Picturing the solar system small bodies with new-generation adaptive-optics systems

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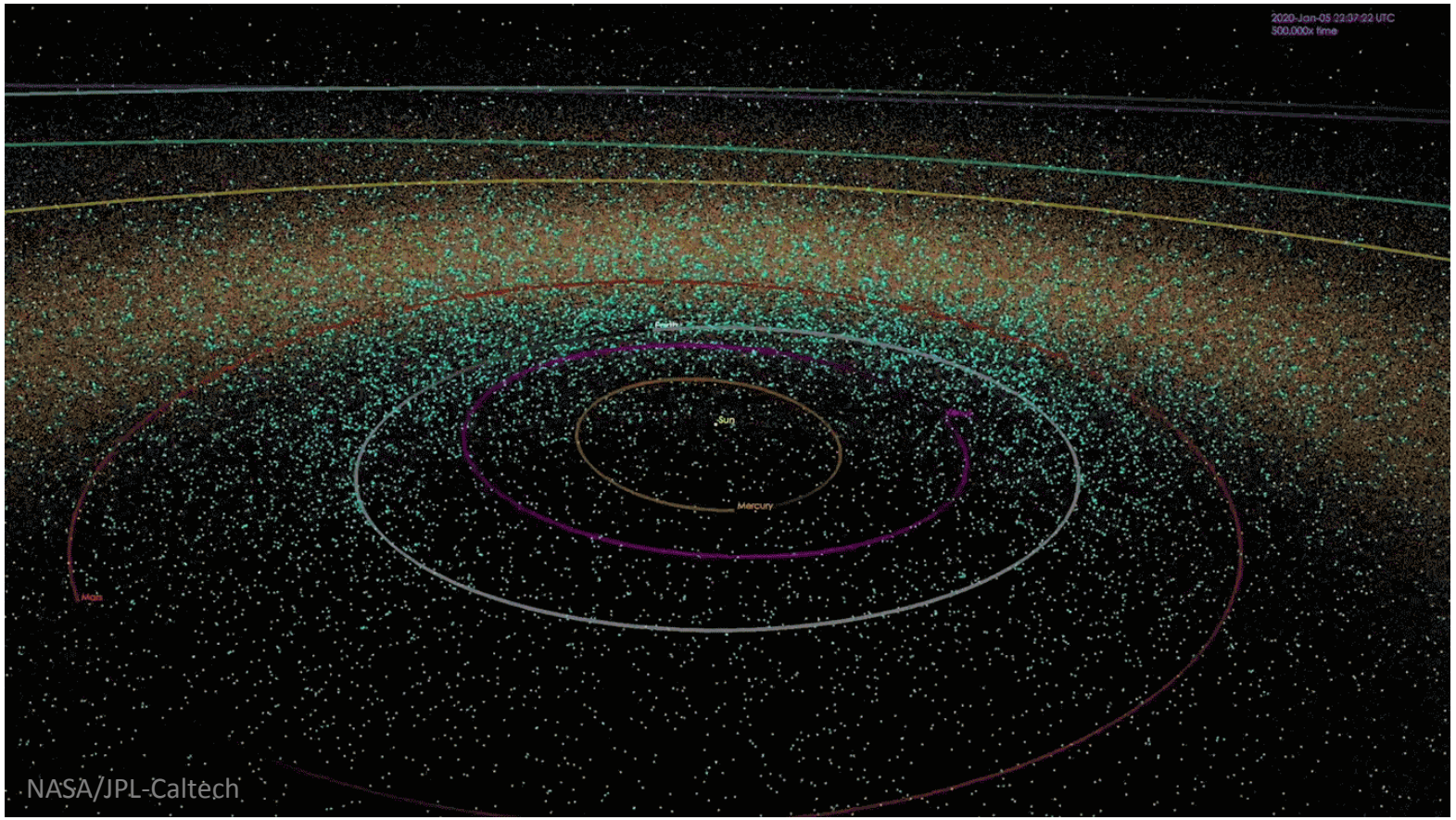
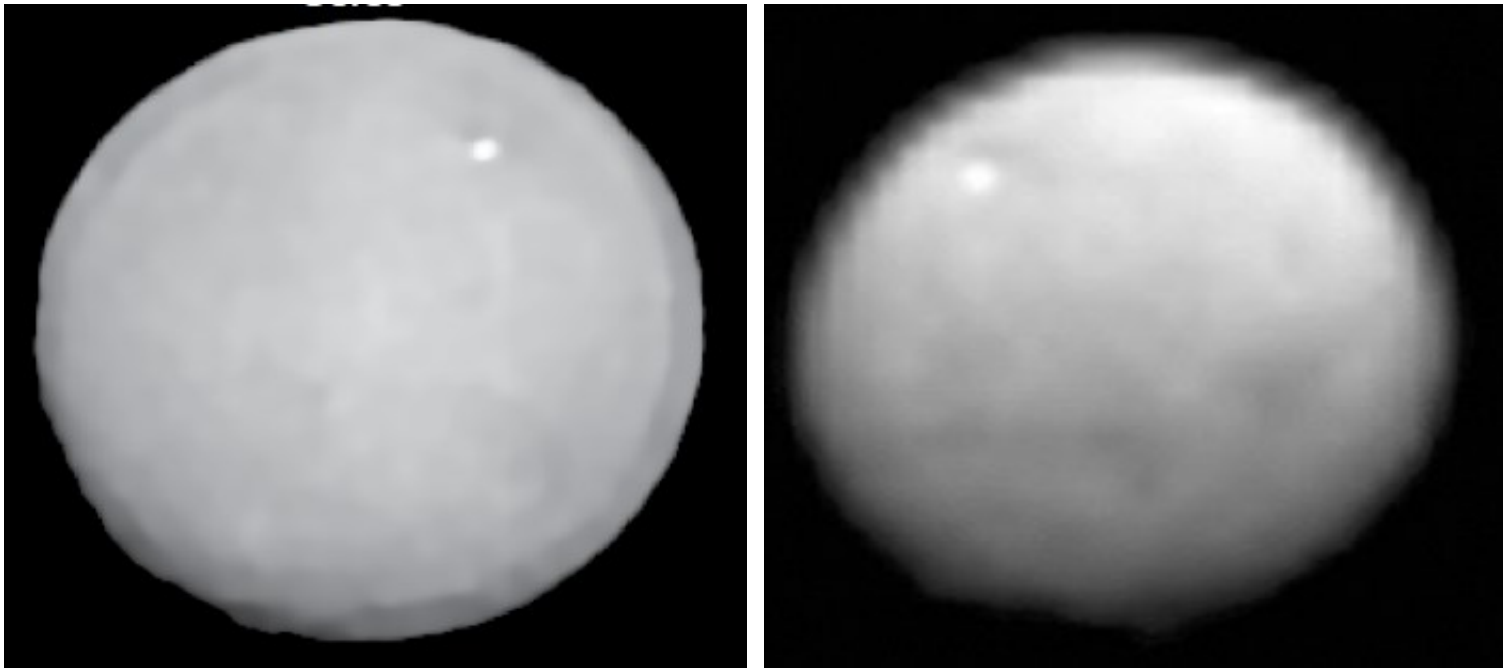
Picturing *the solar system small bodies with new-generation adaptive-optics systems*



