

# Athena: The First-Ever Encounter of a Main Belt Asteroid with a SmallSat

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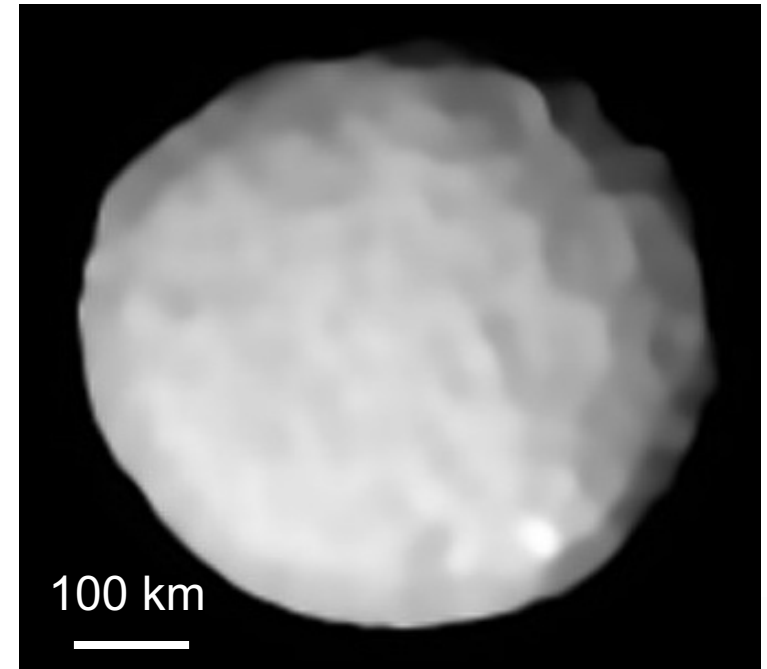
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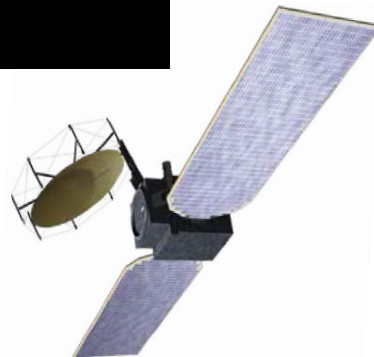
# Athena: Category 1 in SIMPLEx 2018

- Athena targeted (2) Pallas
  - Largest unexplored, most off-ecliptic protoplanet in the main belt
  - Parent of a populous impact family with near-Earth asteroids
- Well-reviewed but not selected

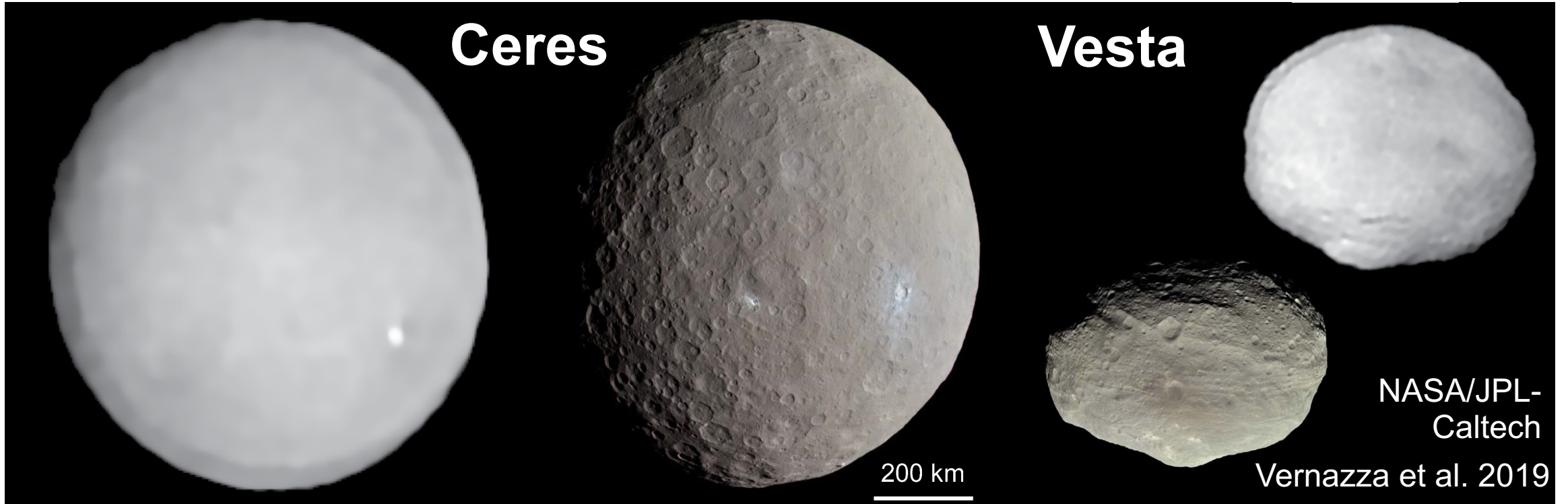
We are excited to propose a new iteration of Athena to the next SIMPLEx opportunity!



