Have Asteroids Brought Water and Organic Molecules to Earth?

OCA Seminar

May 20, 2014

Humberto Campins

- University of Central Florida, Orlando
- Center for Lunar & Asteroid Surface Science (CLASS)
- Science Team Member NASA's OSIRIS-REx Mission

UCF

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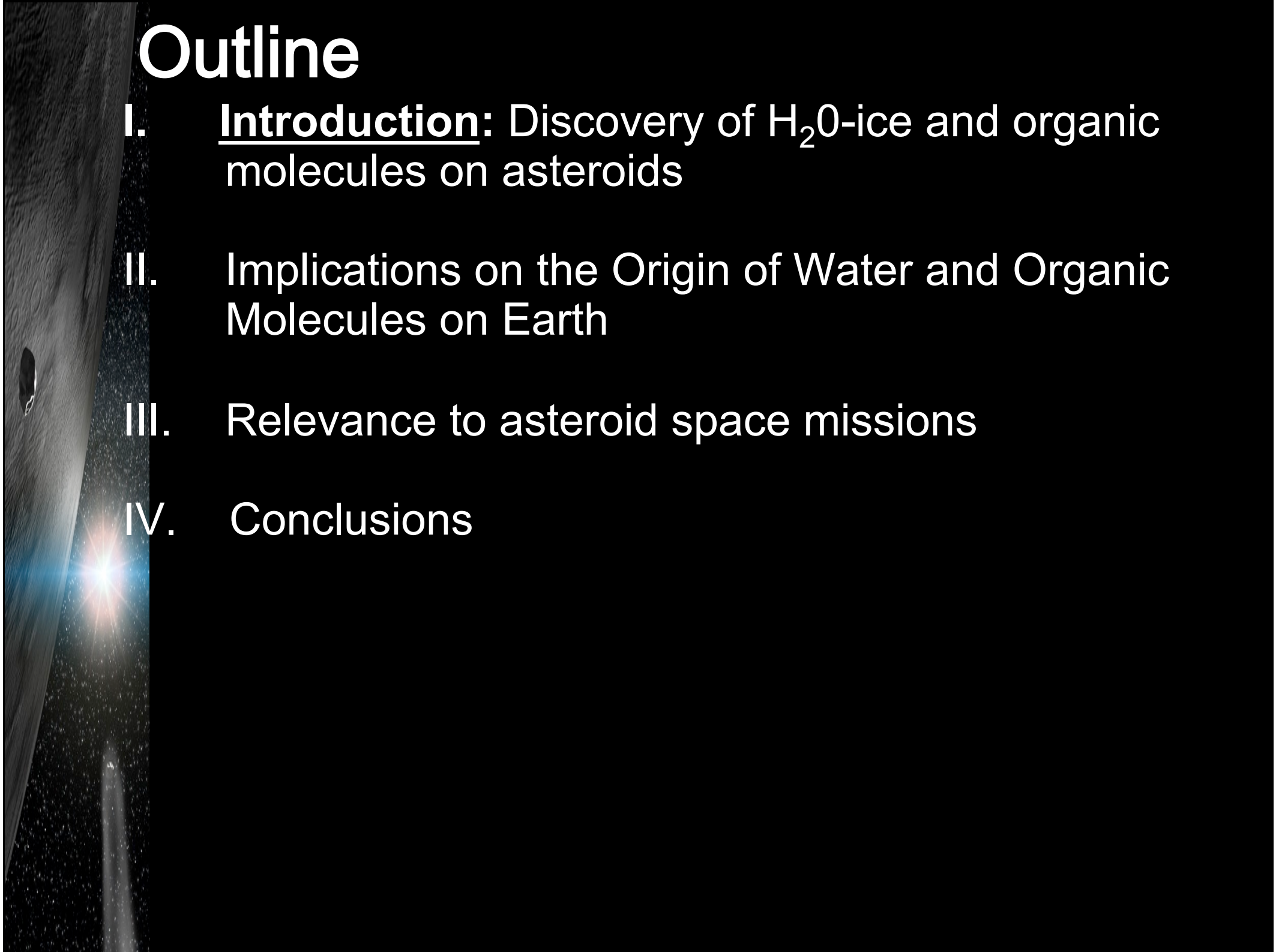


Outline

I. **Introduction:** Discovery of H_20-ice and organic molecules on asteroids

II. Implications on the Origin of Water and Organic Molecules on Earth

III. Relevance to asteroid space missions

IV. Conclusions

IV. Conclusions

- H_2O-ice and organic molecules discovered on two asteroids
- These results support views that asteroids and comets contributed water and organics to the pre-biotic Earth
- Relevant to sample-return and other missions to asteroids by ESA, JAXA & NASA

Ice and Organics on Asteroids: 24 Themis & 65 Cybele

nature Vol 464|29 April 2010|doi:10.1038/nature09029

LETTERS

Water ice and organics on the surface of the asteroid 24 Themis

Humberto Campins[1], Kelsey Hargrove[1], Noemi Pinilla-Alonso[2], Ellen S. Howell[3], Michael S. Kelley[4], Javier Licandro[5,6], T. Mothé-Diniz[7], Y. Fernández[1] & Julie Ziffer[8]

Detection of ice and organics on an asteroidal surface

Andrew S. Rivkin[1] & Joshua P. Emery[2]

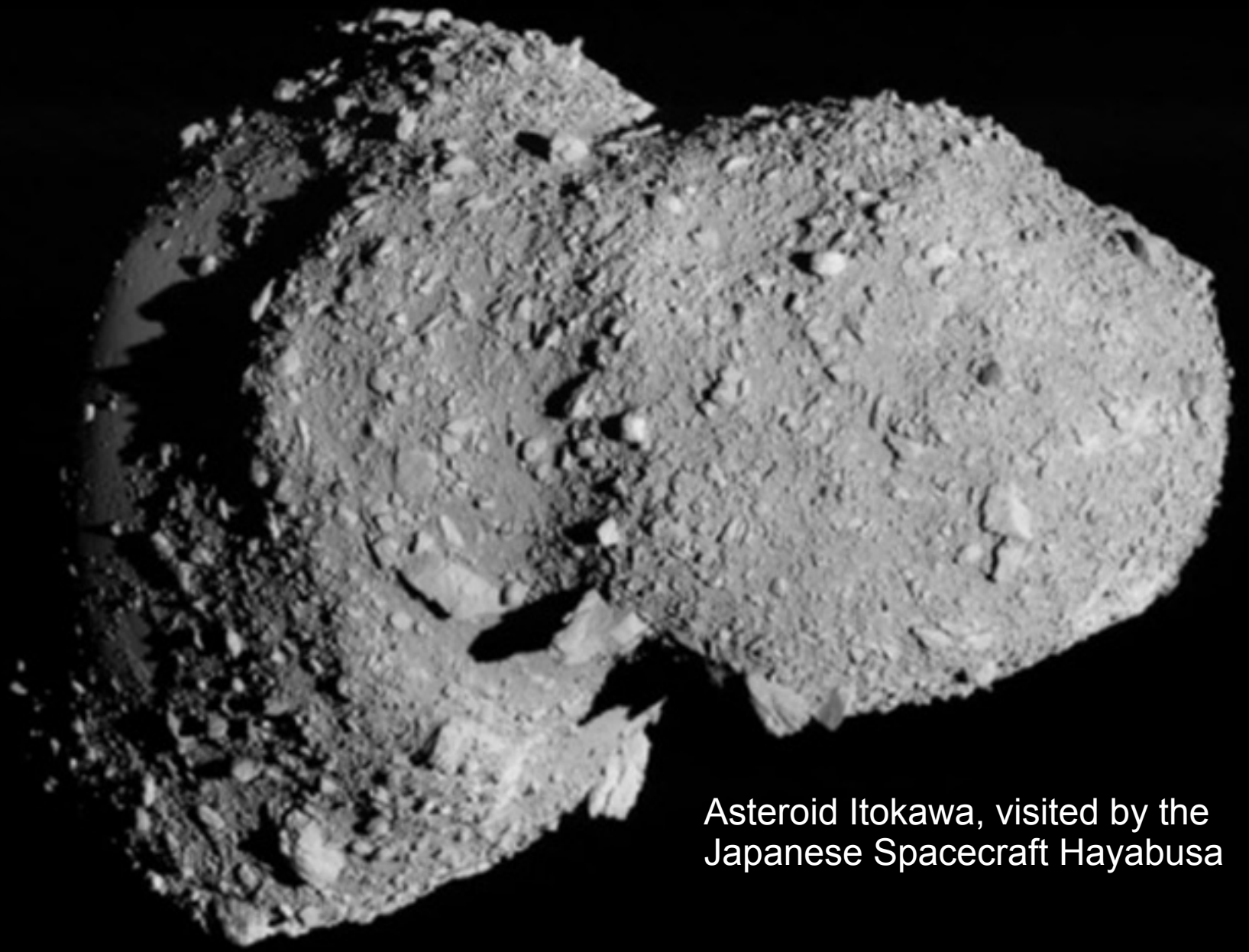
A&A 525, A34 (2011)
DOI: 10.1051/0004-6361/201015339