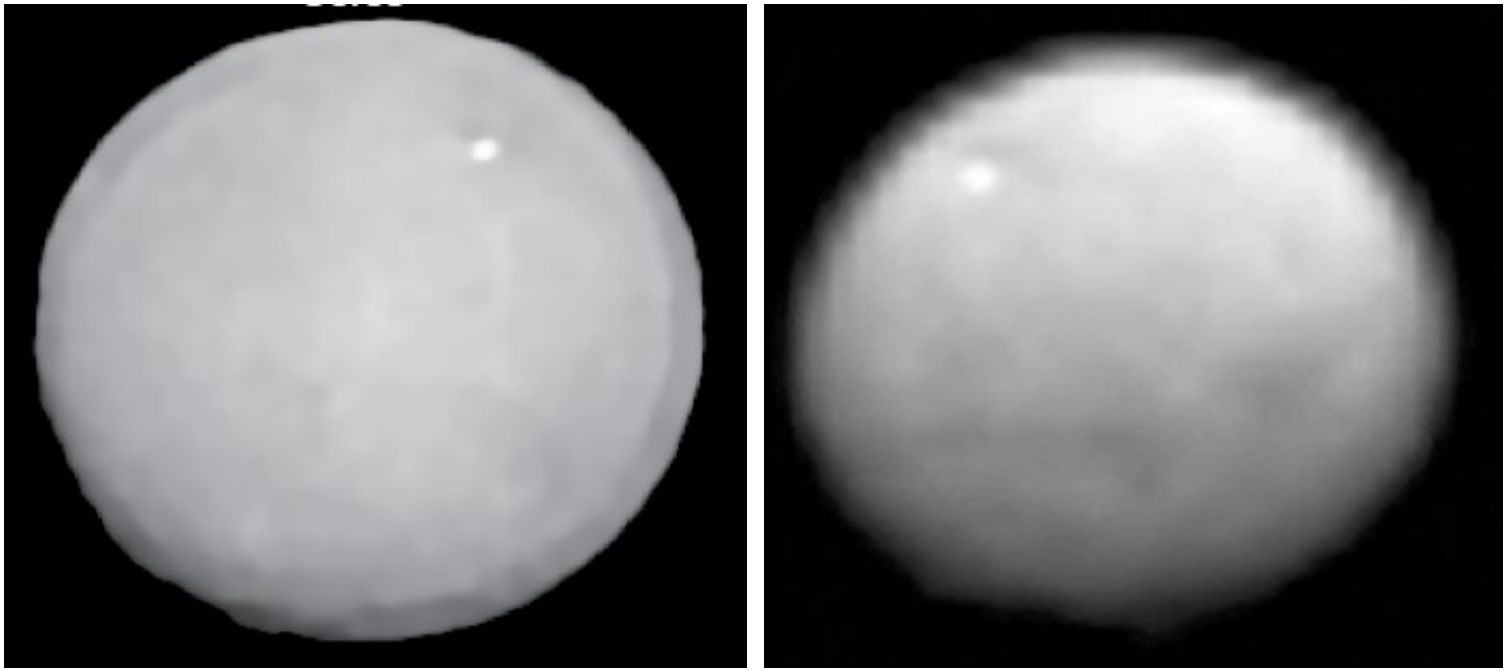
From “dots”…

Picturing *the solar system small bodies with new-generation adaptive-optics systems*



… to disk-resolved images!

Picturing *the solar system small bodies with new-generation adaptive-optics systems*



… to disk-resolved images!

Ceres: VLT/SPHERE vs. Dawn (383.000 km)

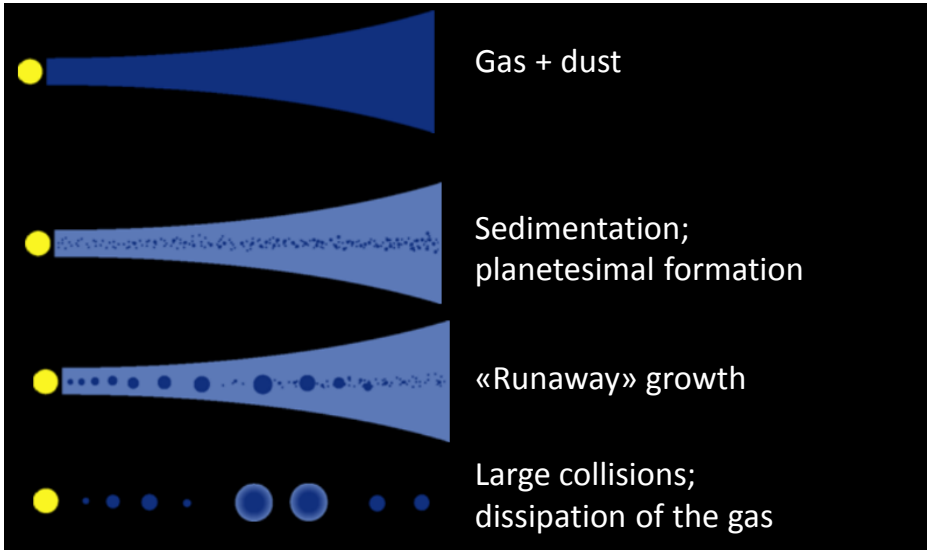
Small bodies: witnesses of the primordial solar system