Marsset et al. 2020  
*Nature Astronomy*



# New Ground-Based Asteroid Survey



Color = NASA Dawn Mission



~100 m pixel scale

Greyscale = Very Large  
Telescope (VLT)/SPHERE

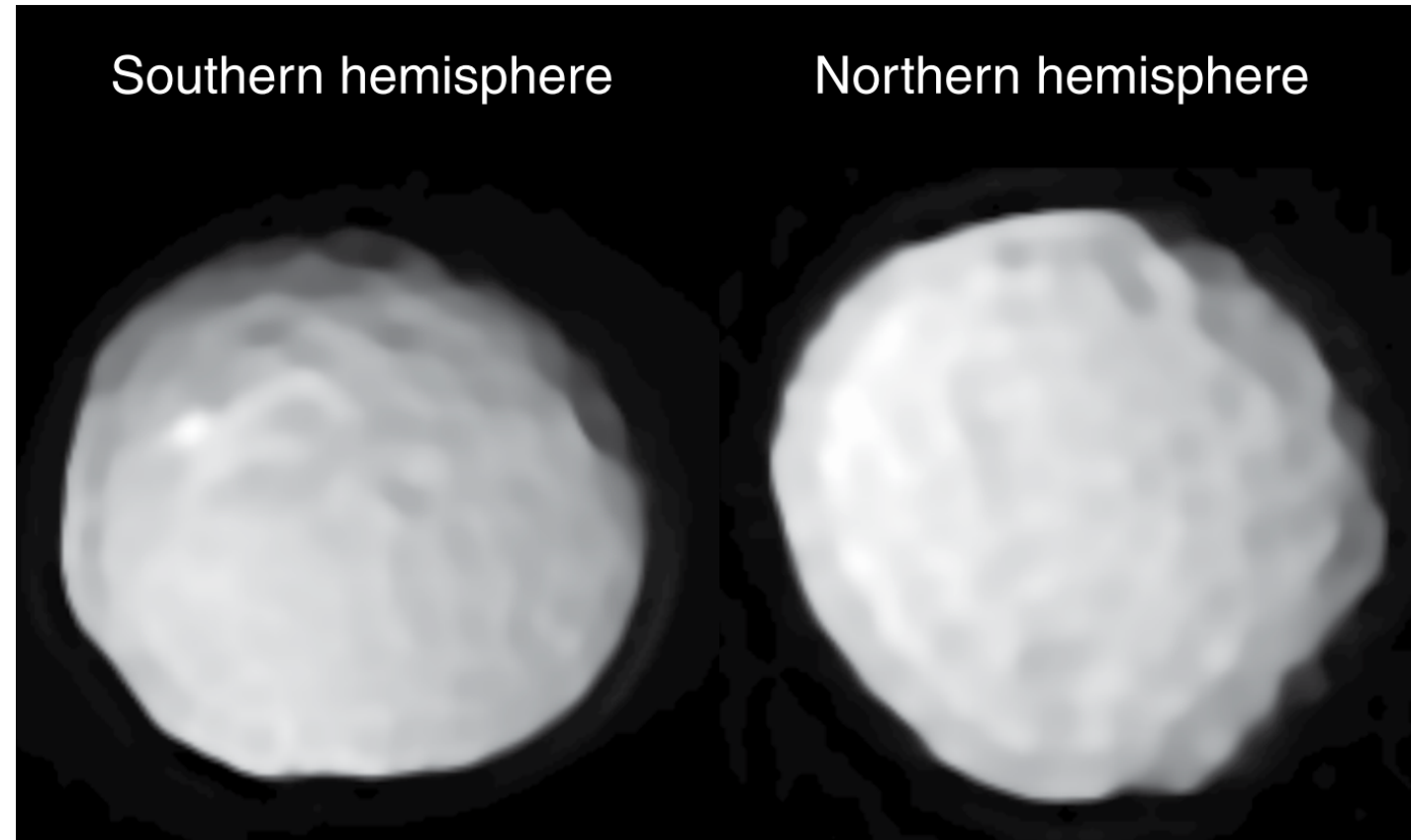


>4 km pixel scale

(~1 km w/ 30-m GMT/TMT)

# New Observations Refine Questions

- Pallas started as a Ceres-like protoplanet, then impacts stripped its ice-rich mantle?
  - Bulk density intermediate to Ceres and Vesta
- Bright spot may indicate aqueous alteration
- Base of ocean exposed?

