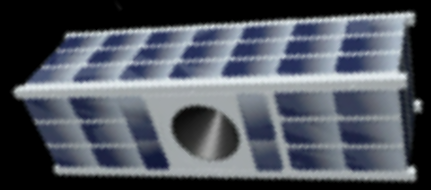
Massachusetts Institute of Technology



Planetary Science: Unique Space Science from Small Satellites

Professor Sara Seager, MIT

Keck Institute for Space Studies Workshop

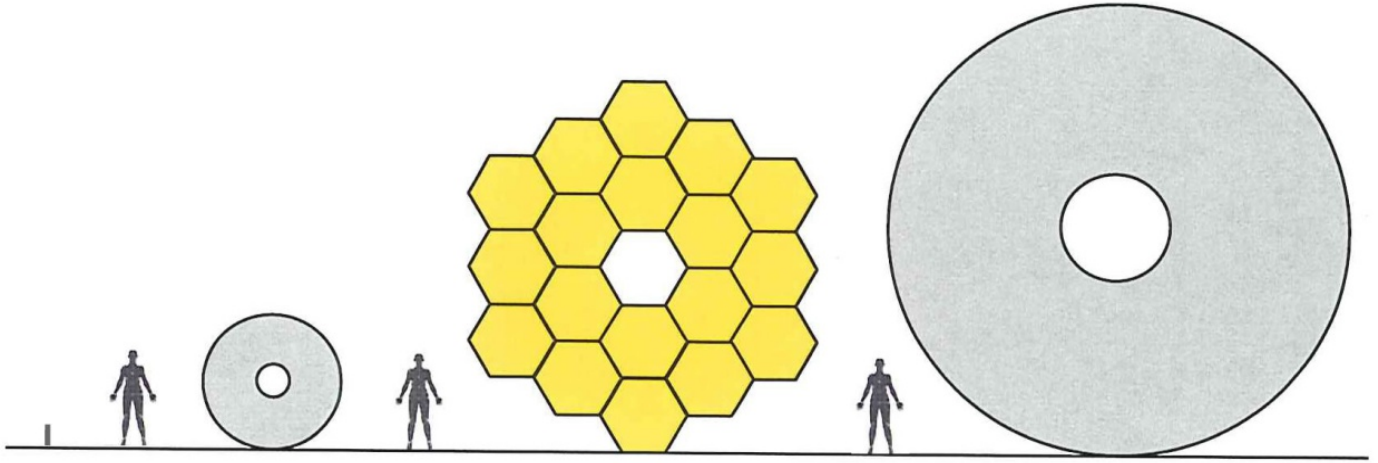
Small Sats: A Revolution in Space Science, July 2012

Acknowledgements: Mary Knapp, Vlada Stamenkovic

High Impact Planetary Science in an iCubeSat Era

- Search for Exoplanets around the Brightest Sun-like Stars
- Characterize Interior Composition of Small Bodies and Moons
- Search for Life in the Solar System