Astronomy & Astrophysics

(65) Cybele: detection of small silicate grains, water-ice, and organics

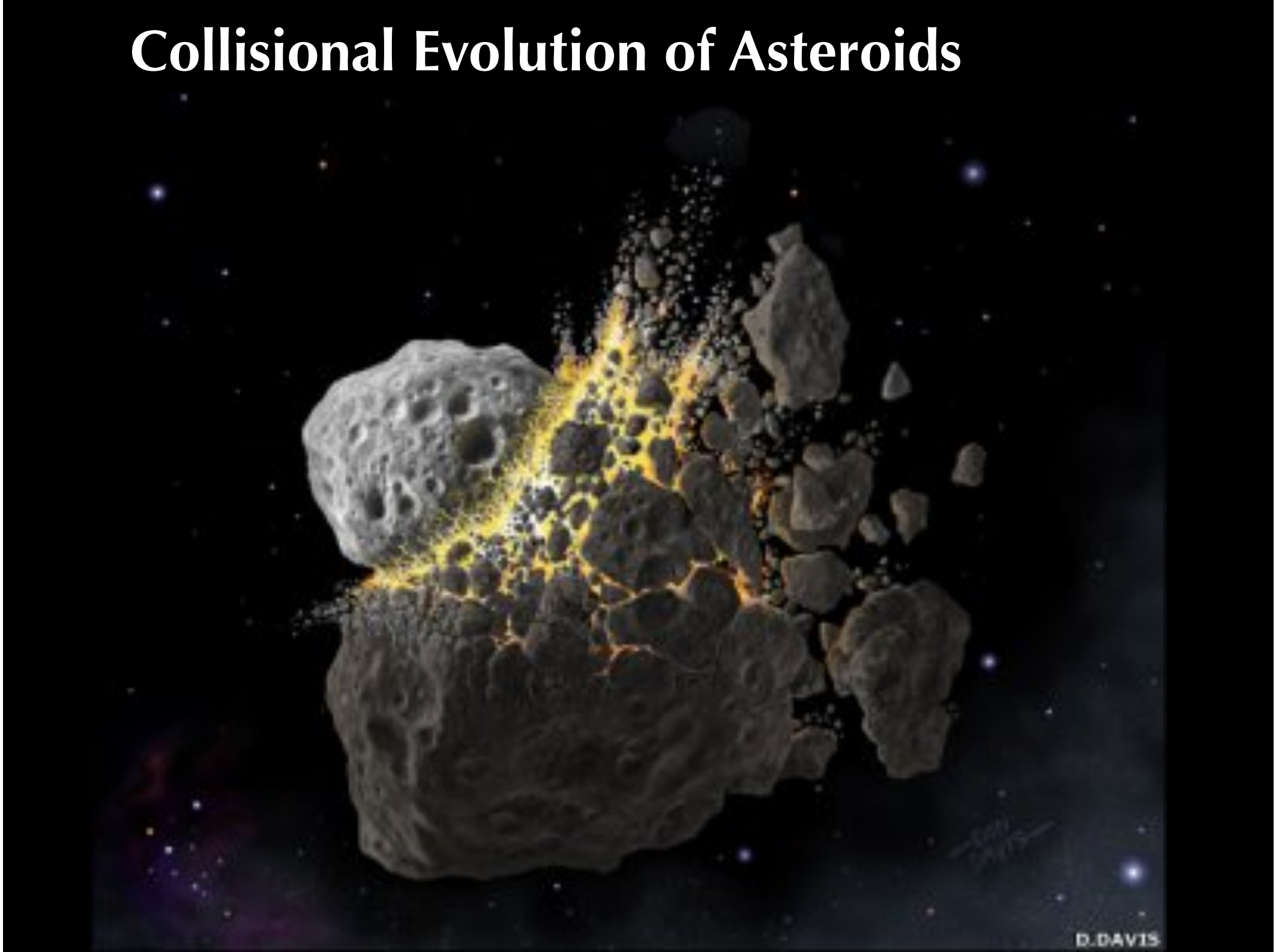
J. Licandro[1,2], H. Campins[3], M. Kelley[4], K. Hargrove[3], N. Pinilla-Alonso[5], D. Cruikshank[5], A. S. Rivkin[6], and J. Emery[7]

Most Asteroids are rubble-piles



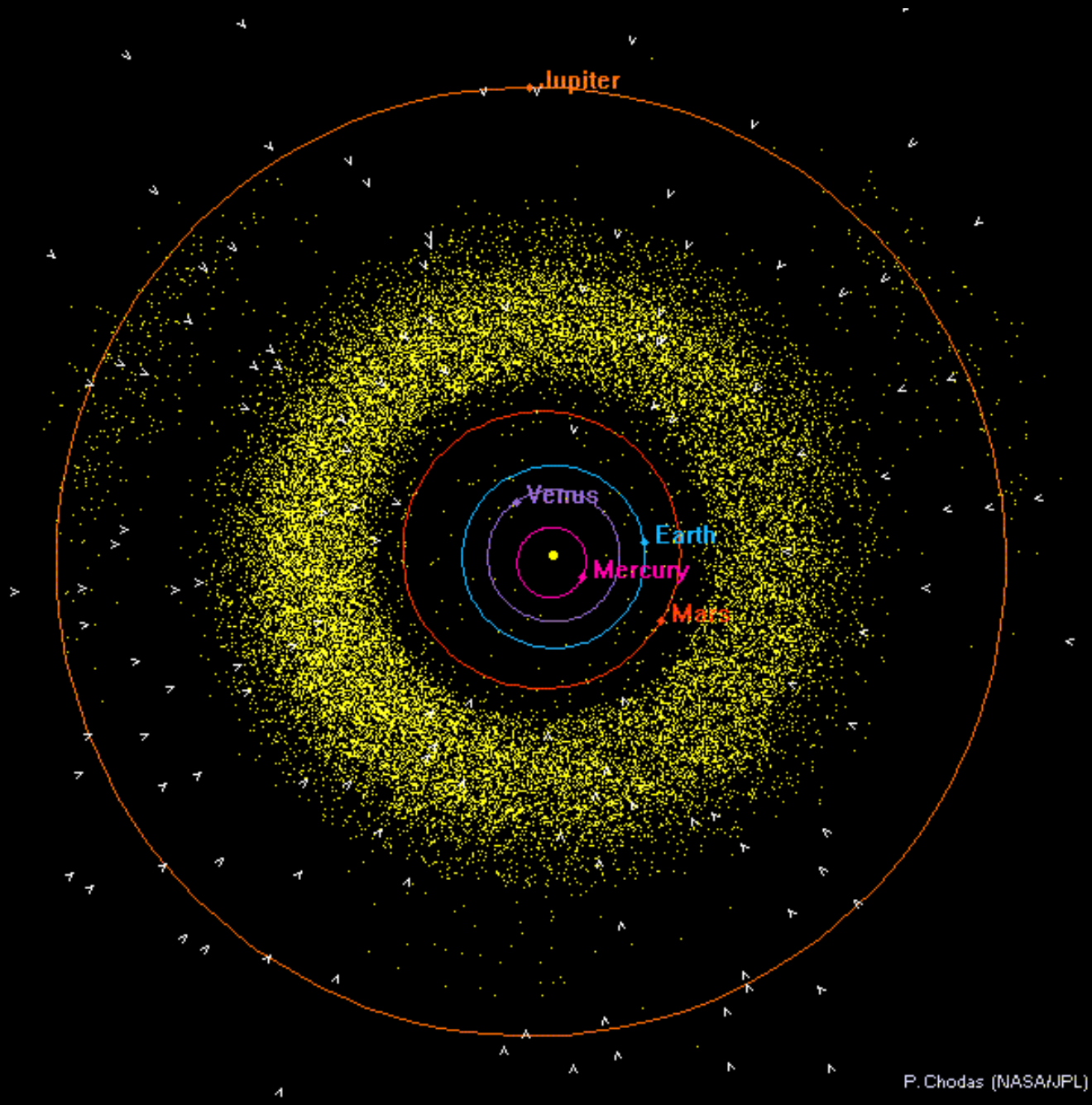
Asteroid Itokawa, visited by the Japanese Spacecraft Hayabusa