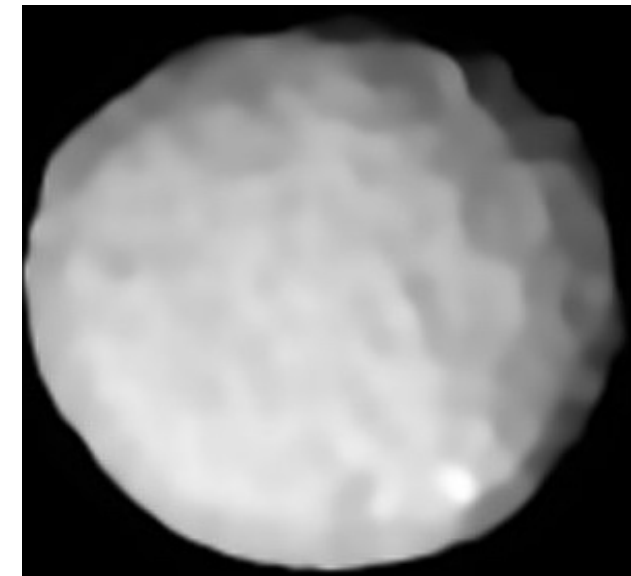


Marsset et al. 2020  
*Nature Astronomy*



# Spacecraft Missions Test Hypotheses

Science Goals	Science Objectives
1. Understand the role of water in the evolution of Pallas	A. Determine the average density → bulk water abundance
	B. Determine the rheology and geology of the near surface → water abundance and form
2. Constrain the dynamical evolution of Pallas & its impact family	C. Determine the history and effects of impacts on Pallas → relative ages and links to NEAs



Marsset et al. 2020

*Nature Astronomy*

# Objective A: Bulk Water Content



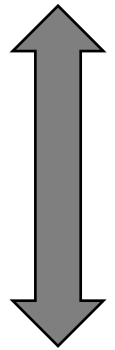
**Ceres**

~30% H<sub>2</sub>O

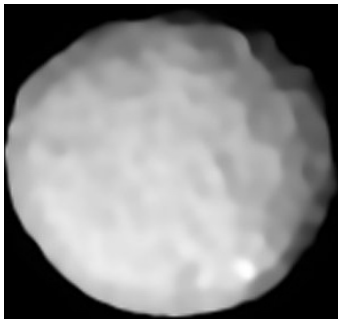
2161 kg/m<sup>3</sup>



Schmidt & Castillo-Rogez 2012

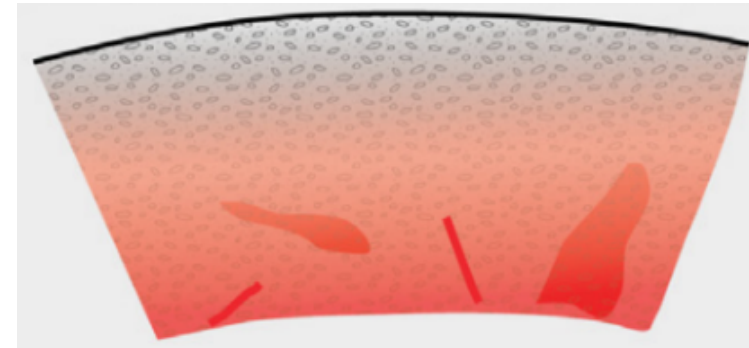


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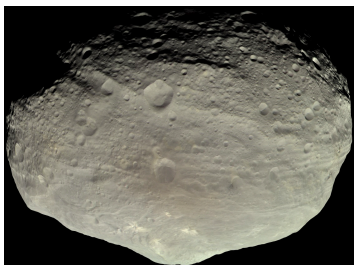