Flagship vs. CubeSat



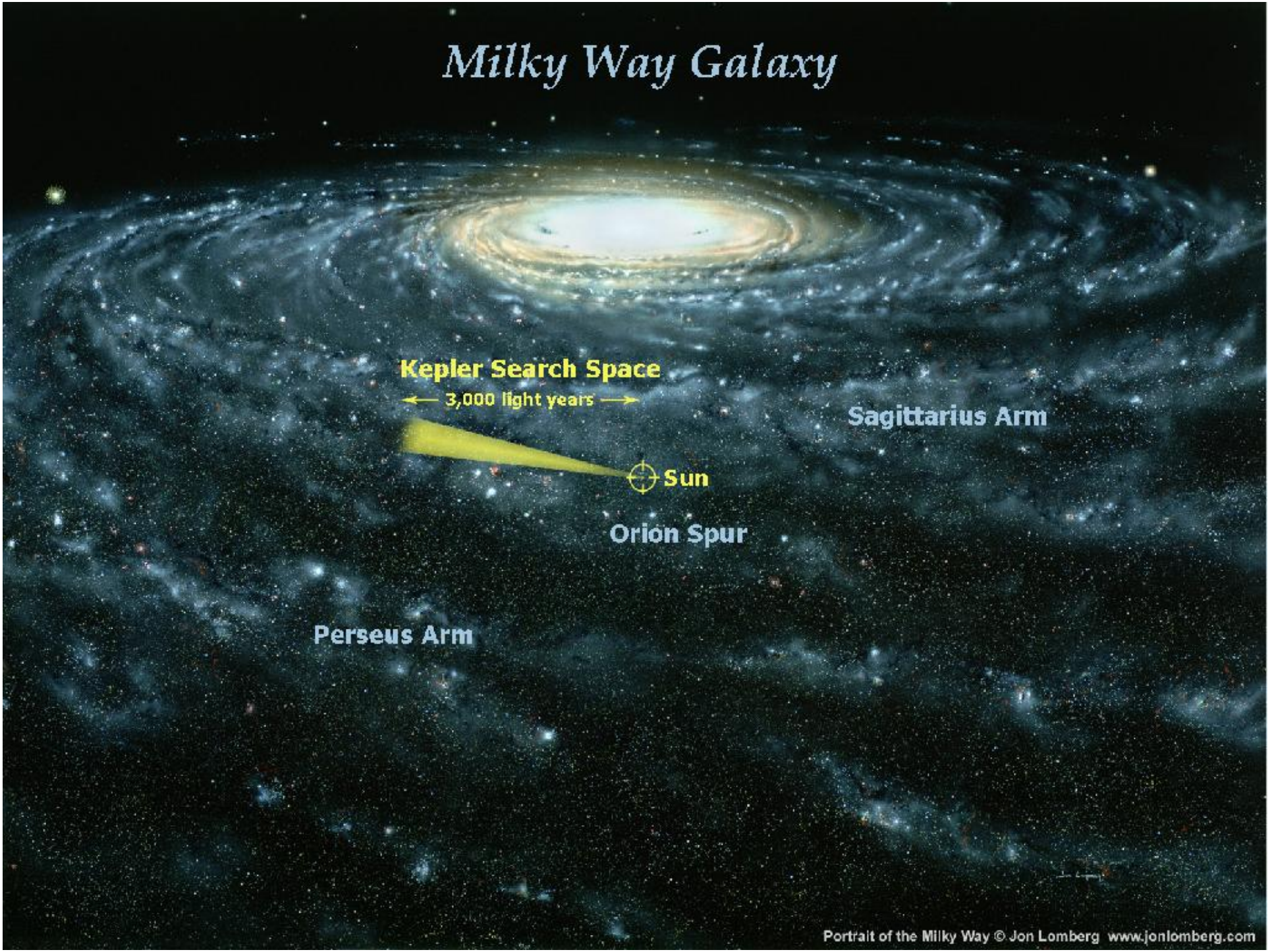
ExoplanetSat
85 mm
Cost 5 M
Sched. 2014

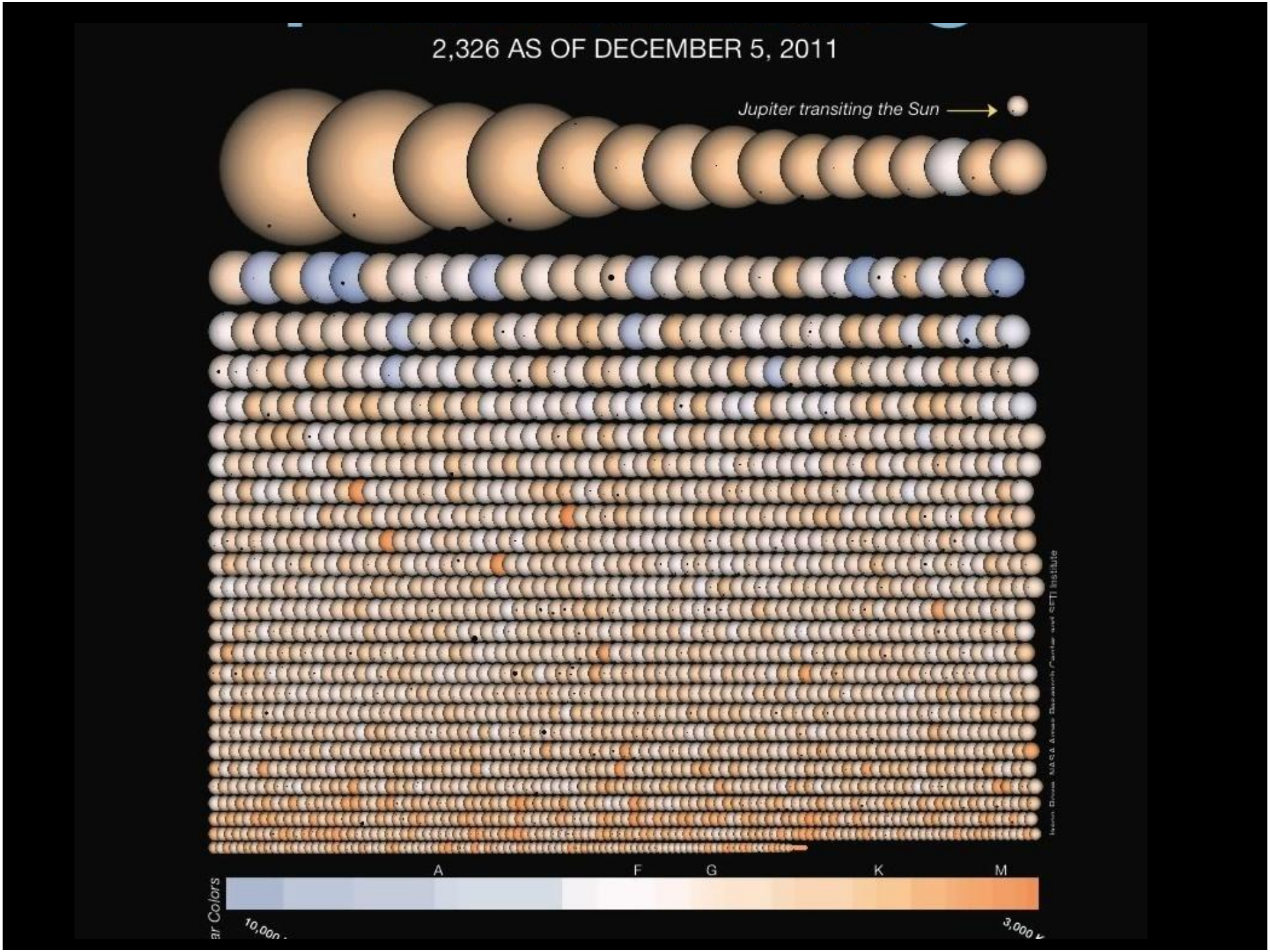
Fleet: ~30 M

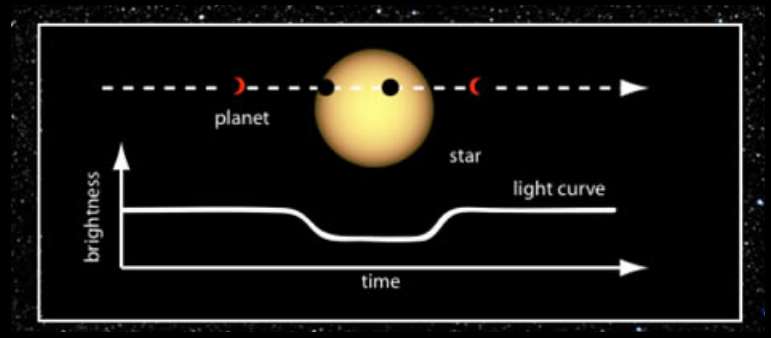
Hubble
2.4 m
Cost > 6B

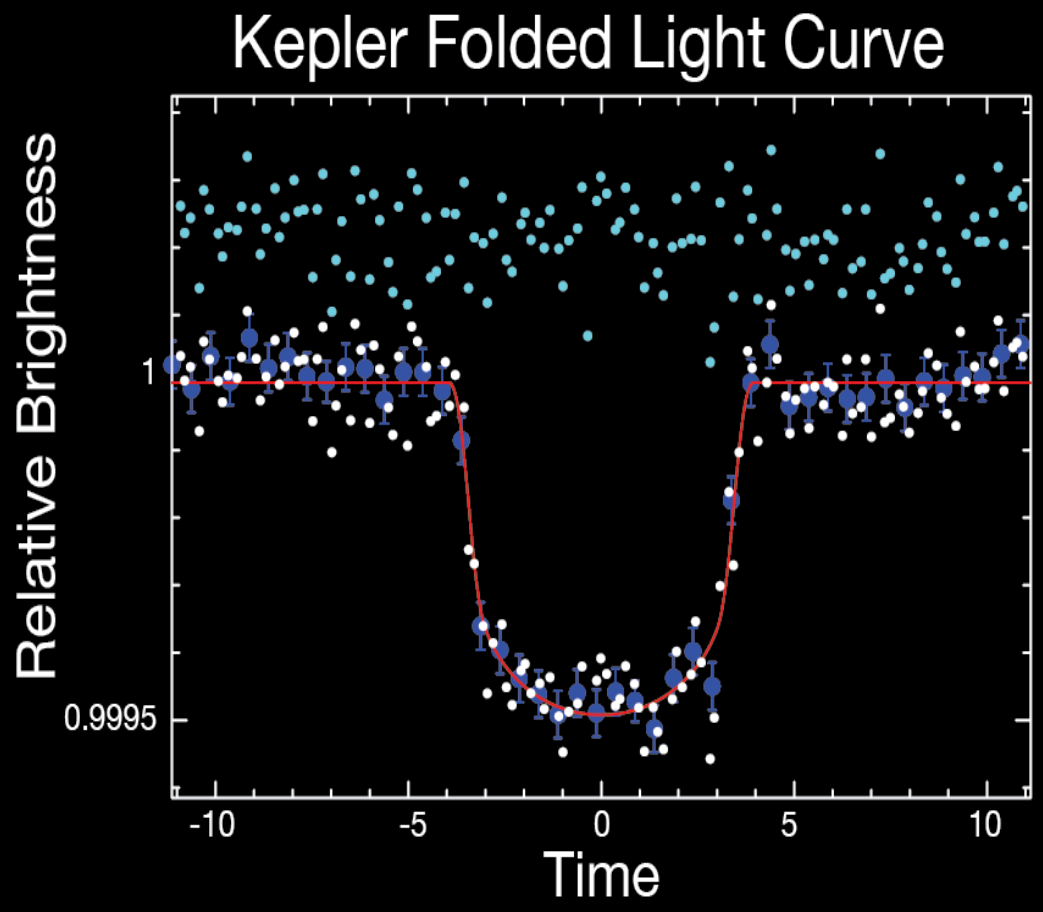
JWST
6.5 m
Cost 8B
Sched. 2018

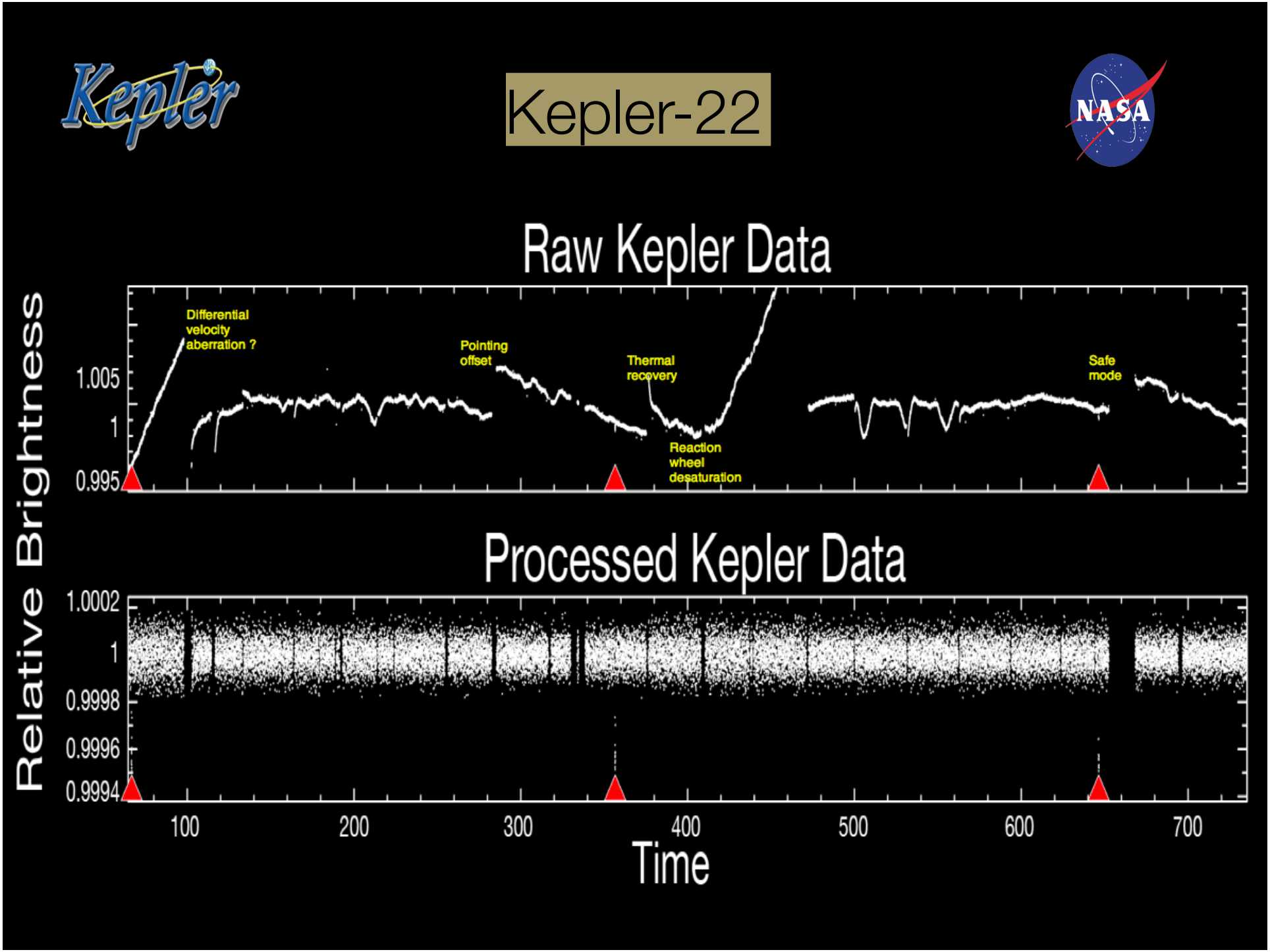
ATLAS
8 m
NASA Concept


Milky Way Galaxy
Kepler Search Space
3,000 light years
Sagittarius Arm
Sun
Orion Spur
Perseus Arm
Portrait of the Milky Way © Jon Lomberg www.jonlomberg.com

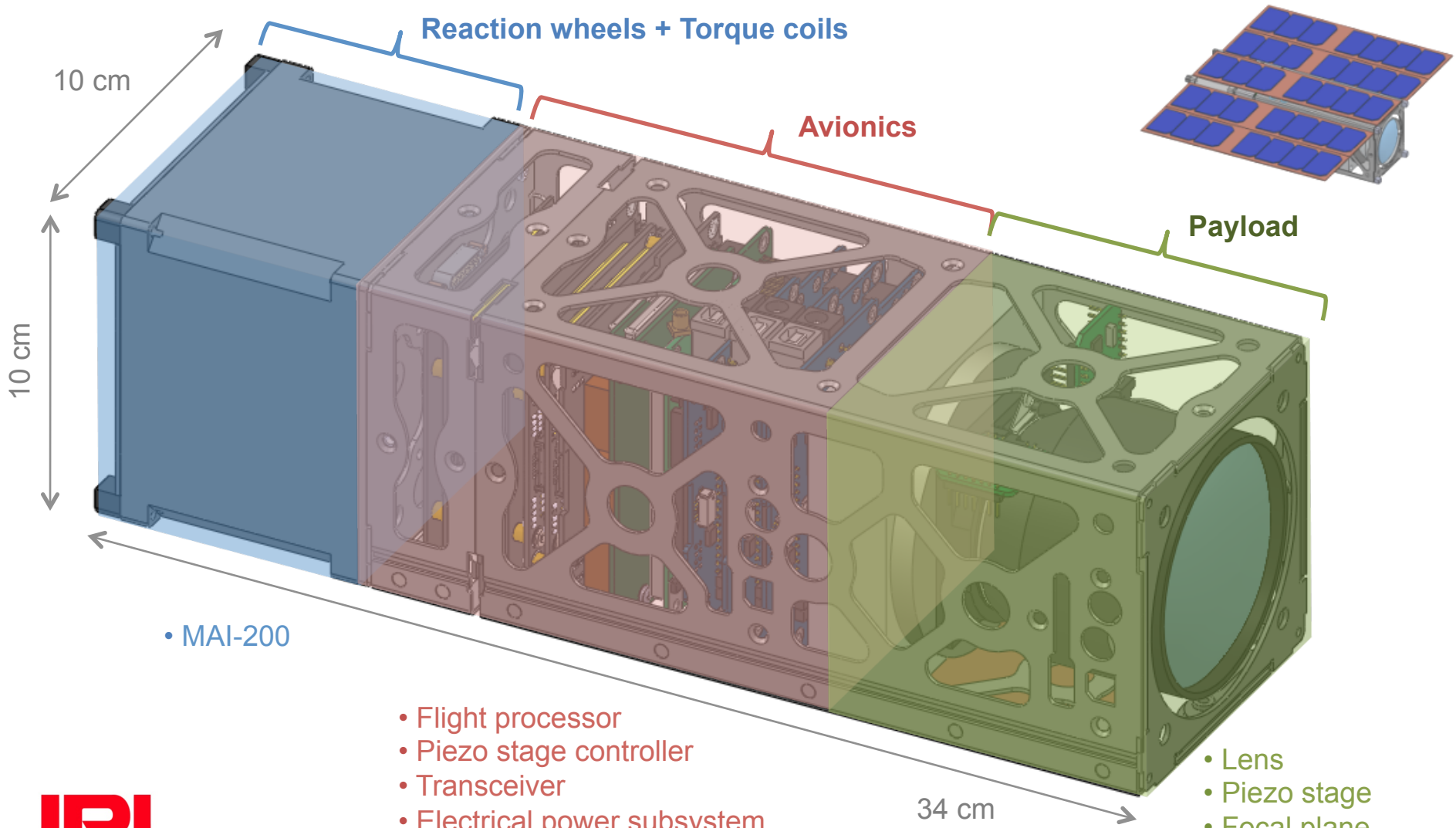

2,326 AS OF DECEMBER 5, 2011
Jupiter transiting the Sun
A
F
G
K
M
3,000
Jason Dixon, NASA Ames Research Center and SETI Institute


planet
star
light curve
brightness
time


Kepler Folded Light Curve
Relative Brightness
1
0.9995
-10
-5
0
5
10
Time


Kepler
Kepler-22
NASA
Raw Kepler Data
Differential velocity aberration ?
Pointing offset
Thermal recovery
Reaction wheel desaturation
Safe mode
1.005
1
0.995
Processed Kepler Data
Relative Brightness
1.0002
1
0.9998
0.9996
0.9994
100
200
300
400
500
600
700
Time