Collisional Evolution of Asteroids

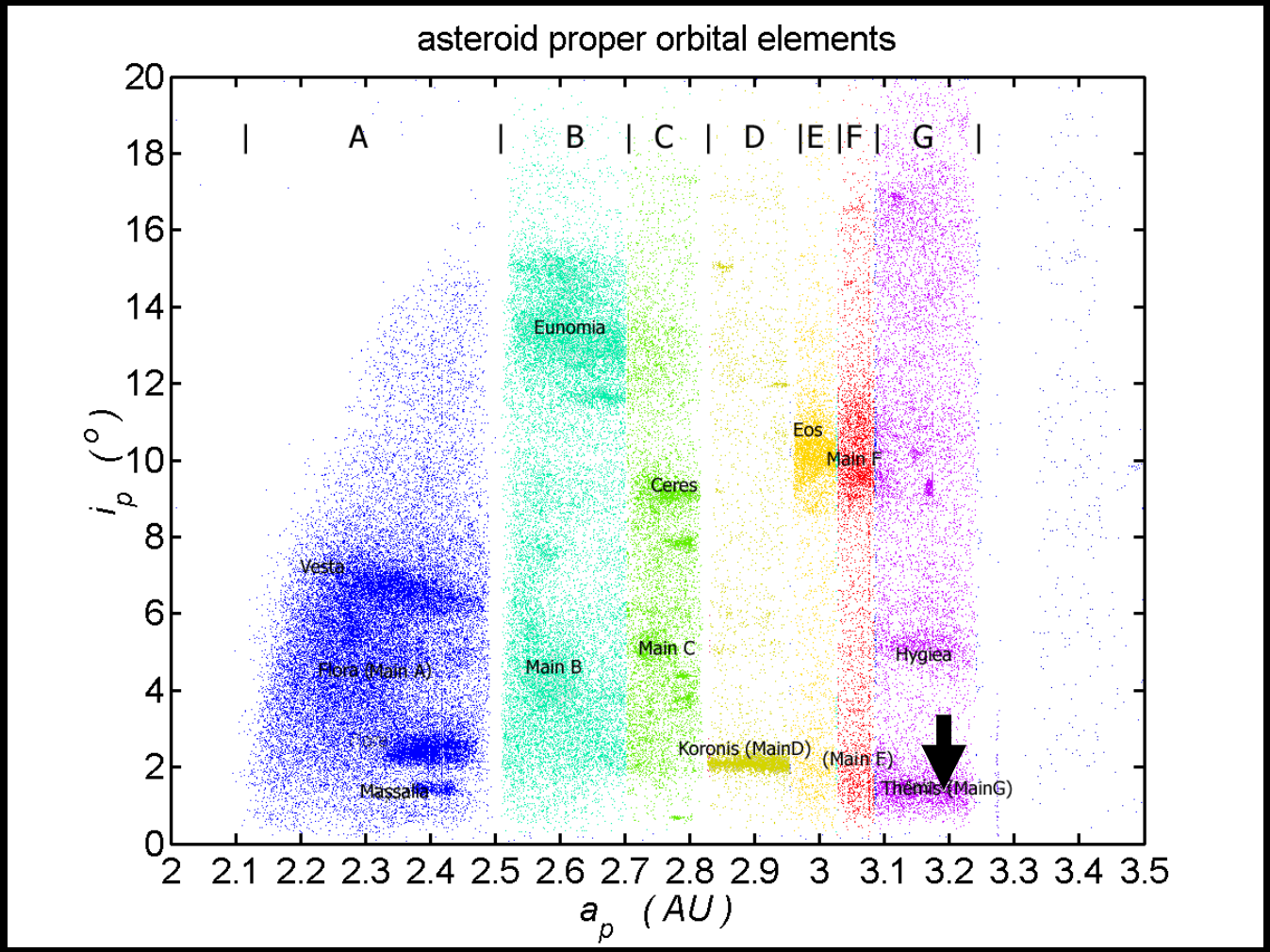


Play
Movie

Asteroid Main Belt and Jupiter Trojans

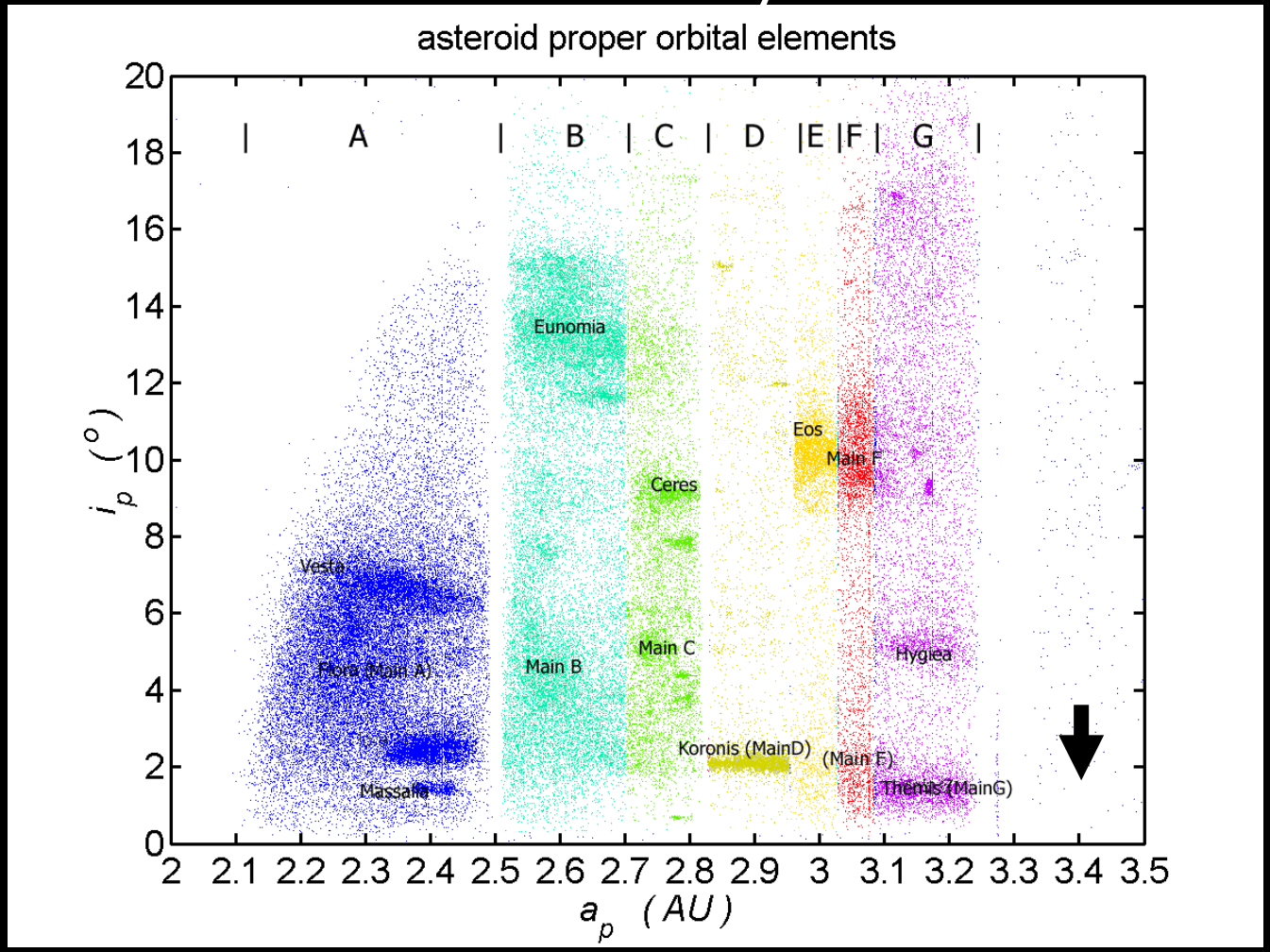


I. Introduction: 24 Themis



- Largest fragment of a family
- Orbiting near 3.2 AU
- Diameter ~ 200 km
- Geometric Albedo of 0.07
- Rotational period: 8.4 h

I. Introduction: 65 Cybele



- **Largest of dynamical group between 3.3 & 3.7 AU**
- **Orbiting near 3.4 AU**
- **Diameter ~ 300 km**
- **Geometric Albedo of 0.07**
- **Rotational period: 4.0 h**