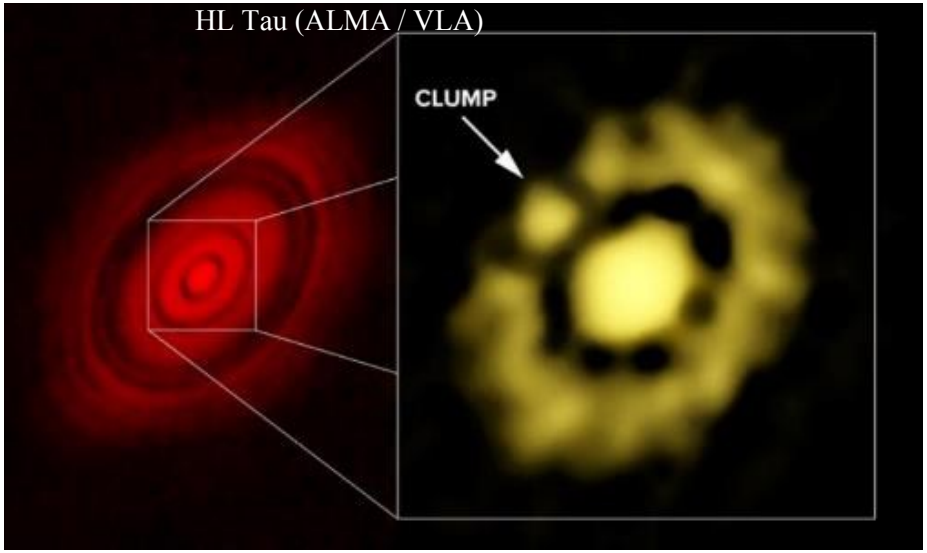
Which processes governed the formation and evolution of the primordial solar system?

Which information we can get for the study of exoplanetary disks?

Solar system small bodies represent the last vestiges of planetesimals and protoplanets

The solar system as a "case model" that we can study in detail, and even in-situ





The «meter-size barrier»

When size of colliding objects approaches a meter:

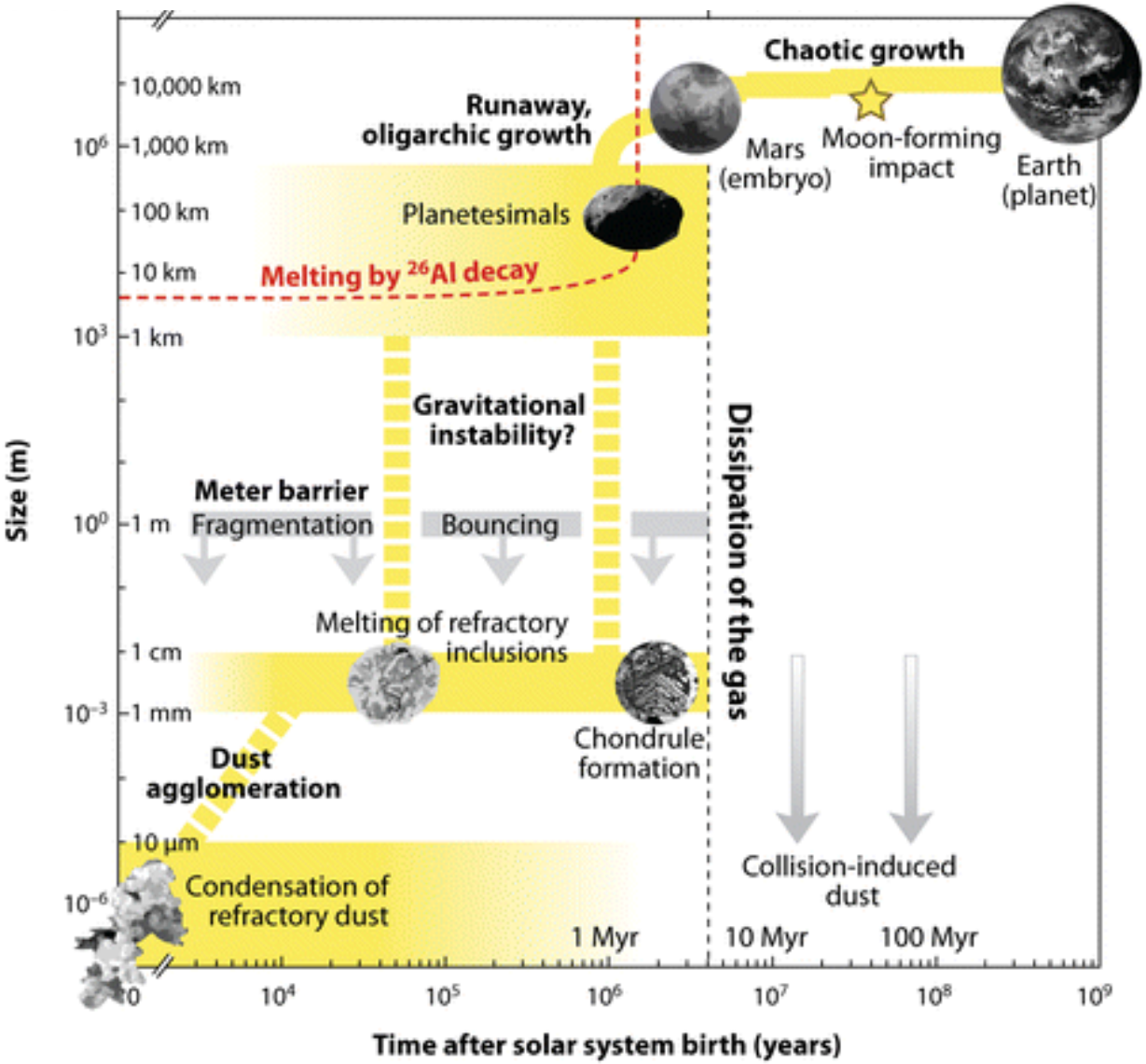
- binding energies decline
- relative velocities increase

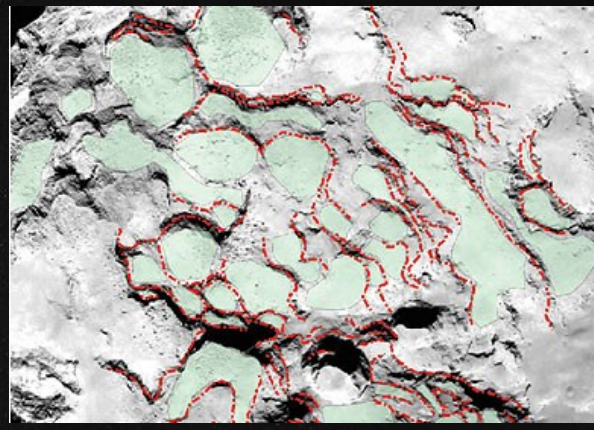
→

neither gravity nor viscous forces can easily explain growth from cm-sized grains to km-sized asteroids

→

"Picturing" small bodies' size, shape and surface structures is crucial to shed light on the mechanisms behind planetary accretion and evolution