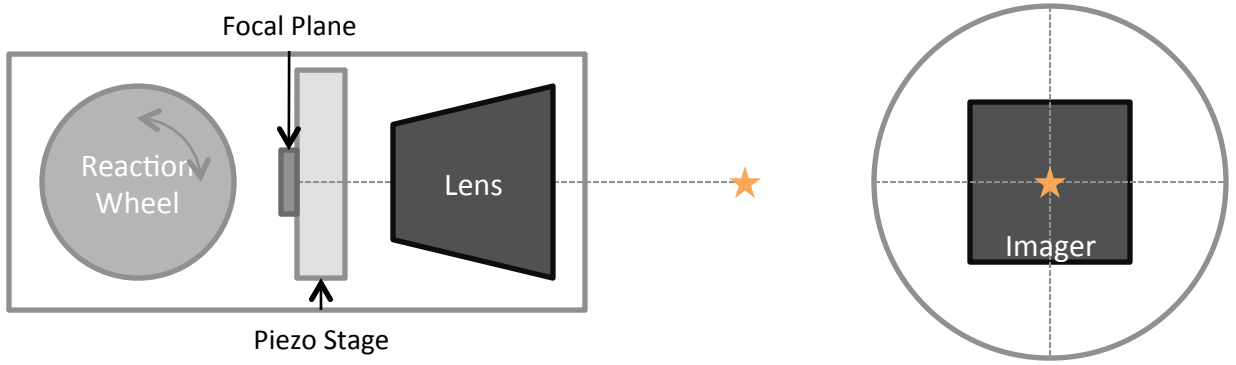
ExoplanetSat



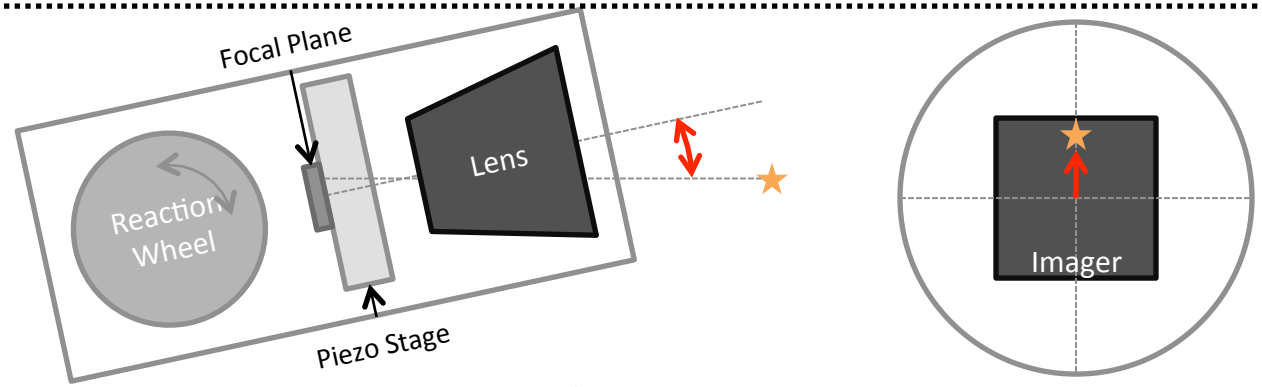
For an overview see Smith et al. 2010

Two-Stage Control Concept

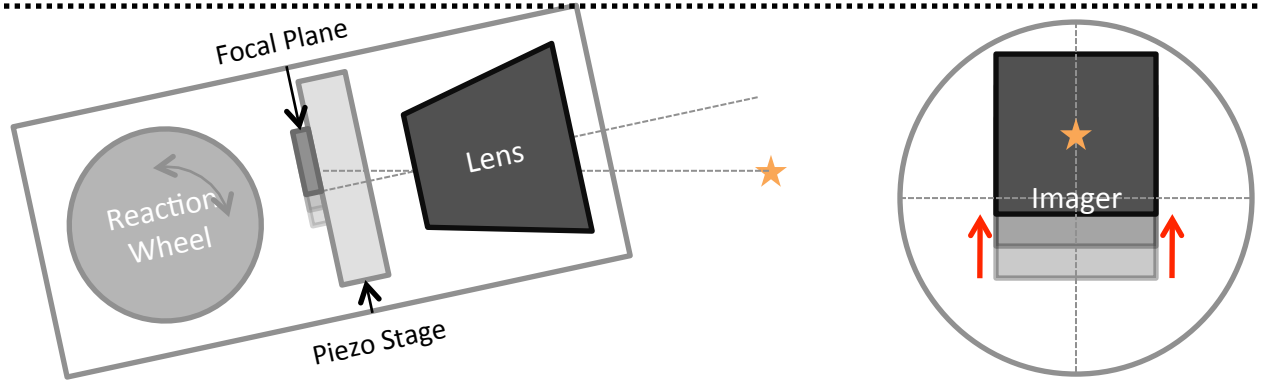
The **reaction wheels** point the spacecraft attitude towards the target star



With slight attitude errors, target star gets offset from boresight

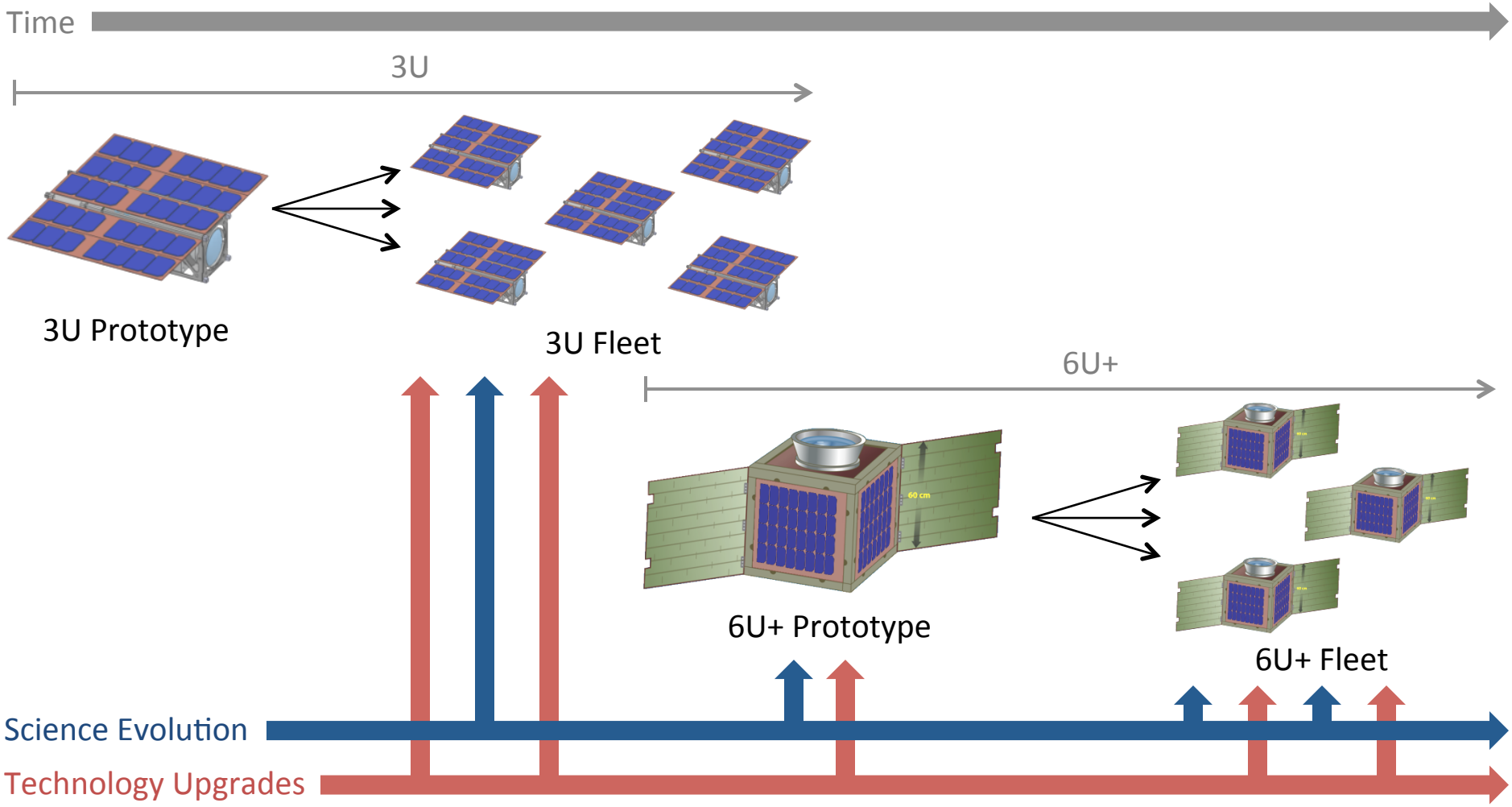


The **piezo stage** can compensate for attitude errors, by translating the imager



Lab-based demo has shown several arcsecond control. See Pong et al. 2010

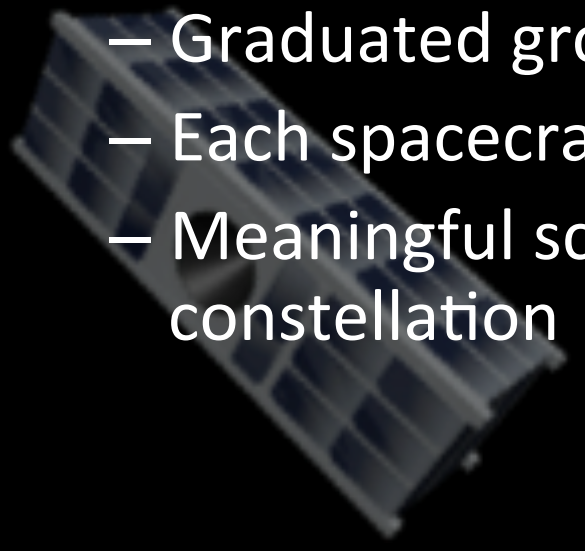
ExoplanetSat Mission Design



The ExoplanetSat 3U prototype lays the technological and scientific foundation for the graduated growth of a modular, extensible fleet of satellites observing bright stars for other Earths.

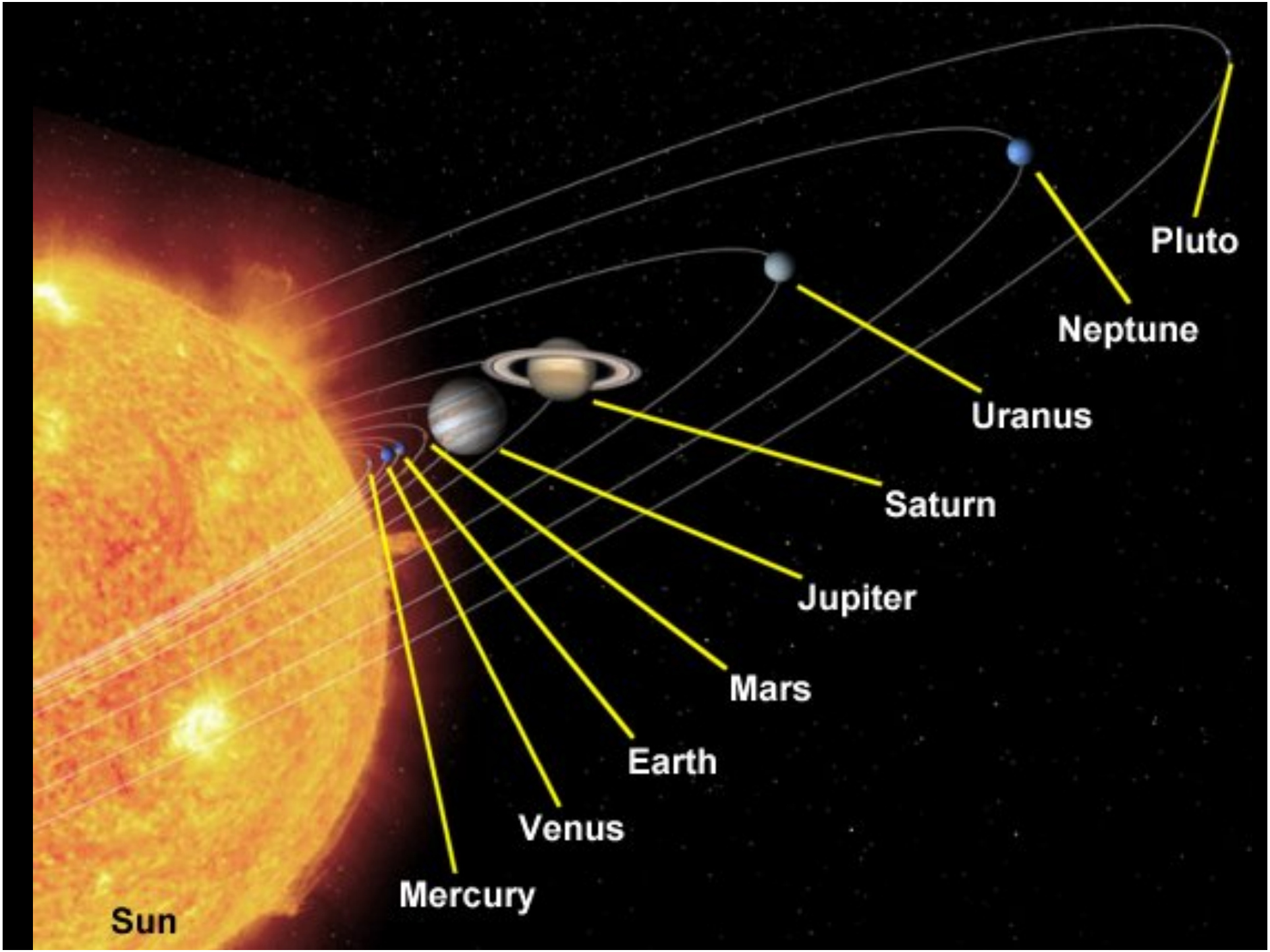
ExoplanetSat Lessons Learned

- A singular focused science goal
- Real science = complexity = cost
- Investment cost for first unit is 10 to 50 times that of most CubeSats
- A new paradigm for space science
  - Graduated growth of a constellation
  - Each spacecraft functions independently
  - Meaningful science achieved from the constellation