Infrared spectra of Asteroids 24 Themis and 65 Cybele

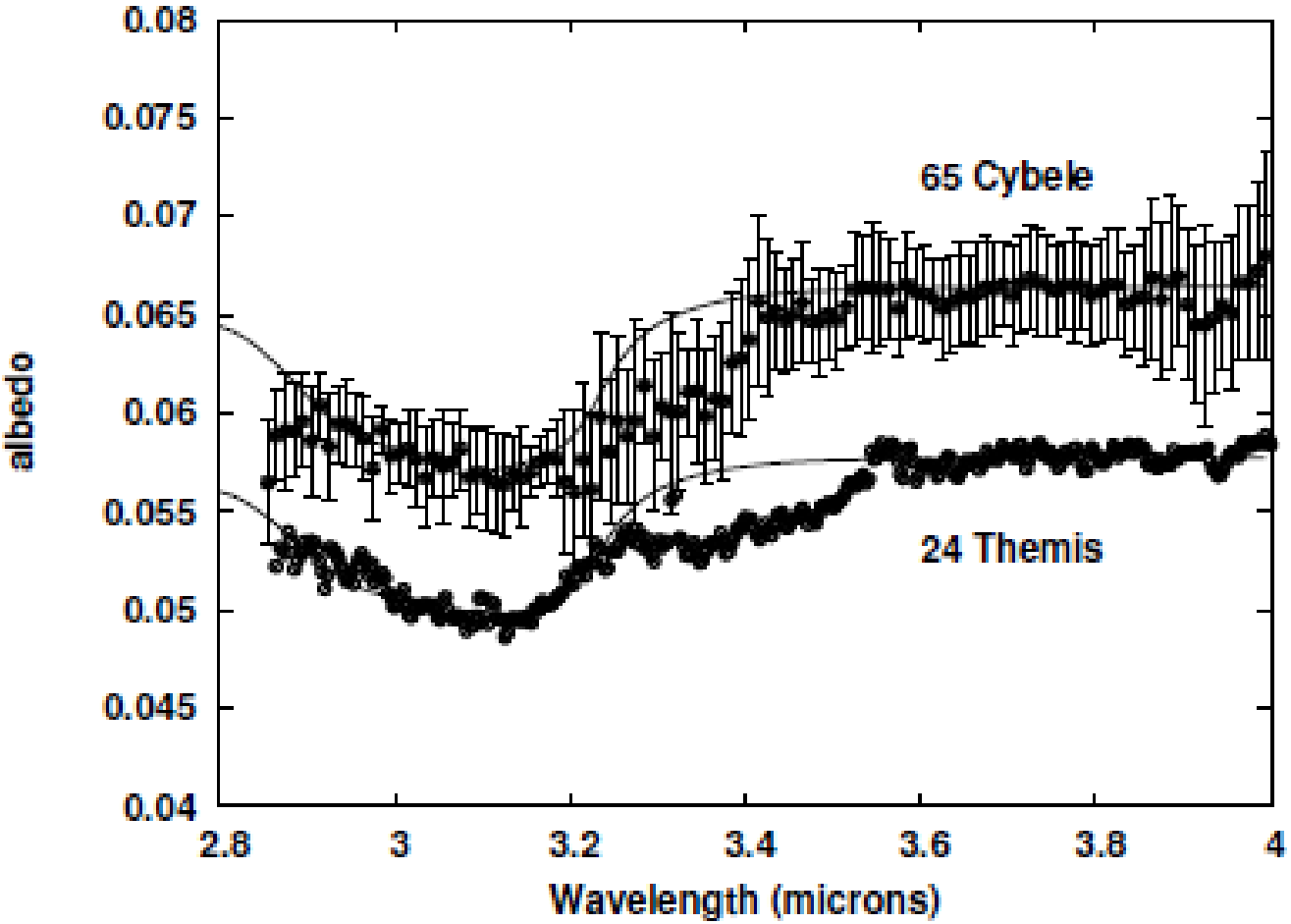
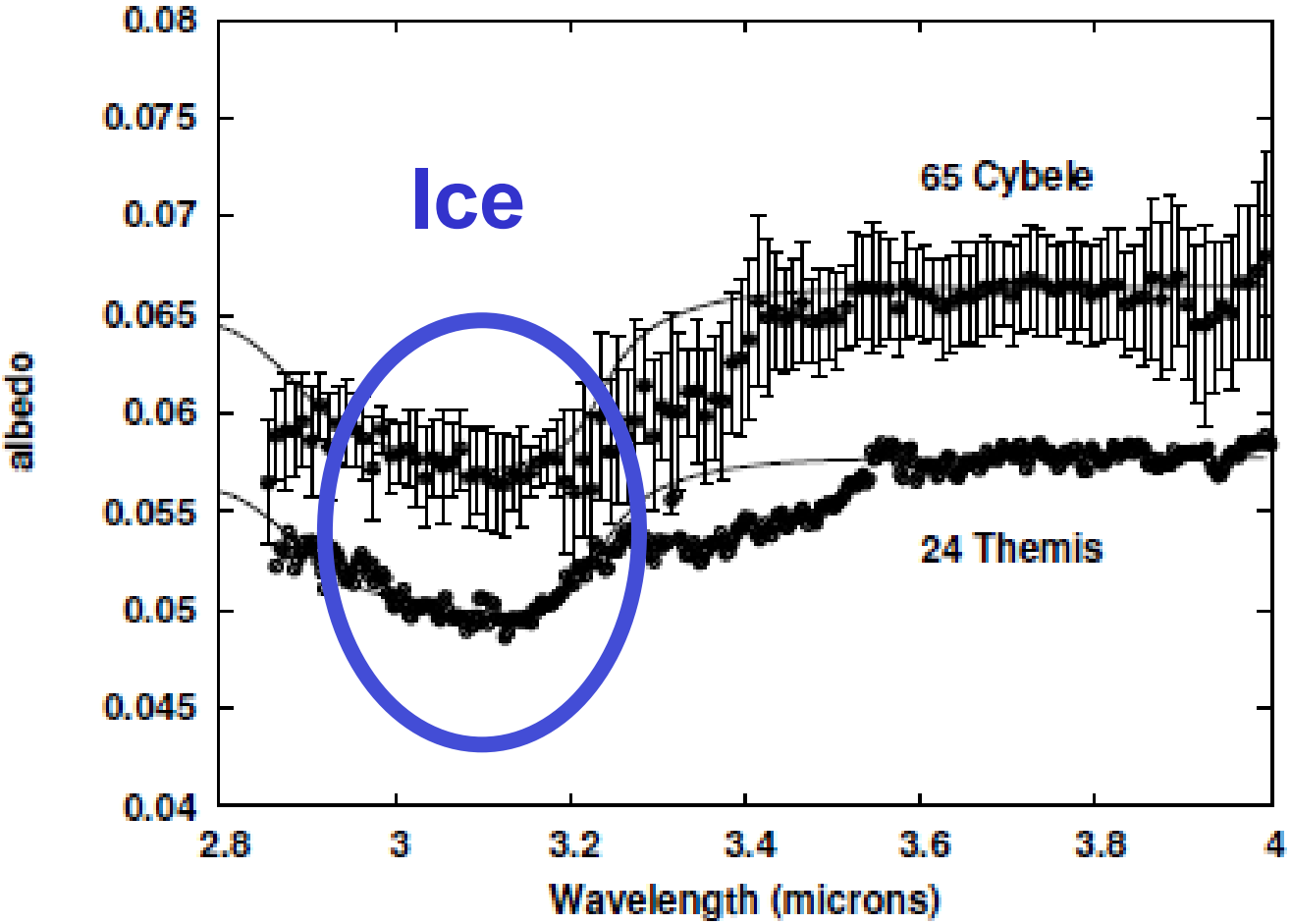


Fig. 7. Reflectance spectrum of Cybele and Themis in albedo units. Within the noise, both spectra looks very similar. Overplotted to Themis spectrum is the spectral model included in Fig. 1 of Rivkin & Emery (2010) . A similar model is overplotted to Cybele's spectrum. These models include a thin coating of H_2O ice on surface grains. Notice that models fit very well the left part of the band while at longer wavelengths there are additional absorptions.

