August - MSL lands on Mars

far future?





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'