High Impact Planetary Science in an iCubeSat Era

- Search for Exoplanets around the Brightest Sun-like stars
- Characterize Interior Composition of Small Bodies and Moons
- Search for Life in the Solar System

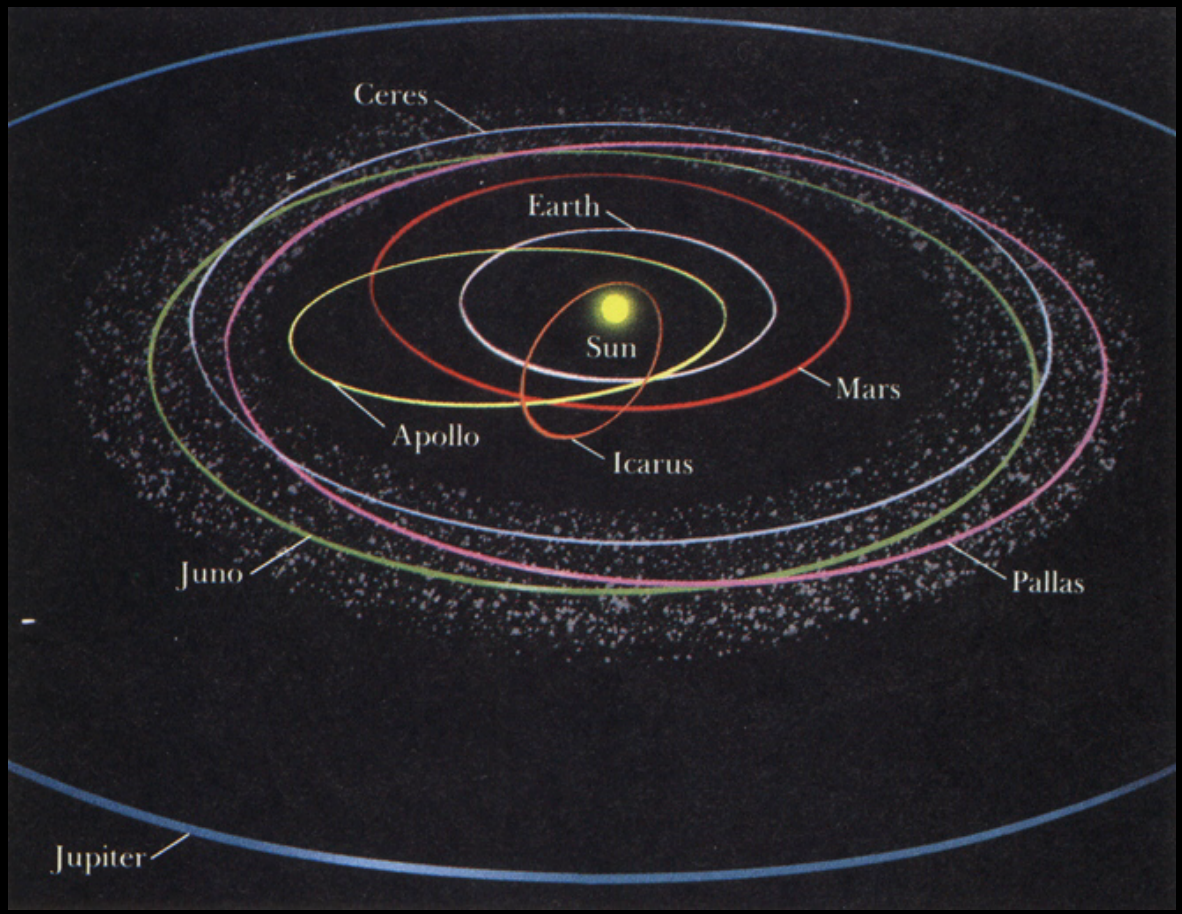

Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
Earth
Venus
Mercury
Sun

Asteroids: Friends or Foes?

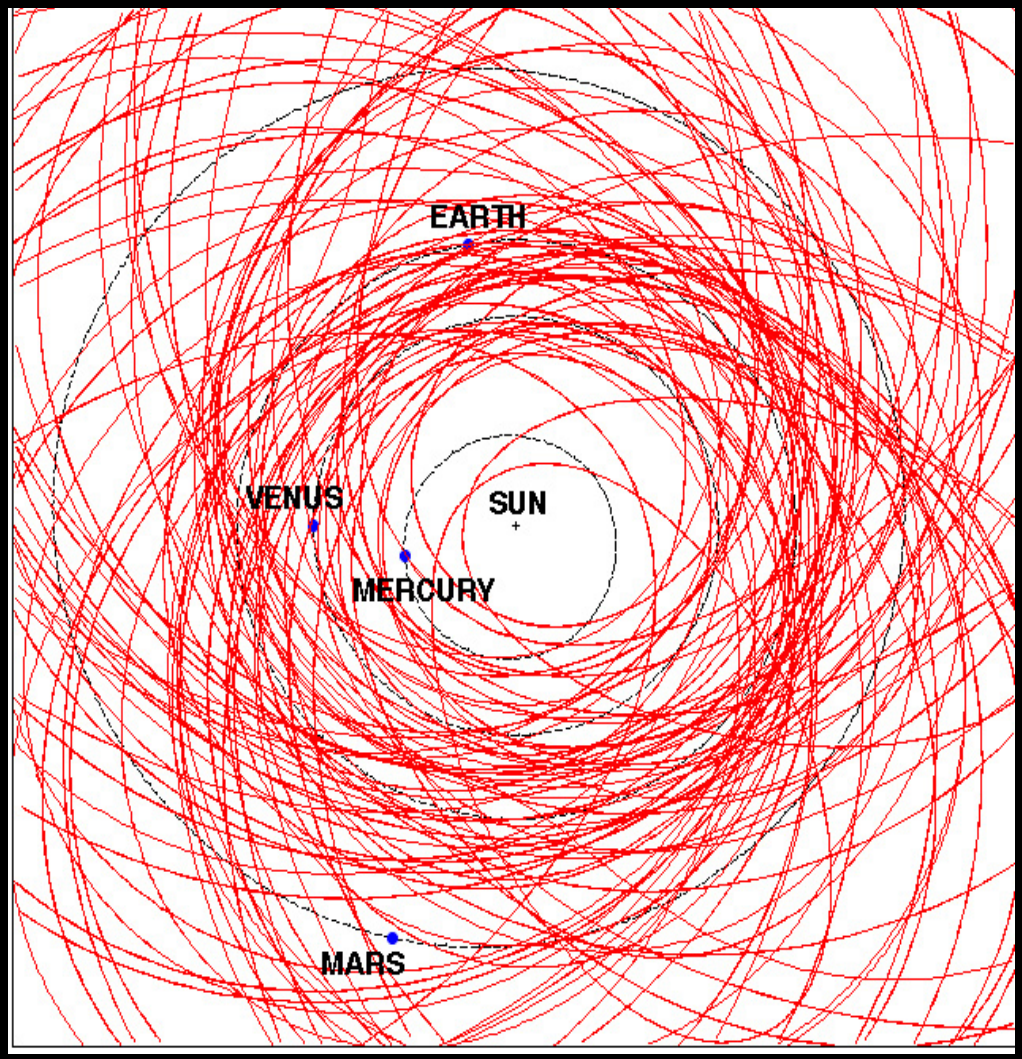
Asteroid 2012 KT 24 passed within 9 Earth radii of Earth on Monday May 28, 2012

Asteroids

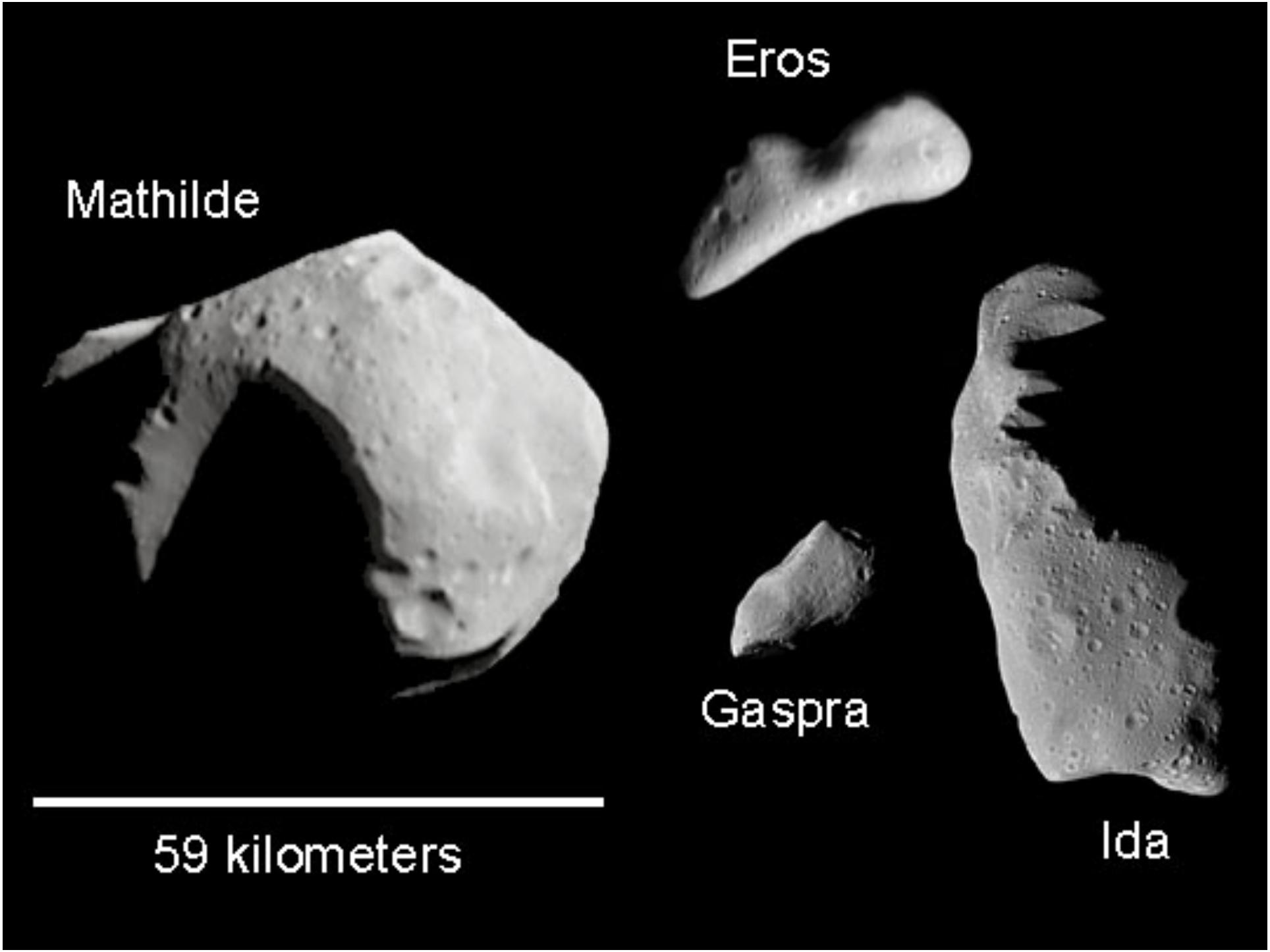
More than 500,000 known.
Most, but not all, between Mars and Jupiter