Infrared spectra of Asteroids 24 Themis and 65 Cybele



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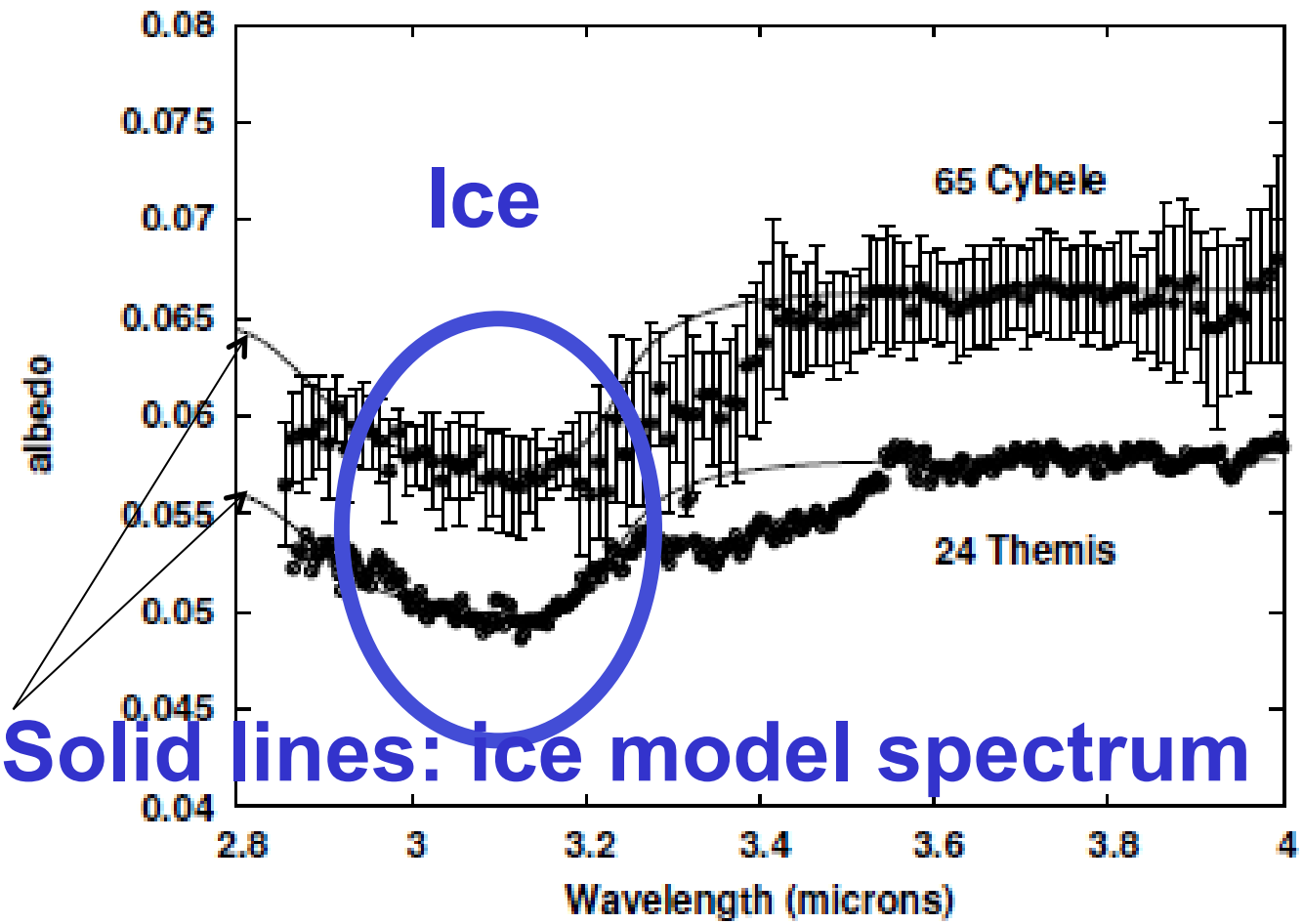

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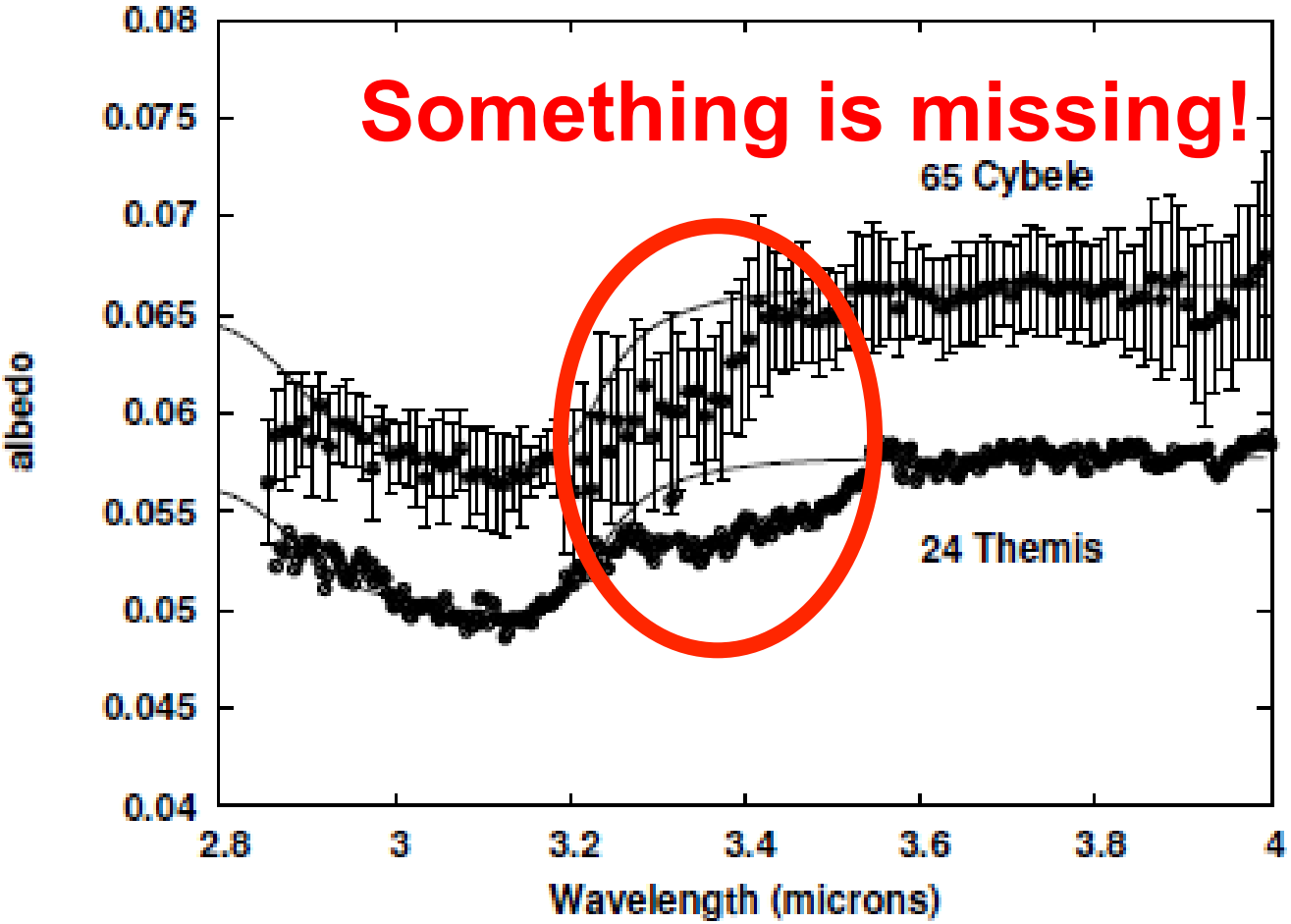
Infrared light from Asteroids 24 Themis and 65 Cybele