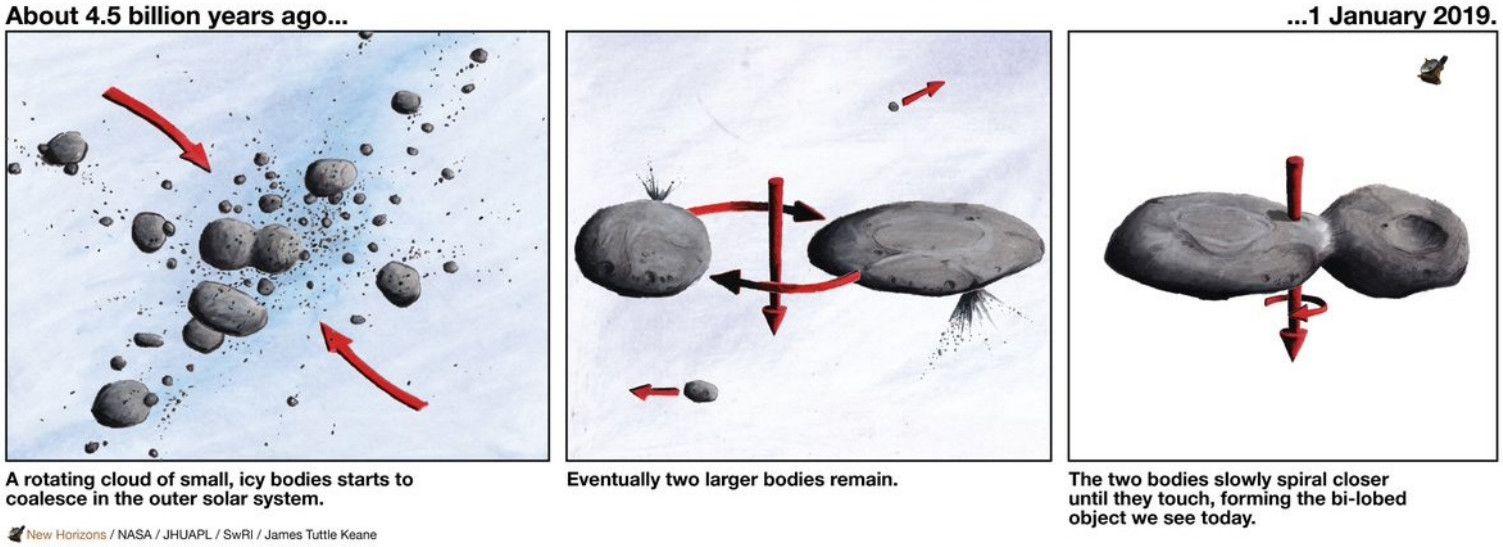




Comet 67P (~4.3×4.1 km)
as seen by ESA/Rosetta: shape arose from a low-speed collision between two similar but separately formed onion-like bodies