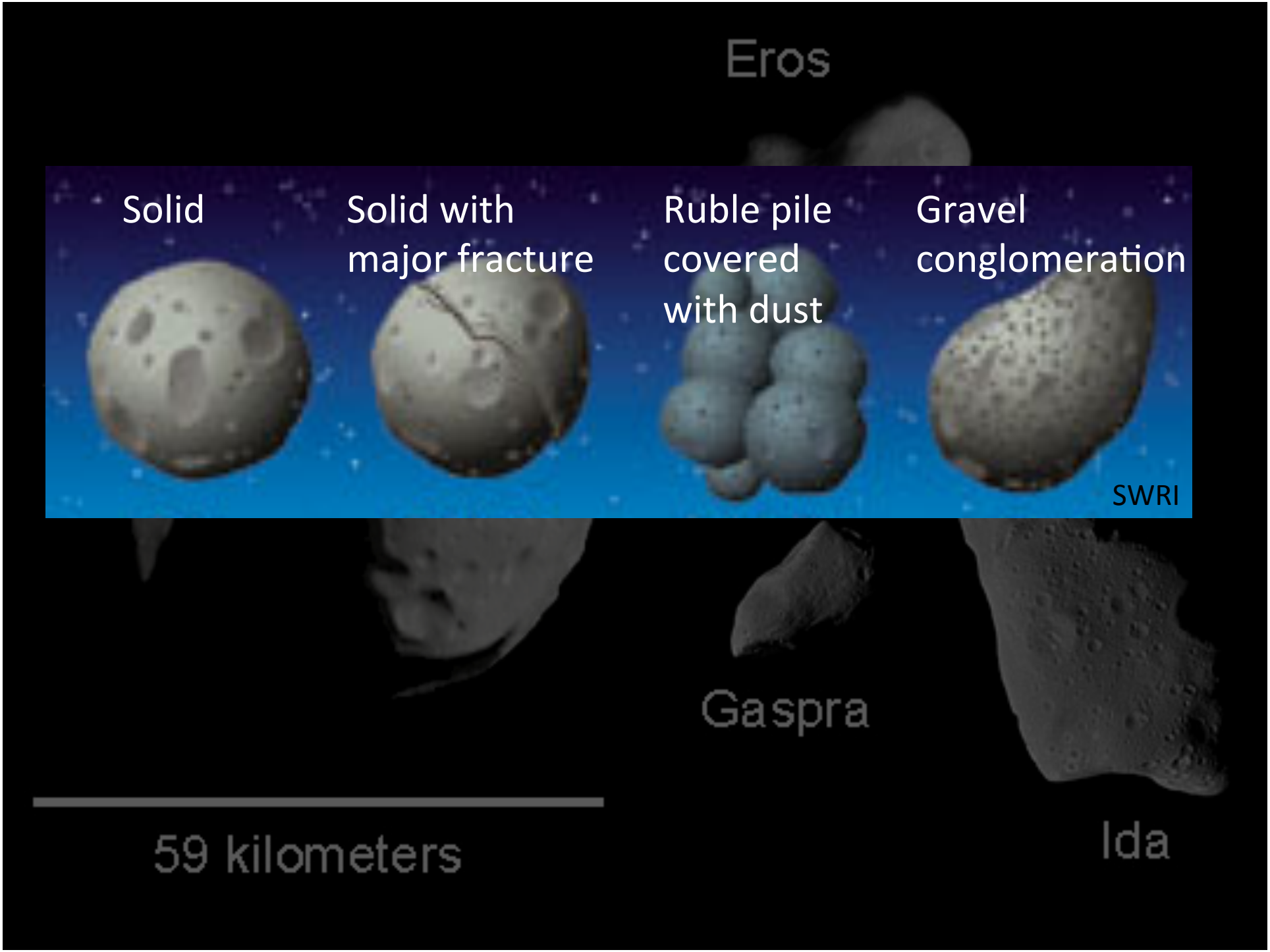


Orbit Crossing “Near-Earth Asteroids”
More than 8,000 known.



Depicted:
Orbits for
100 largest


Eros
Mathilde
Gaspra
Ida
59 kilometers


Eros
Solid
Solid with major fracture
Ruble pile covered with dust
Gravel conglomeration
SWRI
Gaspra
59 kilometers
Ida

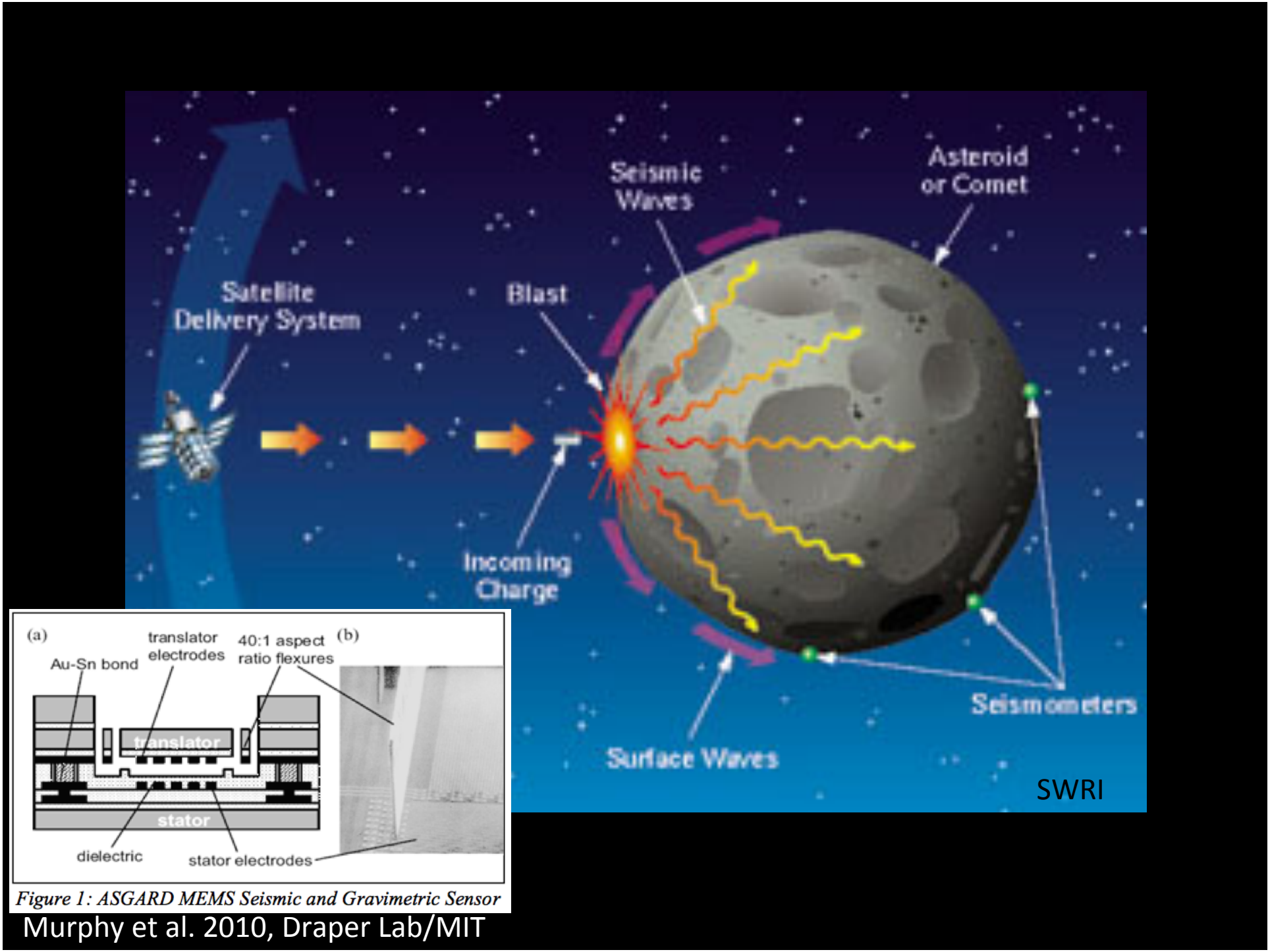


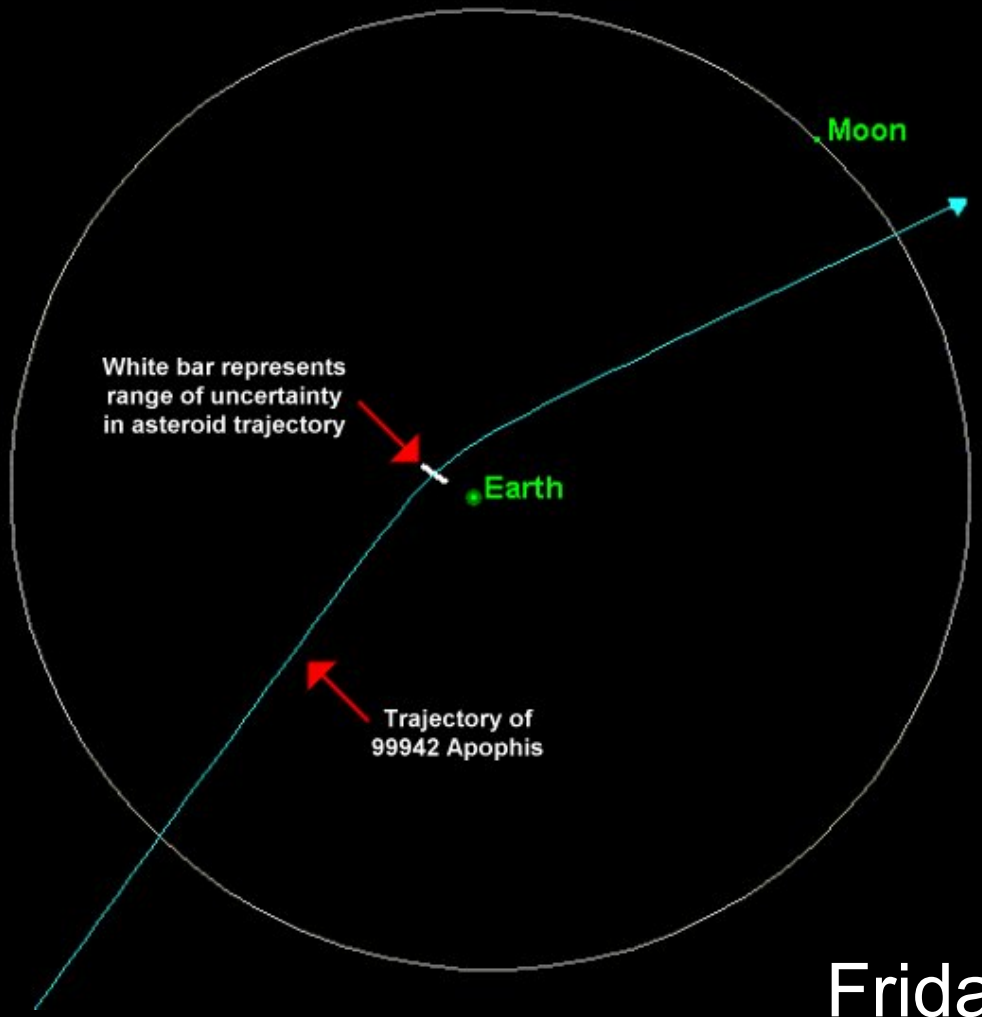
Figure 1: ASGARD MEMS Seismic and Gravimetric Sensor

Murphy et al. 2010, Draper Lab/MIT

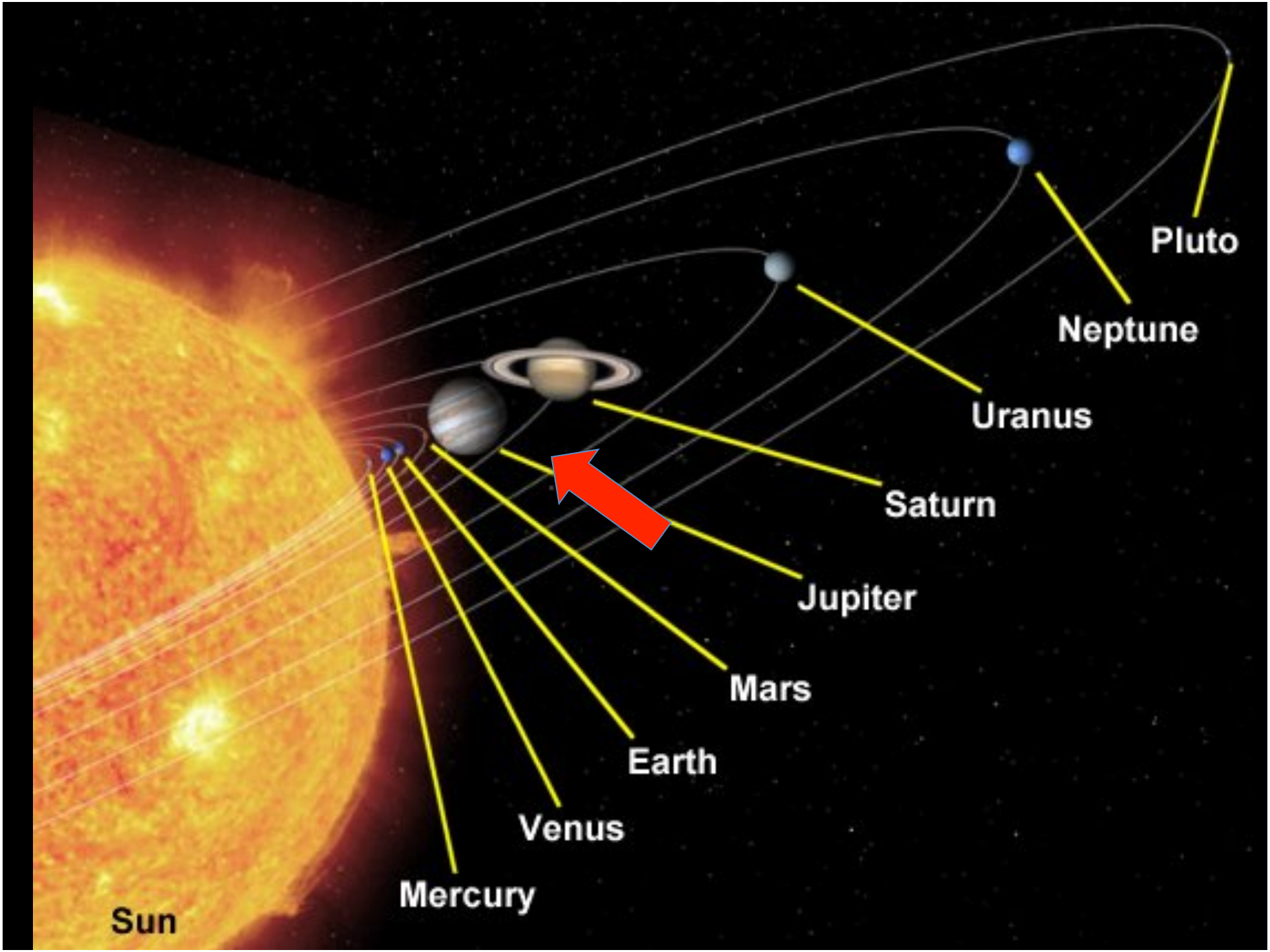
Asteroids: Friends or Foes?