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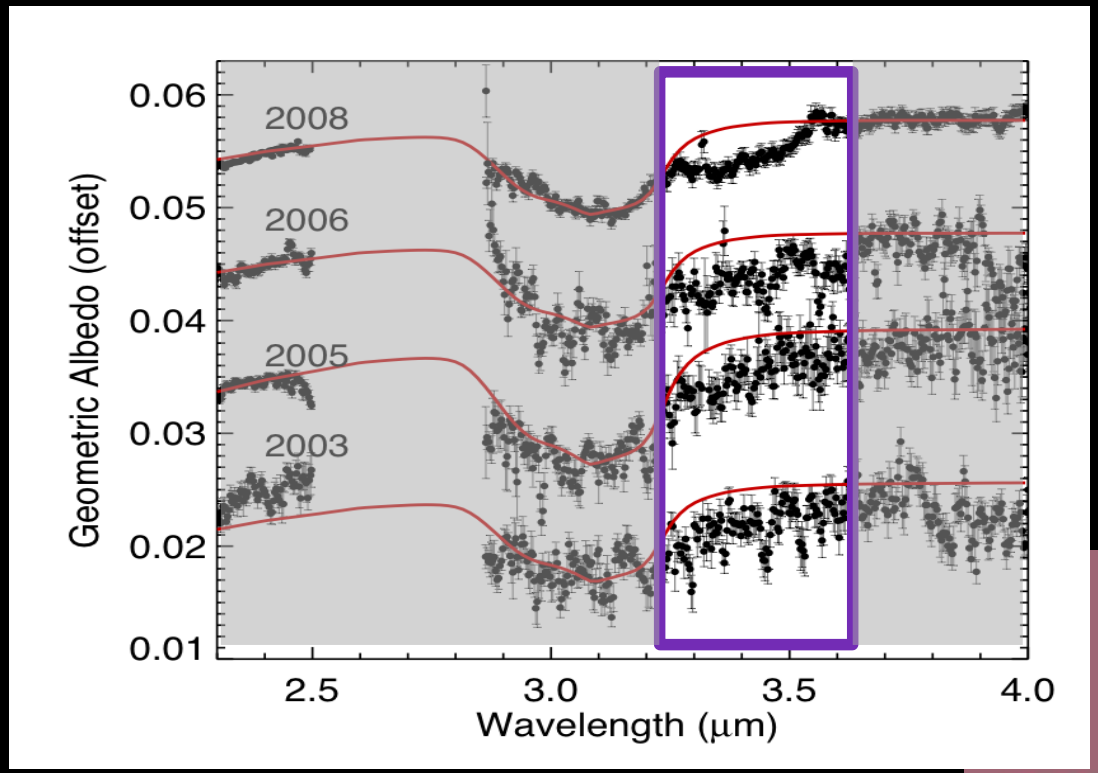
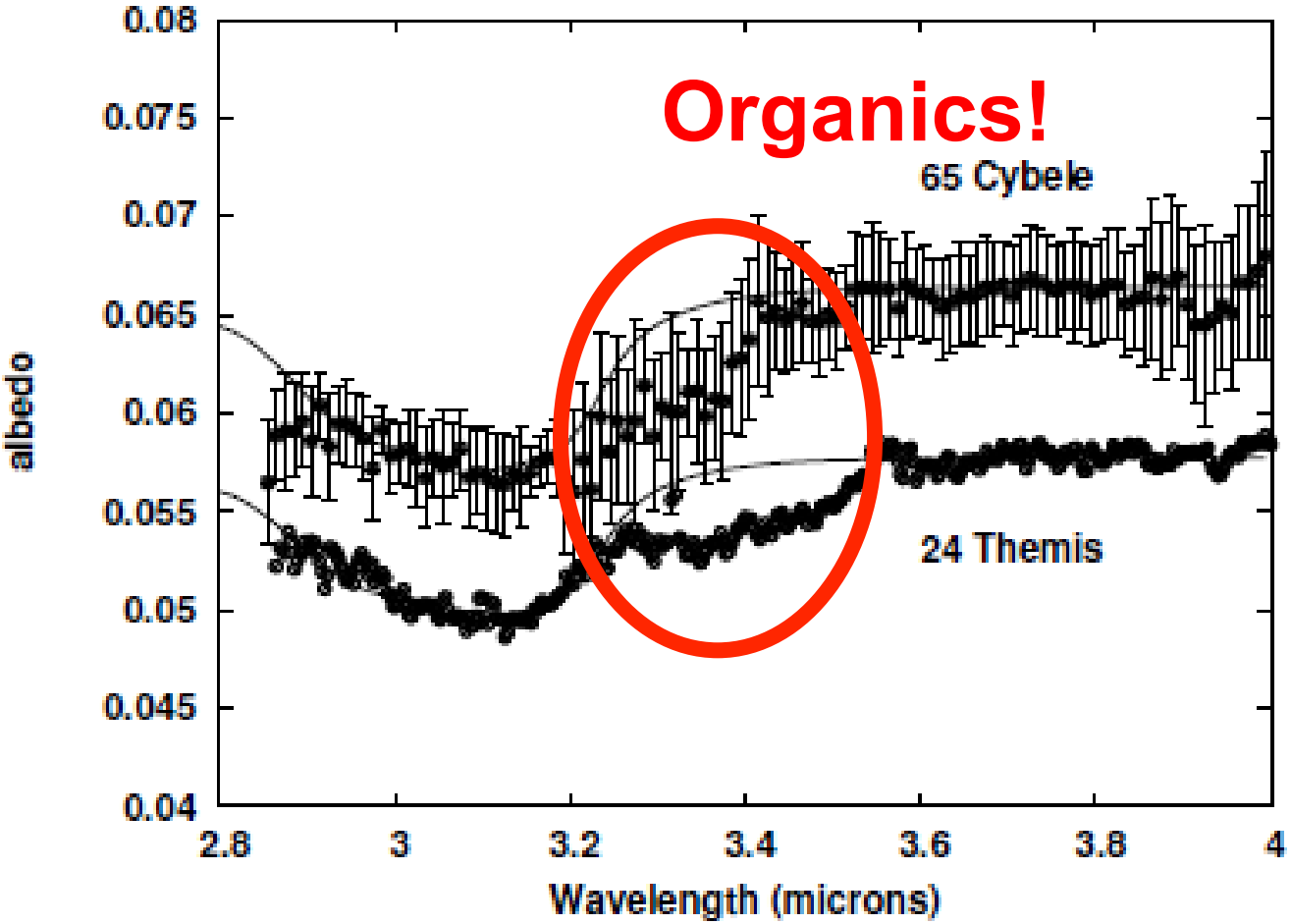
Something is missing !!!



Hogwarts School of Astronomical Potions

Infrared light from Asteroids 24 Themis and 65 Cybele



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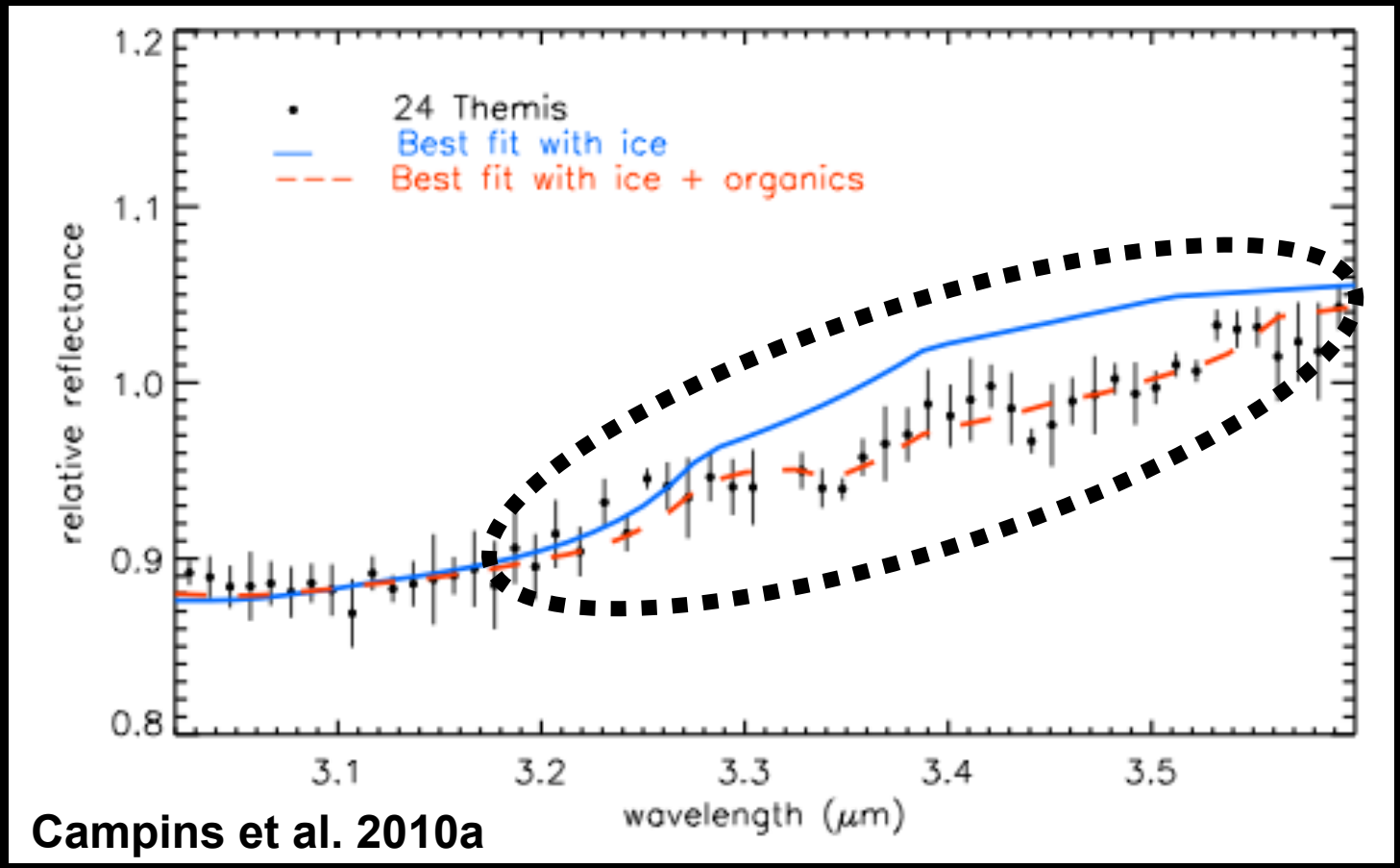
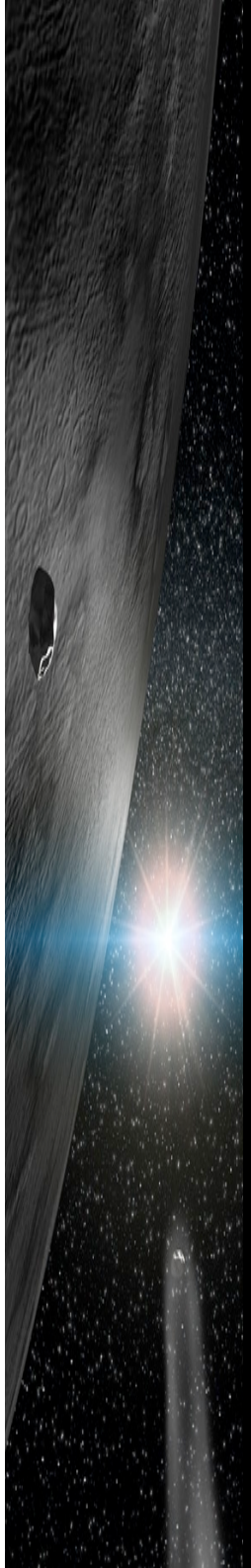
ORGANICS: the missing ingredient !!!