**Pallas**

2890 ± 80 kg/m<sup>3</sup>



Fu & Elkins-Tanton 2014



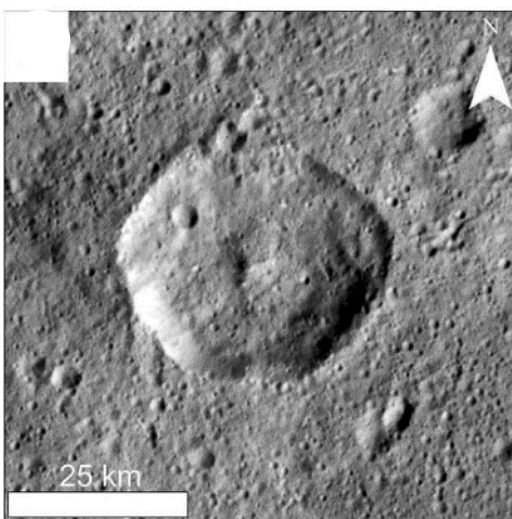
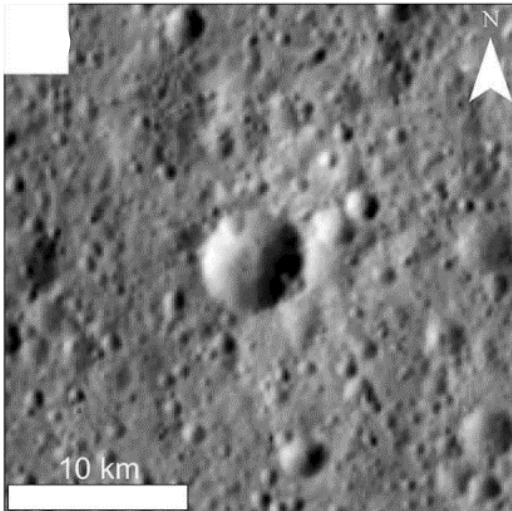
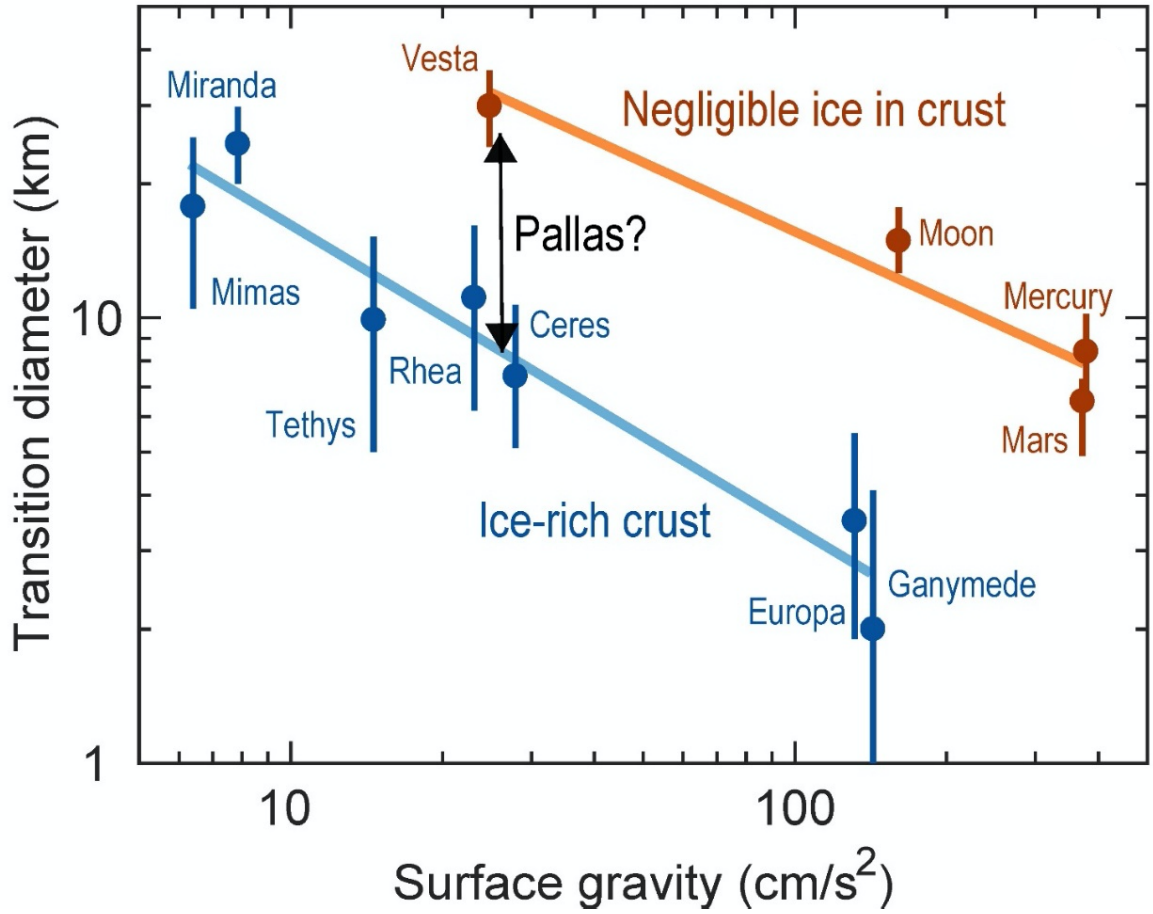
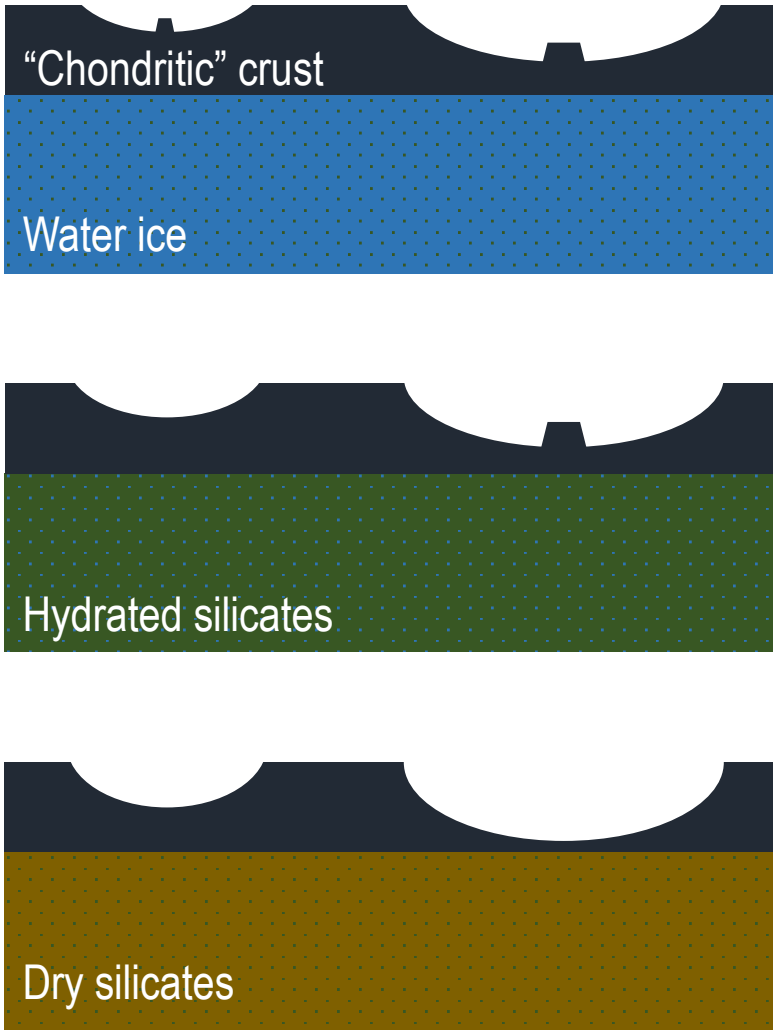
**Vesta**