Asteroid 2012 KT 24 passed within 9 Earth radii of Earth on Monday May 28, 2012

Asteroid 99942 Apophis



Friday April 13, 2029


Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
Earth
Venus
Mercury
Sun

Europa

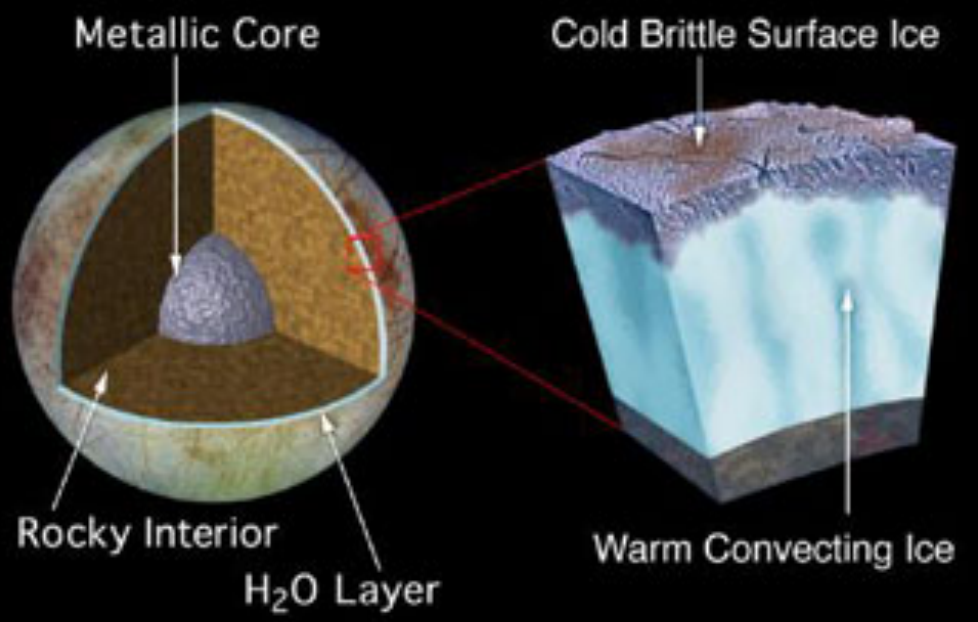
Subsurface life?

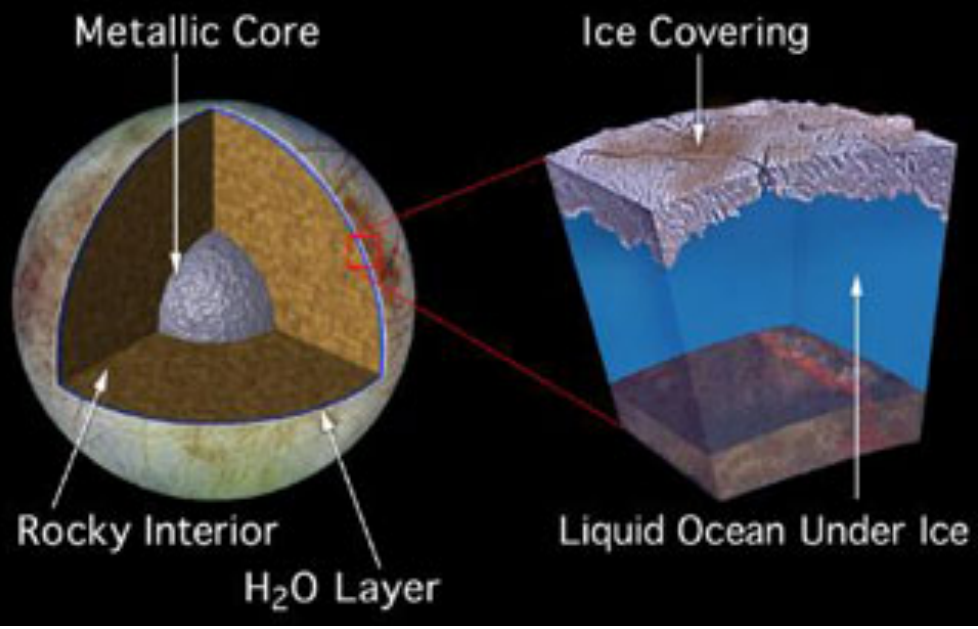
Indirect evidence for a liquid water ocean

Thickness of the ice covering?

Europa should have natural seismic signals

Kovac and Chyba 2001





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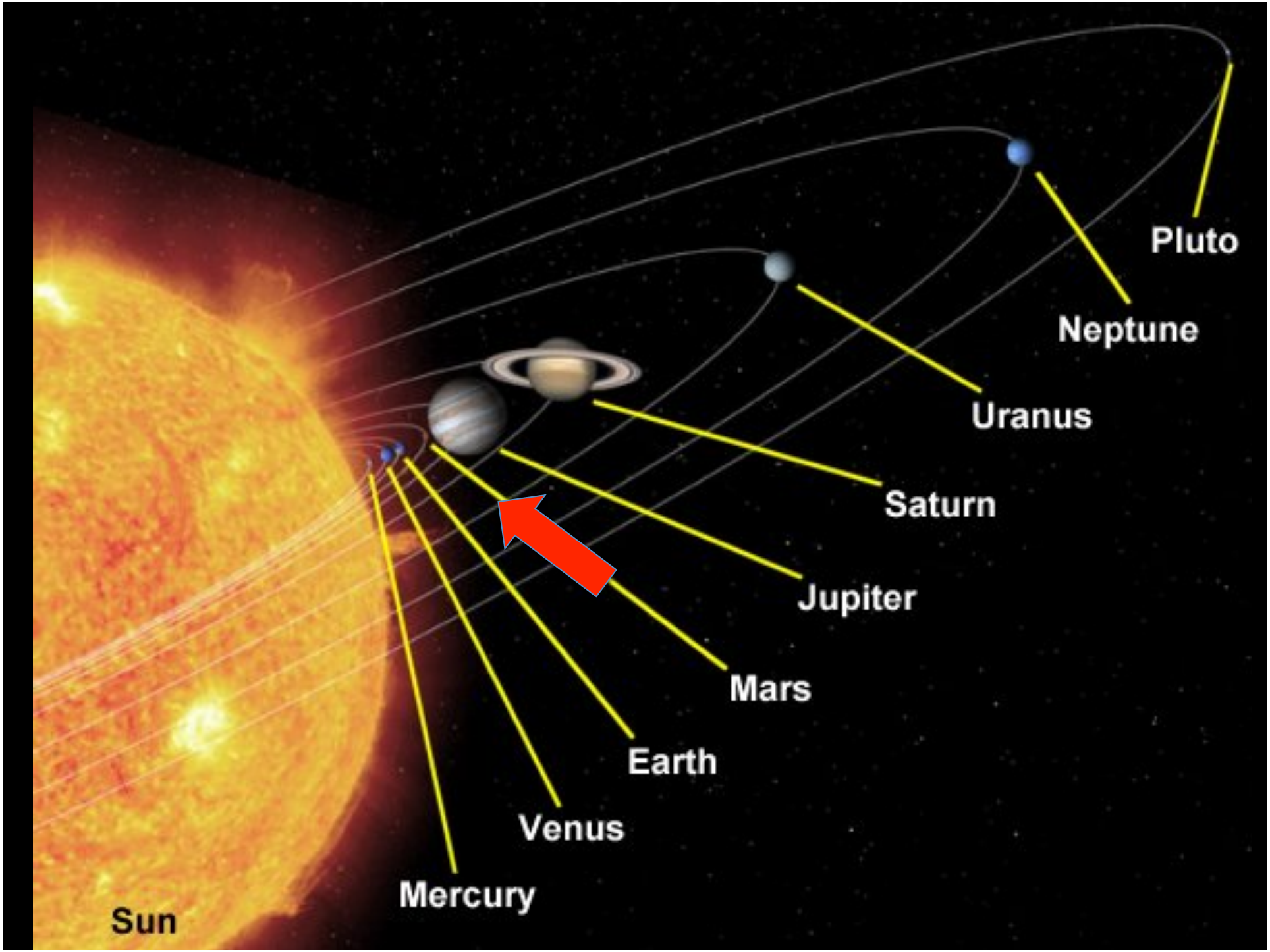

Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
Earth
Venus
Mercury
Sun

The Search for Life on Mars

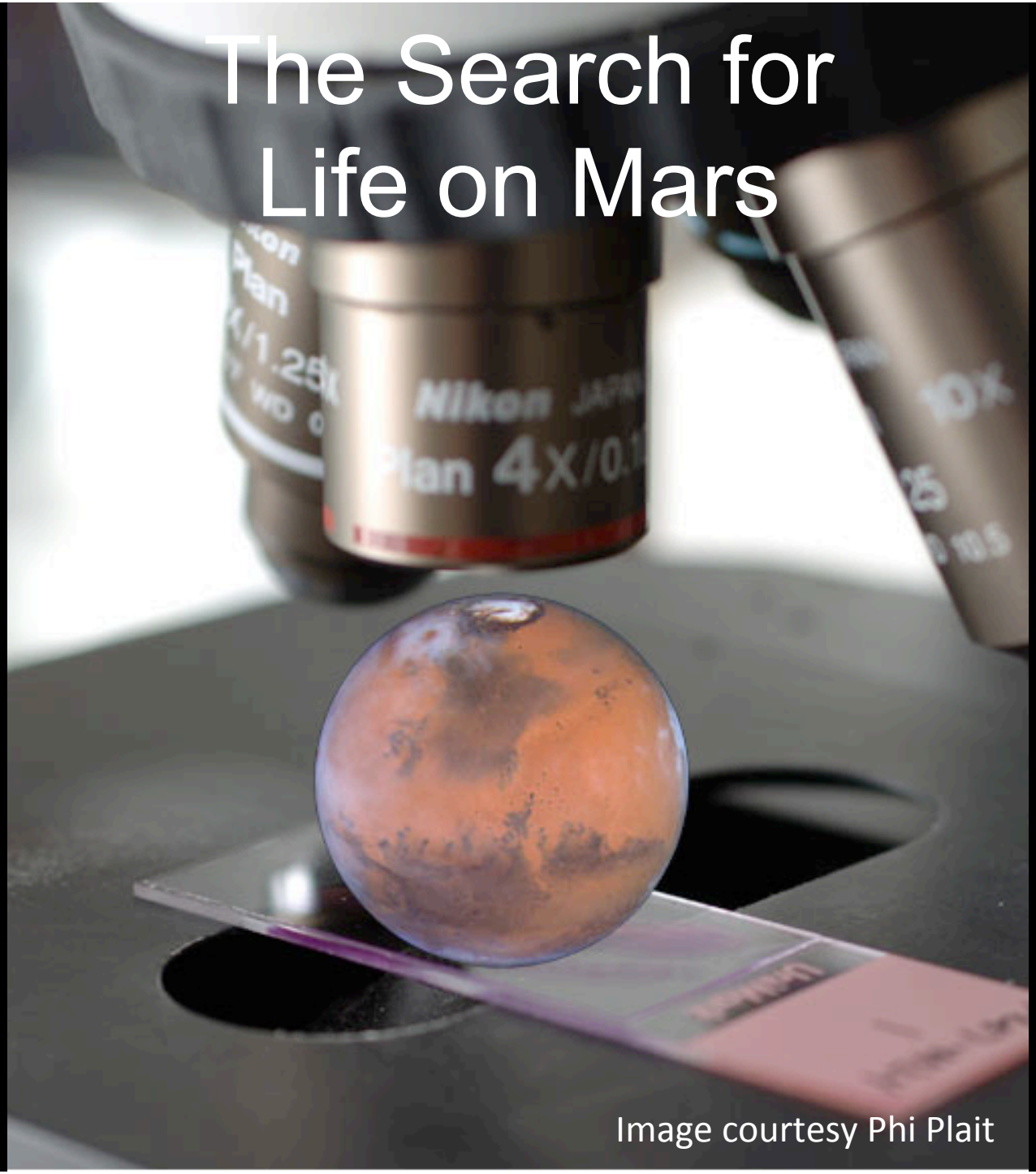
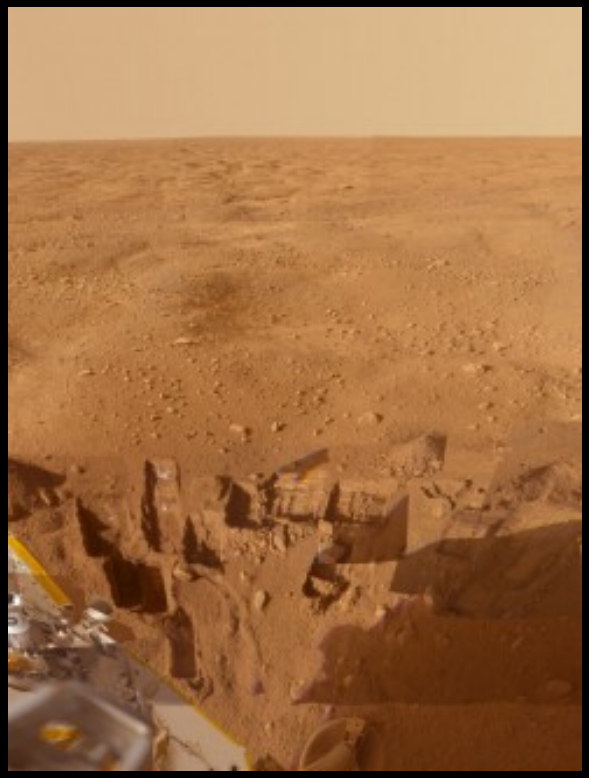