A 5% of "Ice Tholin" added to the mixture of water ice and anhydrous silicate works best!



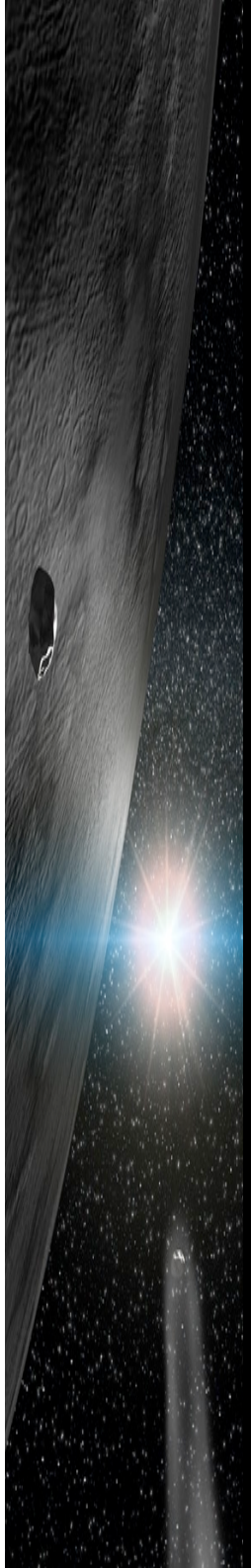
Campins et al. 2010a



Rotationally Resolved Observations:

- We obtained spectra of both asteroids as they rotated and there was no change in the spectral features

- This means: ice and organics are widespread on both asteroids



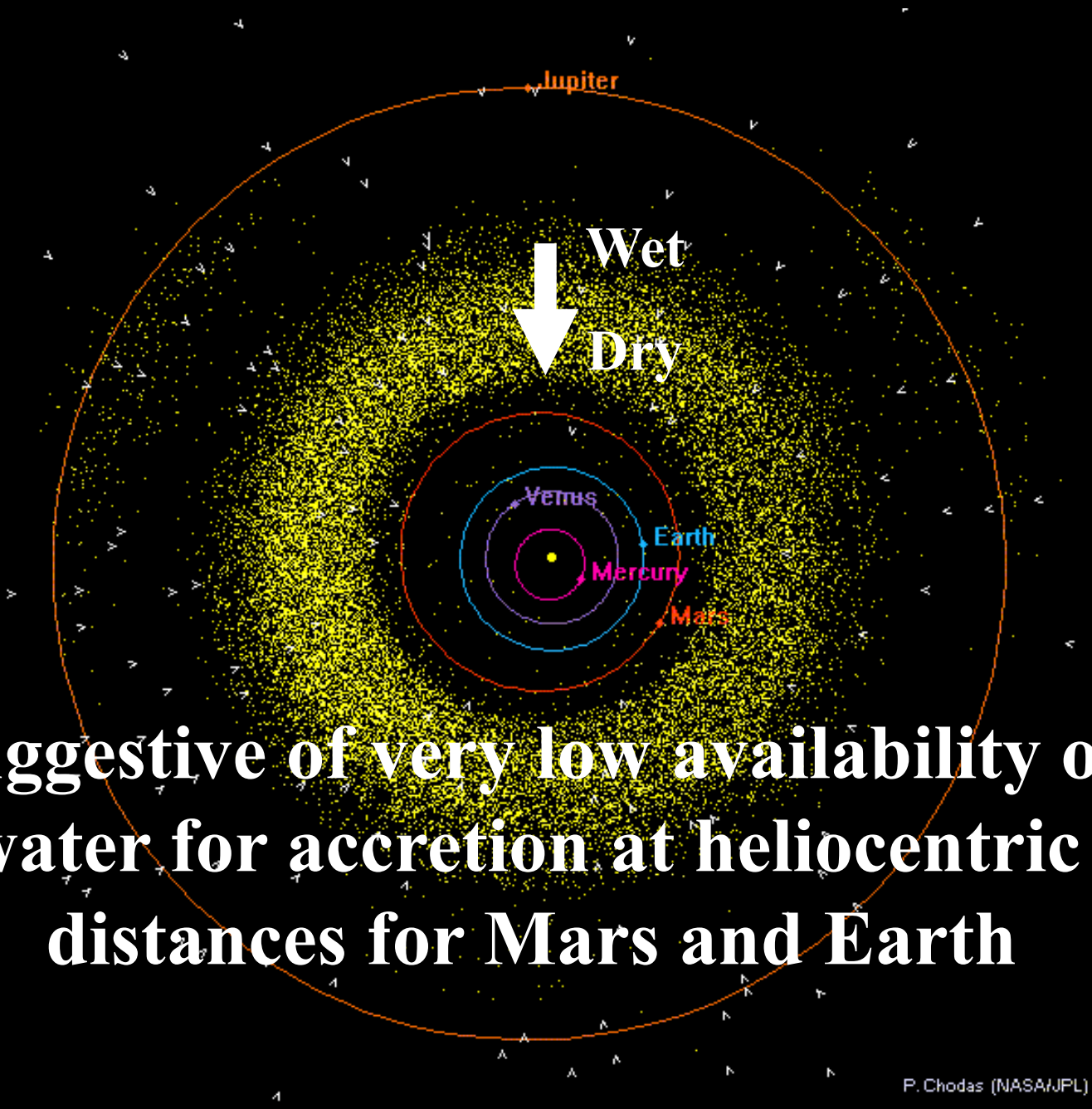
II. Implications on Origin of Earth's Water and Organic Molecules

Water in Meteorites

- Most meteorites come from asteroids
- The contents of H_2O in meteorites indicates a decrease in water abundance in the asteroid belt with decreasing distance from Sun
- Meteorites believed to have originated in the innermost part of the asteroid belt <u>are the driest known material in the solar system</u>

This suggests that the building blocks that formed Earth & Mars should have had an even lower water content

Water in Meteorites



Suggestive of very low availability of water for accretion at heliocentric distances for Mars and Earth

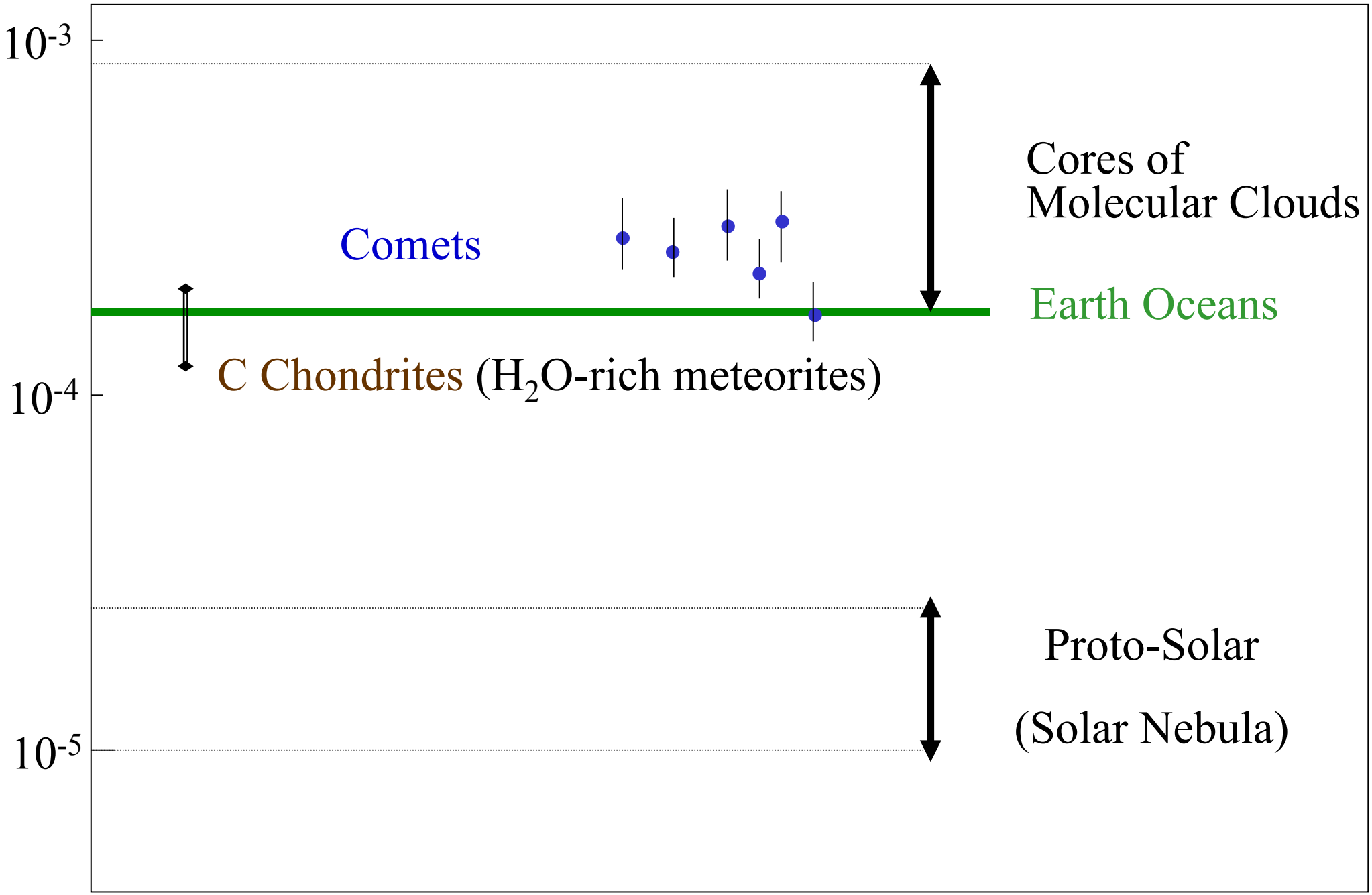
II. Implications on Origin of Earth's Water and Organic Molecules (Cont.)