~0% H<sub>2</sub>O

3456 kg/m<sup>3</sup>

Does aqueous alteration on the surface signal that Pallas is water-rich?

# Objective B: Internal Structure



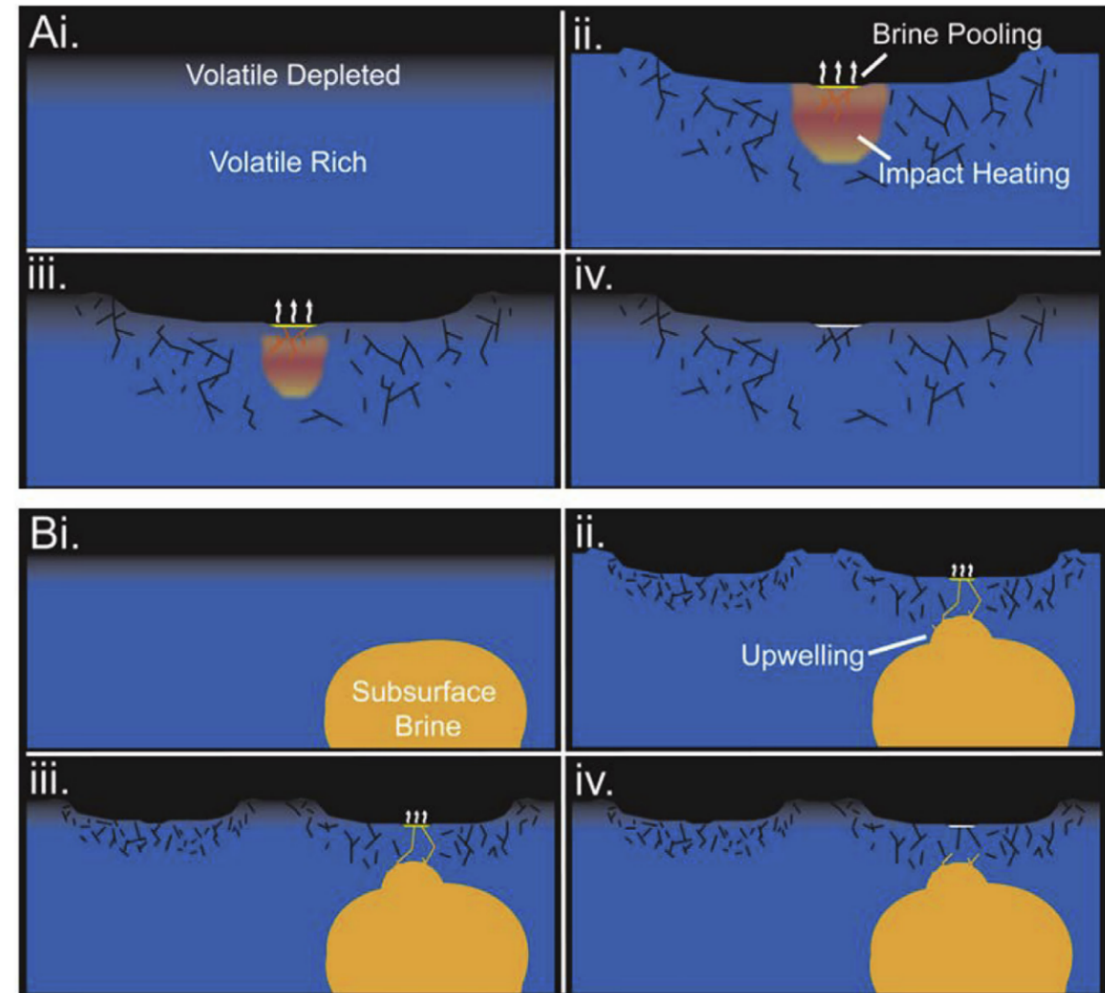
Hiesinger et al. 2016

# Objective C: Fast Impacts on Pallas

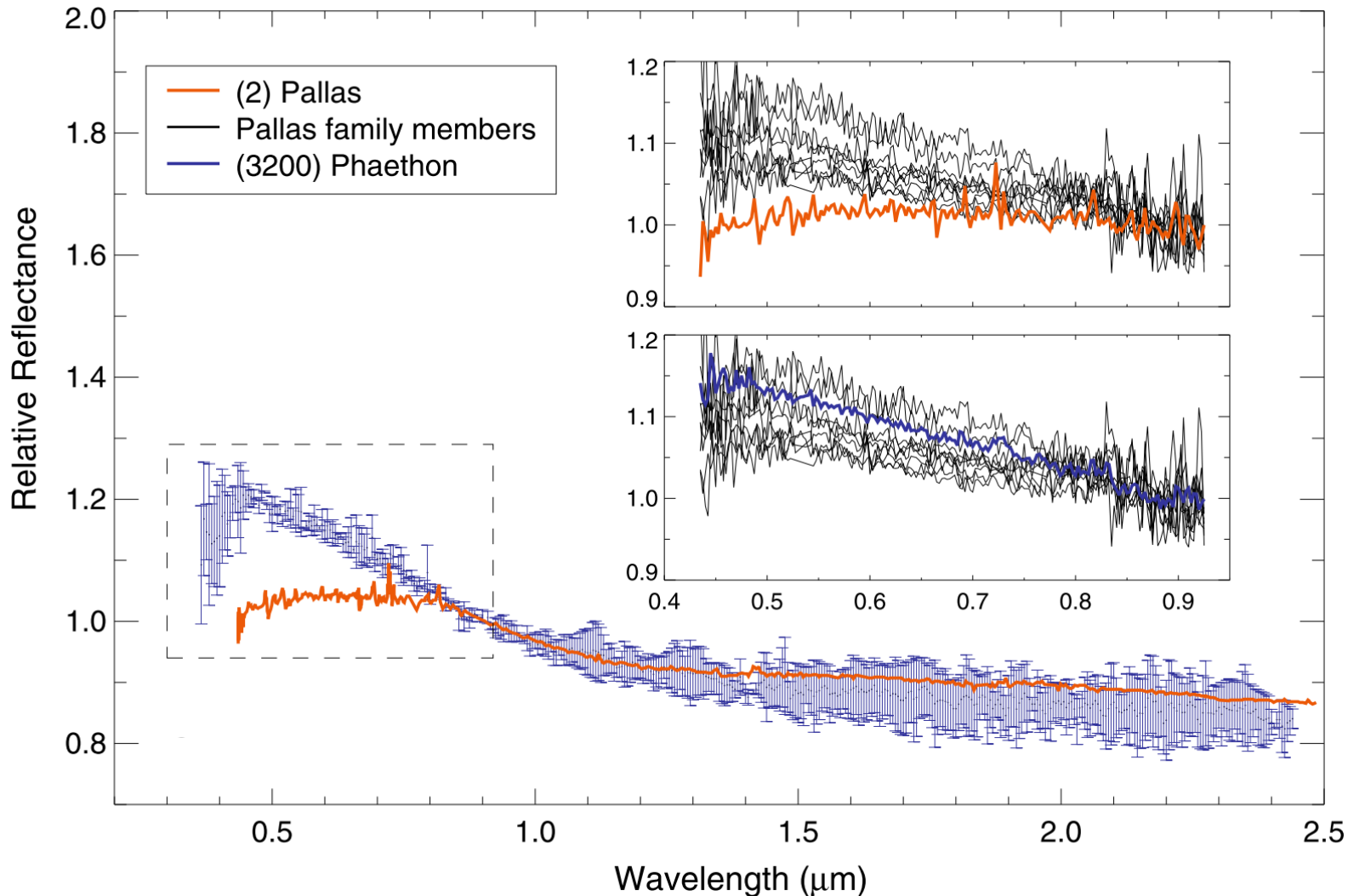
Widespread bright spots are expected on a Ceres-like surface for Pallas (Stein et al. 2019)