Image courtesy Phi Plait

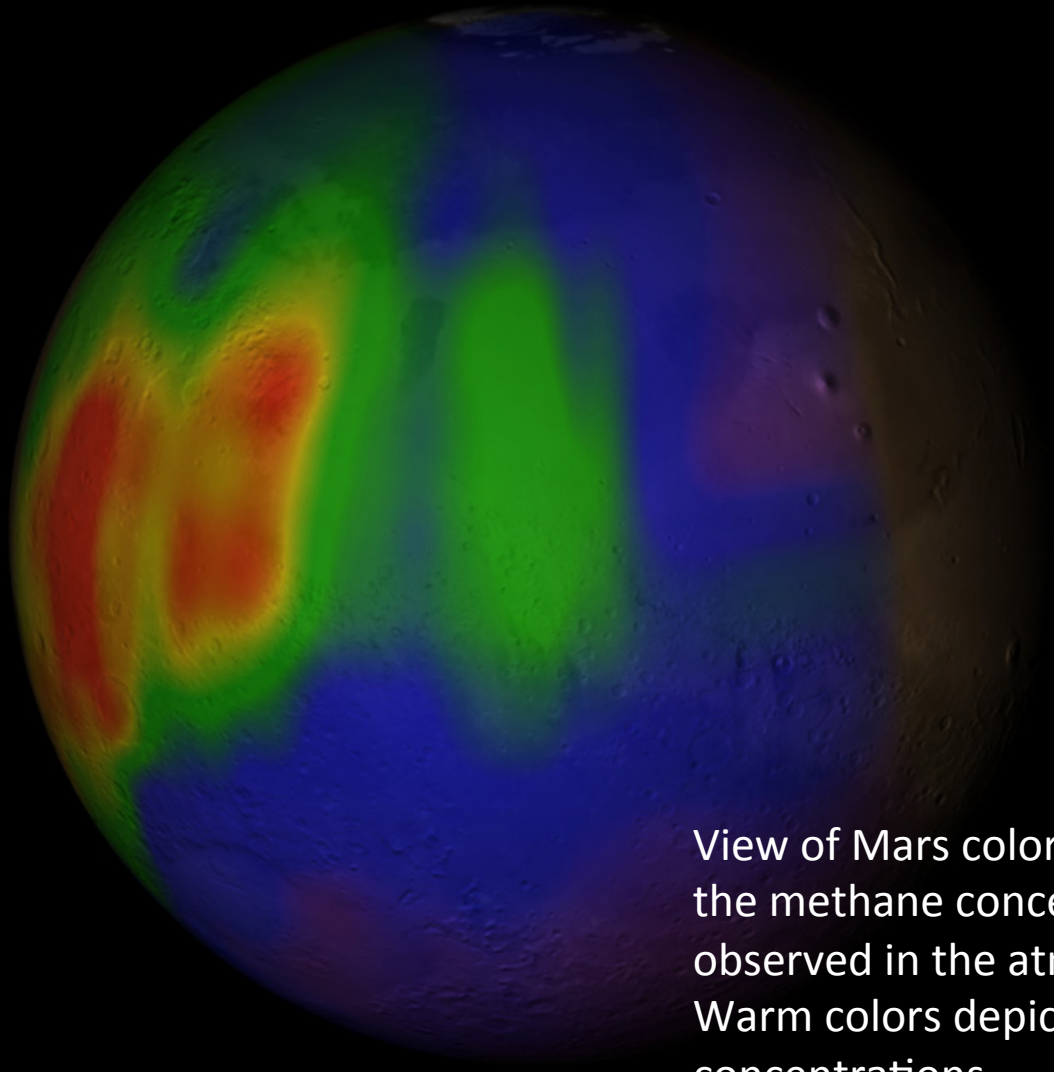
The Search for Water on Mars

Gullies with characteristics of water-carved channels.
Mars Reconnaissance Orbiter
Image: NASA/JPL/University of Arizona



Trenches dug by the Phoenix Mars Lander.
Photo credit: NASA/JPL-Caltech/ University of Arizona/Texas A&M University

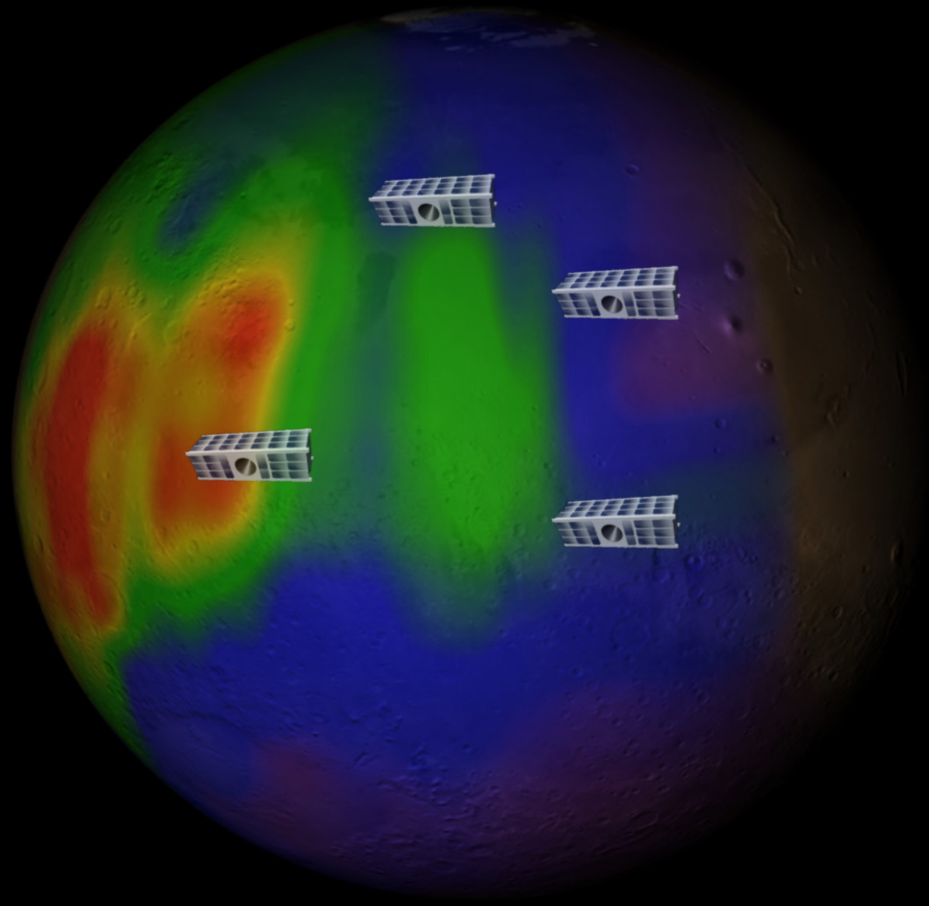
Methane on Mars



View of Mars colored according to the methane concentration observed in the atmosphere. Warm colors depict high concentrations.
http://dps.aas.org/education/

Methane on Mars

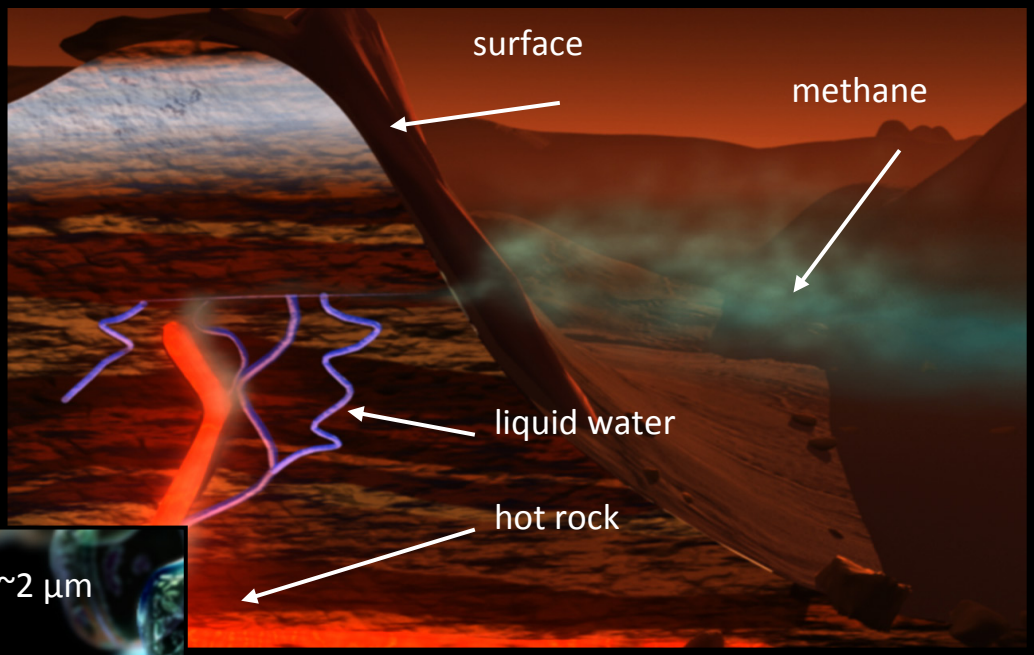
- View of Mars colored according to the methane concentration observed in the atmosphere. Warm colors depict high concentrations.
- Methane has a short lifetime, implying recent production
- Variations in space and time suggest origin from localized areas