- Why is Earth rich in H_2O? Where did it come from?
- It has been suggested that most of Earth's water came from impacts with asteroids and comets
- For example, Morbidelli et al. (2000) suggested Earth's water could have come from a single impact with an object formed in the outer asteroid belt
- Asteroids 24 Themis and 65 Cybele are in the outer asteroid belt

II. Implications on Origin of Earth's Water and Organic Molecules (Cont.)

- The composition Earth's water is consistent with an asteroidal and cometary contribution to Earth's volatiles
- Main evidence from Deuterium to Hydrogen isotopic ratios (D/H)

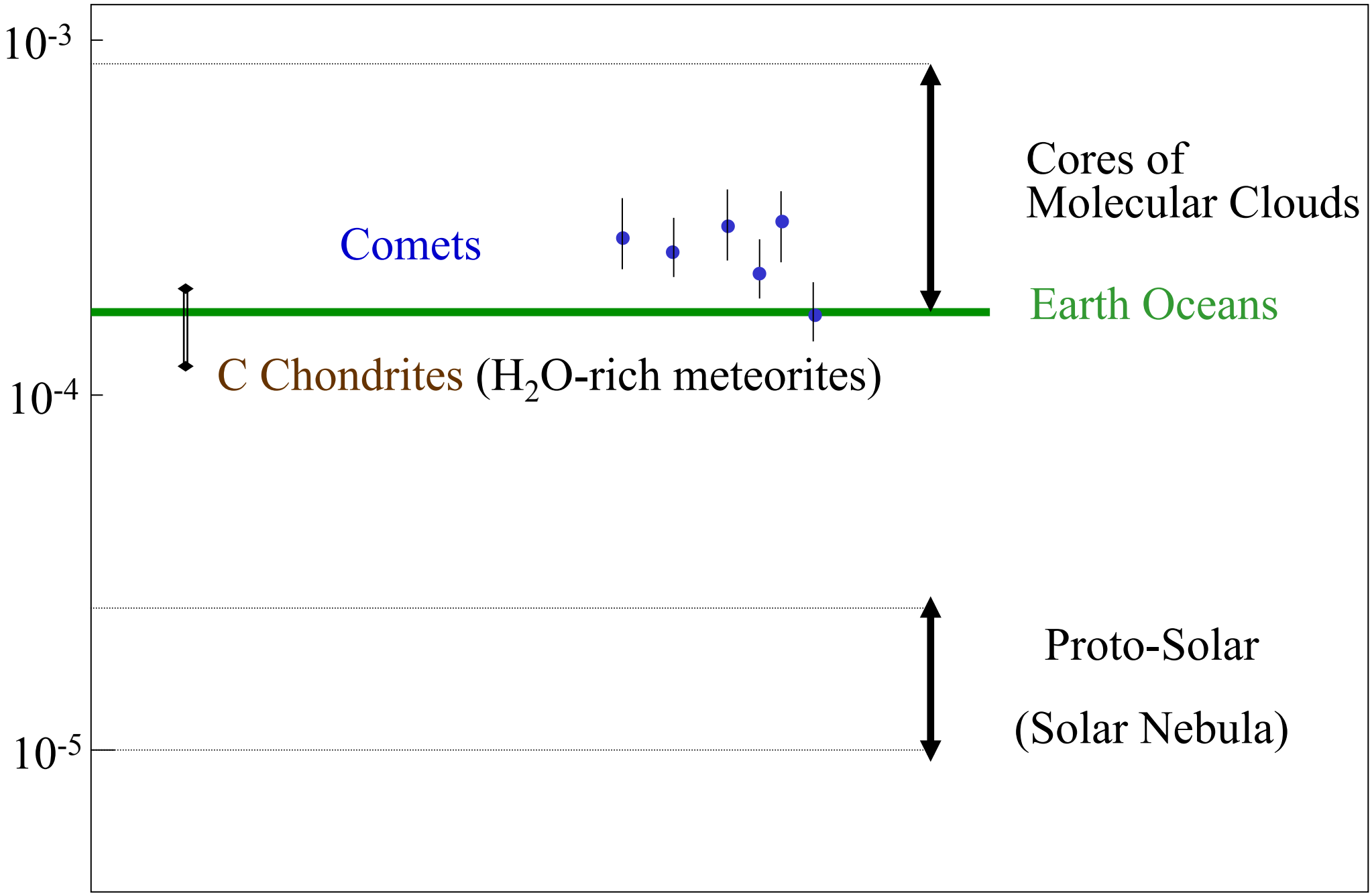
D/H Ratios


10^{-3}
10^{-4}
10^{-5}
Comets
Cores of
Molecular Clouds
Earth Oceans
C Chondrites (H_2O-rich meteorites)
Proto-Solar
(Solar Nebula)

II. Implications on Origin of Earth's Water and Organic Molecules (Cont.)

- Water-rich meteorites have the appropriate D/H ratio to be a source of Earth's Water
- The few comets properly observed have D/H ratios higher or same as Earth, so comets may have contributed to raise the D/H from the Solar Nebula value

D/H Ratios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10^{-4}
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II. (cont.)

Magma Oceans destroyed any primordial organics on Earth
i.e., Earth sterilized itself when it formed

<u>Meteorites and Comets have significant amounts of organic molecules</u>:

- the most primitive meteorites, are rich in amino acids, and
- about half of the cometary dust is organic

Meteorites and Comets have significant amounts of organic molecules:

For example, the Murchison meteorite contains a large assemblage of amino acids including many of the amino acids incorporated into Earth's living systems

Murchison CM2
Carbonaceous Chondrite Meteorite

II. (cont.)

- Hence, impacts with asteroids and comets, may have also contributed significantly to the organic molecule inventory of early Earth
- **The discovery of water ice and organics on 24 Themis and 65 Cybele supports an asteroidal origin of at least some of Earth's water and organic molecules**

III. Relevance to Space Missions

1. 24 Themis may be related to near-Earth Asteroid (NEA) 101955 Bennu, target of NASA's asteroid sample return mission: OSIRIS-REx

The Astrophysical Journal Letters, 721:L53–L57, 2010 September 20 doi:10.1088/2041-8205/721/1/L53

THE ORIGIN OF ASTEROID 101955 (1999 RQ_{36})

Humberto Campins[1], Alessandro Morbidelli[2], Kleomenis Tsiganis[3], Julia de León[4], Javier Licandro[5,6], and Dante Lauretta[7]

3. Same for NEA 1999 JU3, target of JAXA's Hayabusa-2 asteroid sample return mission

A&A 503, L17–L20 (2009)
DOI: 10.1051/0004-6361/200912374

Astronomy & Astrophysics

Letter to the Editor

Spitzer observations of spacecraft target 162173 (1999 JU3)

H. Campins[1,2], J. P. Emery[3], M. Kelley[4], Y. Fernández[1], J. Licandro[2], M. Delbó[5], A. Barucci[6], and E. Dotto[7]

[1] Instituto de Astrofísica de Canarias, c/Vía Láctea s/n, 38200 La Laguna, Tenerife, Spain
e-mail: campins@physics.ucf.edu
[2] Physics Department, University of Central Florida, Orlando, FL 32816, USA

III. Relevance to Space Missions

- **Record of pre-biotic organics on Earth is lost (erased by life itself):**
  Sample of organics on asteroids may provide that record and help determine origin and evolution of life on Earth and possibly elsewhere.

IV. Conclusions

- H_2O-ice and organic molecules discovered on two asteroids
- These results support views that asteroids and comets contributed water and organics to the pre-biotic Earth
- Relevant to sample-return and other missions to asteroids by ESA, JAXA & NASA

NASA's OSIRIS-REx