ESO/HLT-SPHERE



# Objective C: Origin of Phaethon



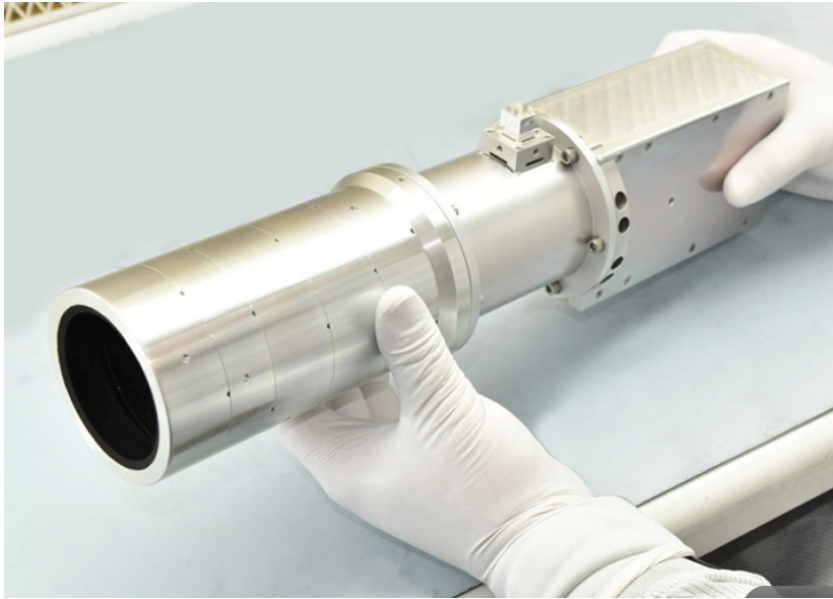
Athena resolves the color difference (visible) between Pallas & Phaethon at  $\sim 5$  km scale