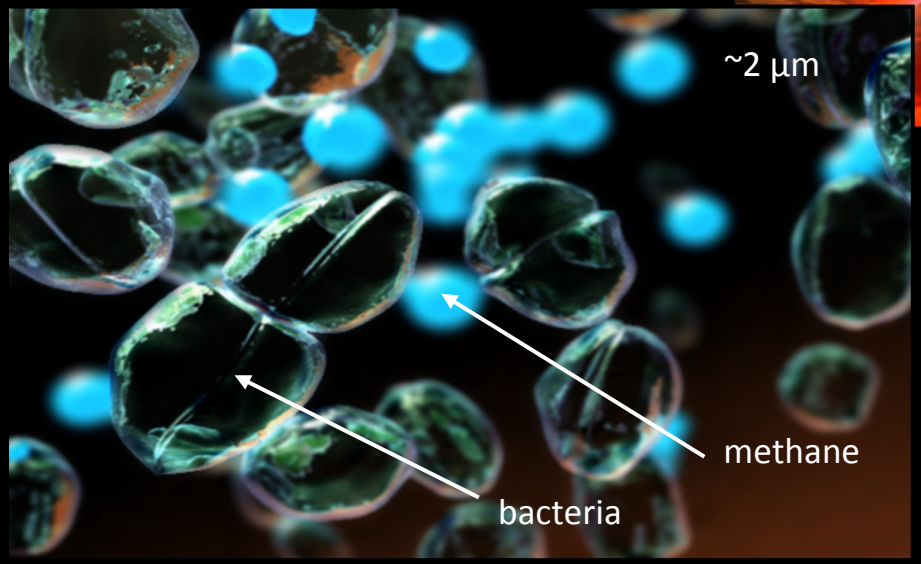


http://dps.aas.org/education/dpsdisc/

Methane on Mars

Explanation #1:
water-rock
interactions

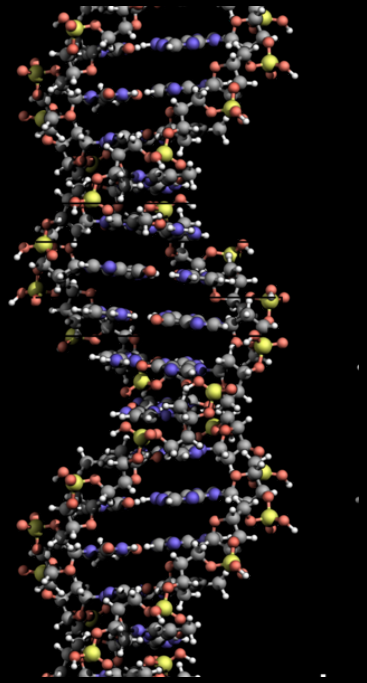




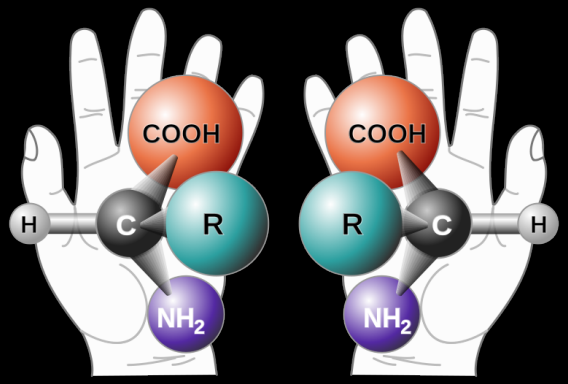
Explanation #2:
Produced by bacteria
in subsurface regions with
liquid water

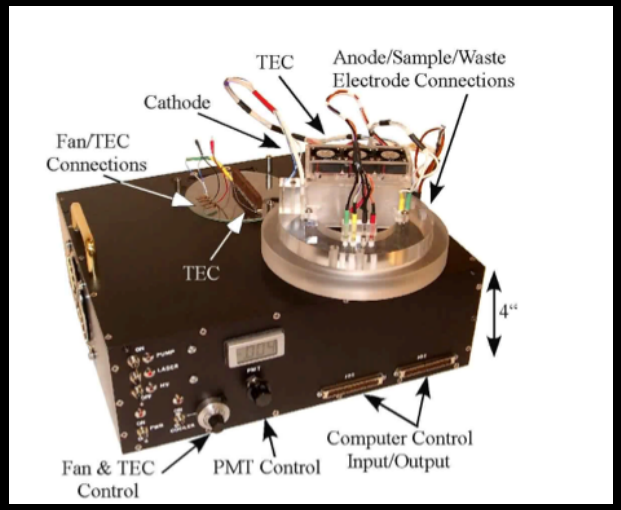
http://dps.aas.org/education/dpsdisc/

How to Detect Life on Mars?



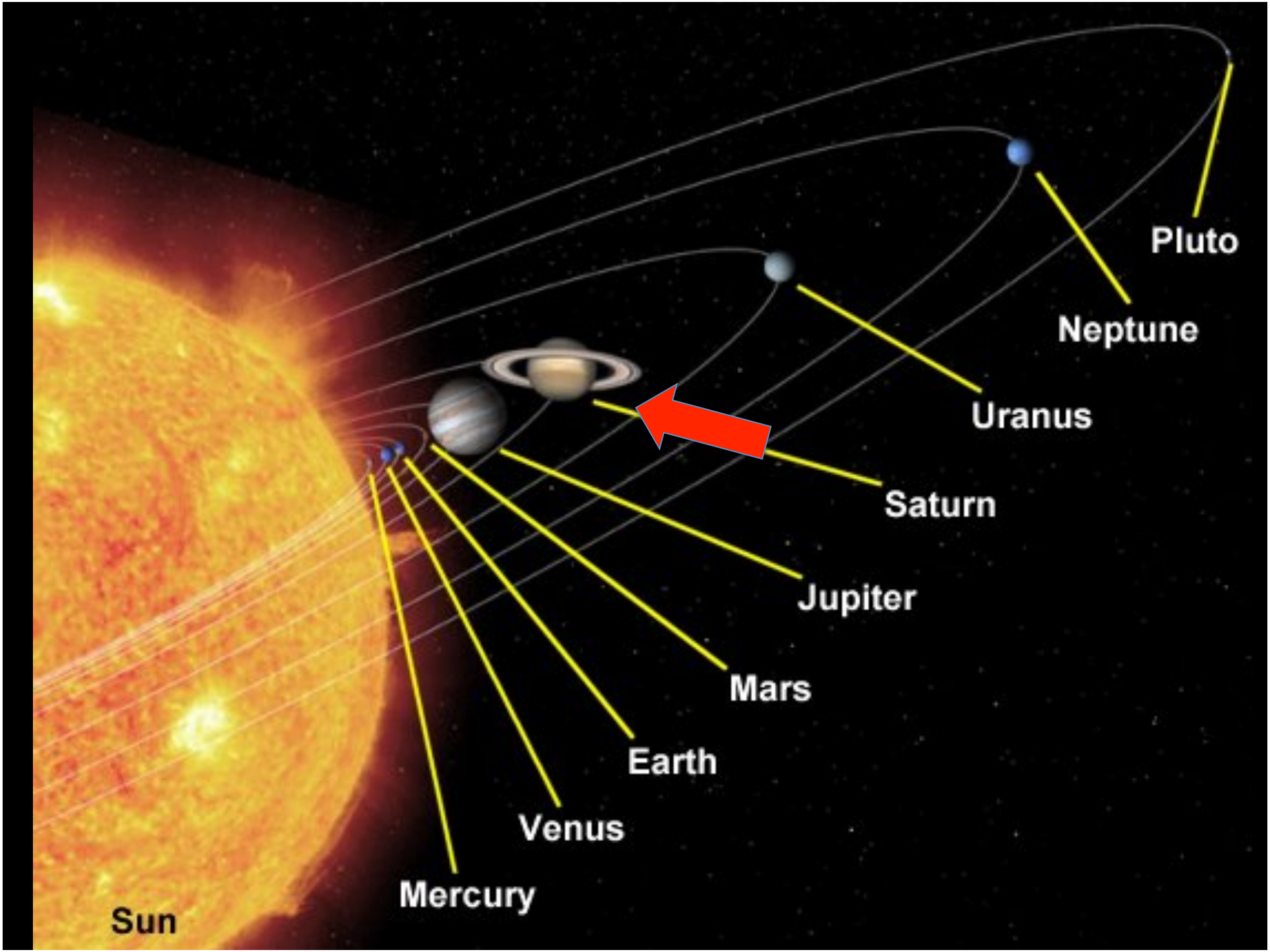
DNA





Mars Organic Analyzer (Mora et al. 2011) Automation of Microfluidics for Extraterrestial In Situ Analysis

Protein

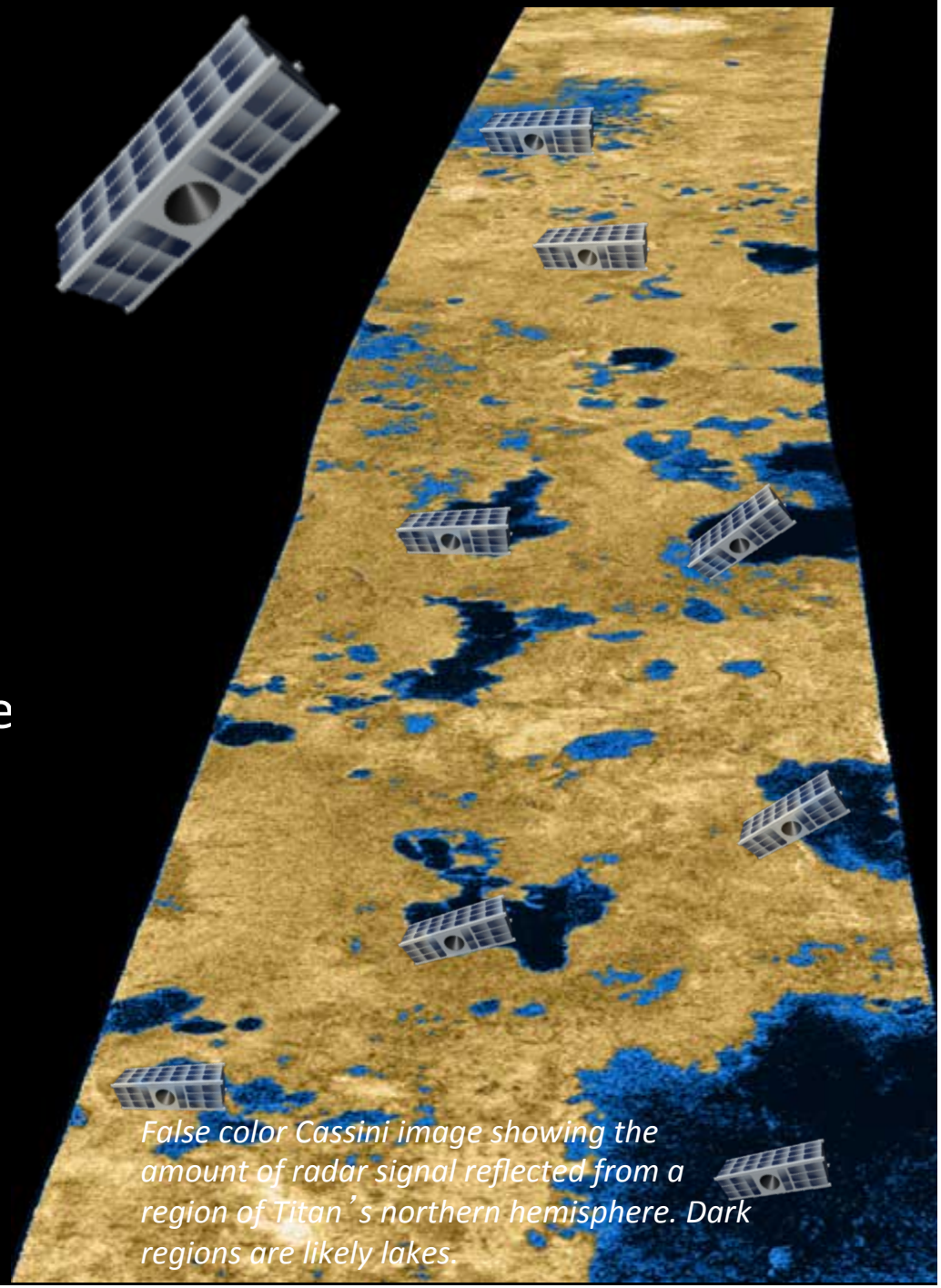

Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
Earth
Venus
Mercury
Sun

Titan: Lakes without Water

- Titan is 94 K - too cold for liquid surface water, but not too cold for liquid methane and ethane

- Sunlight should rapidly convert atmospheric methane to ethane and other species. But methane is abundant, so must be replenished.

- Robust evidence for liquid lakes from Cassini radar, imaging, and spectra



False color Cassini image showing the amount of radar signal reflected from a region of Titan's northern hemisphere. Dark regions are likely lakes.

A New Paradigm for Planetary Space Science

A New Paradigm for Planetary Space Science

- Frequent iCubeSat launches as complimentary to the rare Flagship/New Horizons/Discovery class NASA missions
- For impact: a singular, focused science goal is essential
- Unique science breakthroughs will come from the iCubeSats unparalleled capability of constellations or fleets of independently functioning spacecraft or landers