Synergy with JAXA DESTINY+ mission

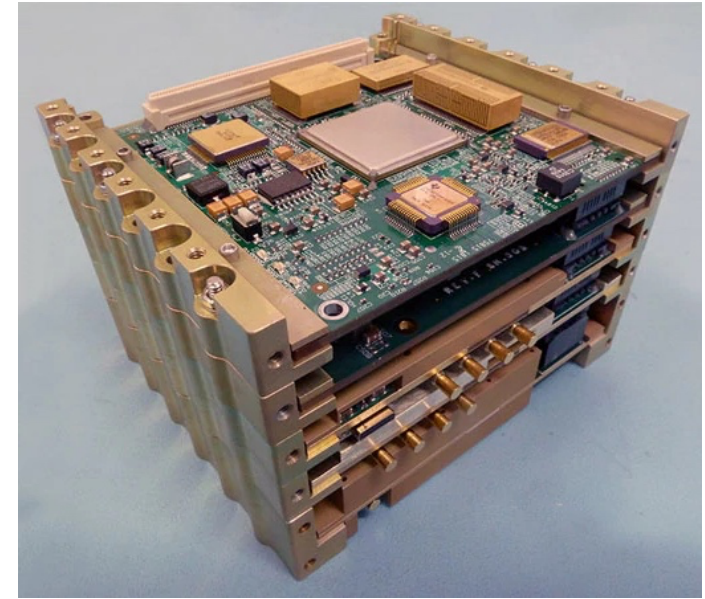
de León et al. 2010



# Payload: High Heritage, Low Cost



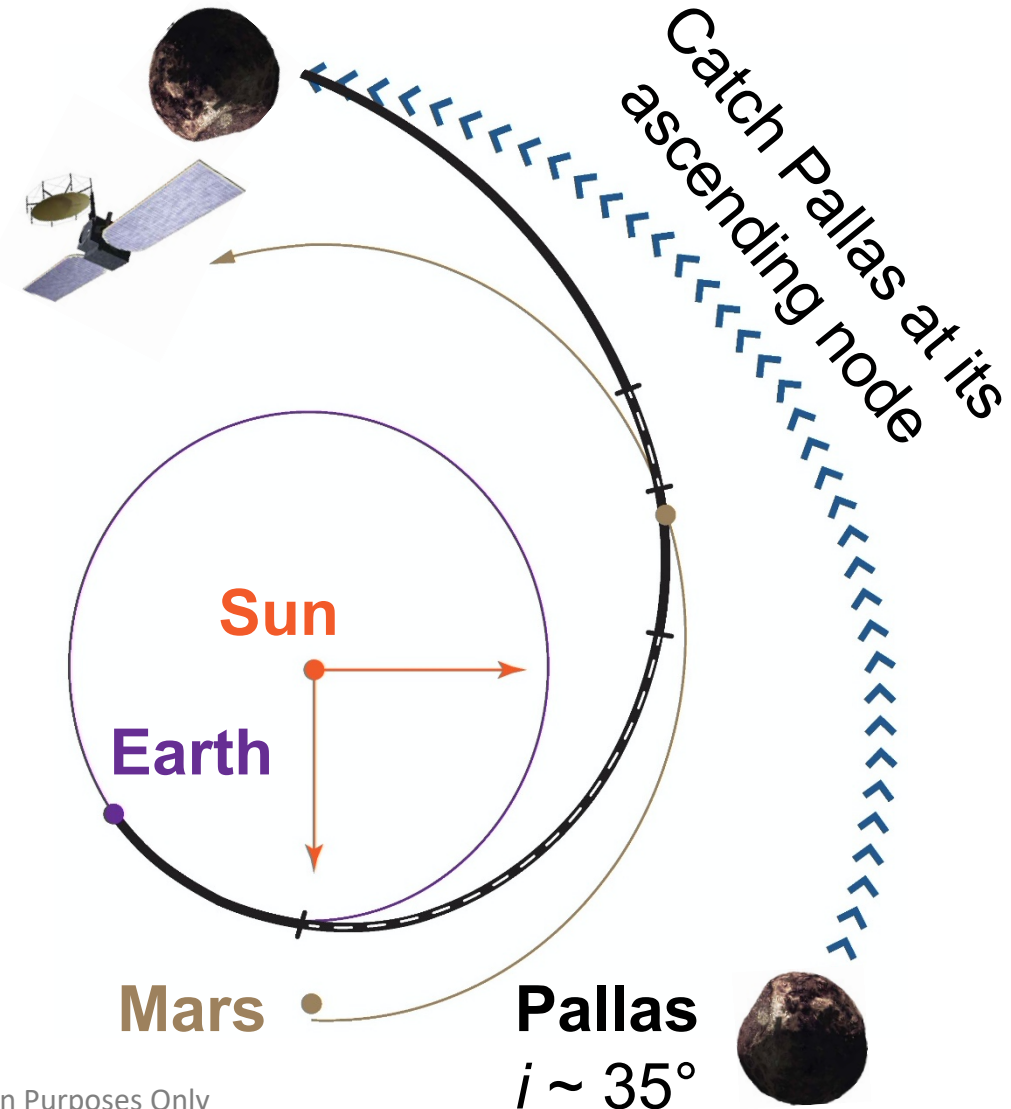
**Athena Science Camera**  
Panchromatic & RGB color  
Geologic mapping & topo.



**Radio science**  
Iris X-band radio  
Mass measurement

# Athena: 2018 Mission Design

- Proposed to launch with Psyche
  - ~1 year cruise with Mars flyby
- Science encounter profile
  - Closest approach ~500–1000 km
  - Radio science within a few days
  - Imaging within  $\pm 1$  rotational period (~8 hours)
- Data downlinked to DSN over a few months after the encounter





# Summary: Athena Mission Concept

- Athena would explore one of the largest main belt asteroids with a SmallSat
  - How do chemical and physical processes operate on water-rich protoplanets?
  - What is the nature of parent bodies that spawn active impact families?
- SmallSat-sized instrument payload can achieve decadal-priority science
  - SmallSats are low-cost pathfinders
  - More flight opportunities → Retire science risks for larger (Discovery+) missions