Arrokoth

- 36×18×10 km
- ~ 44 AU from Earth
- New Horizons' flyby (6600 km) on 1/1/2019

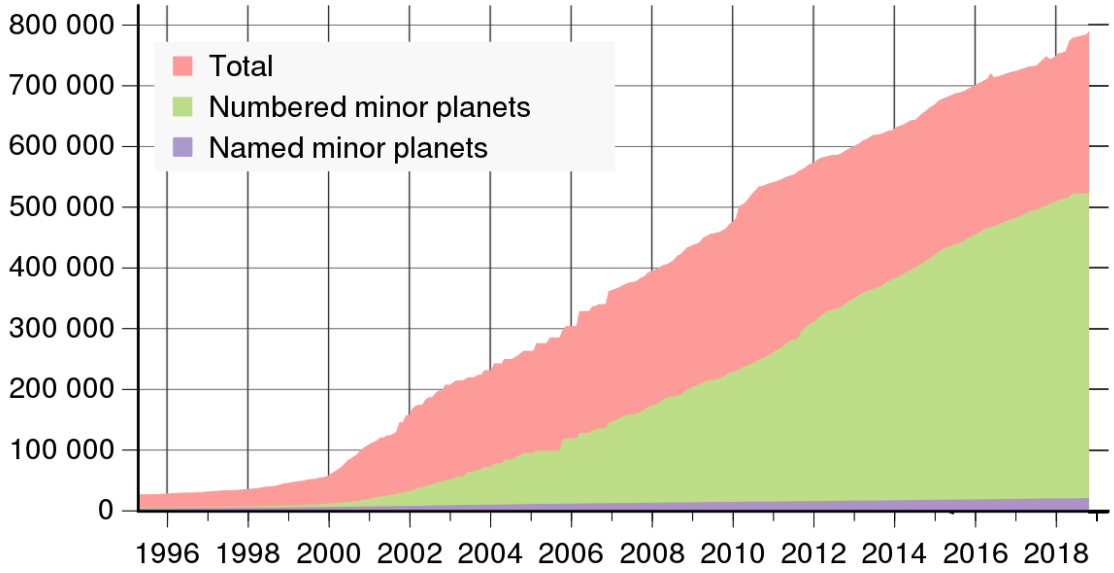


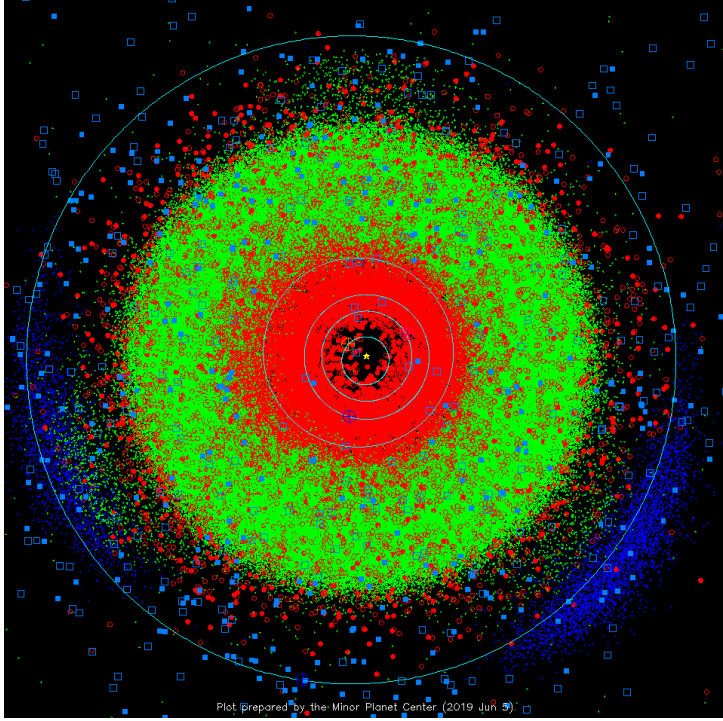
Solar System Small Body census

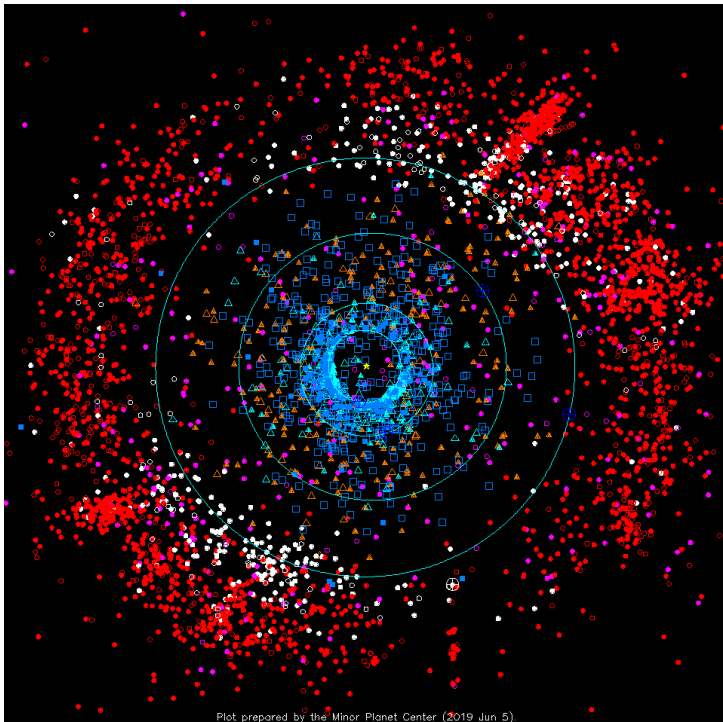
- Existing: ≈ 10^{12} - 10^{14} (MBA+KBO >10 m)
- Discovered: ~10^{6} (~10^{7} with LSST)
- Space mission targets: 26 (in orbit: 7)

→

ground-based disk-resolved investigation of a much greater, statistically significant, number of small bodies is fundamental!

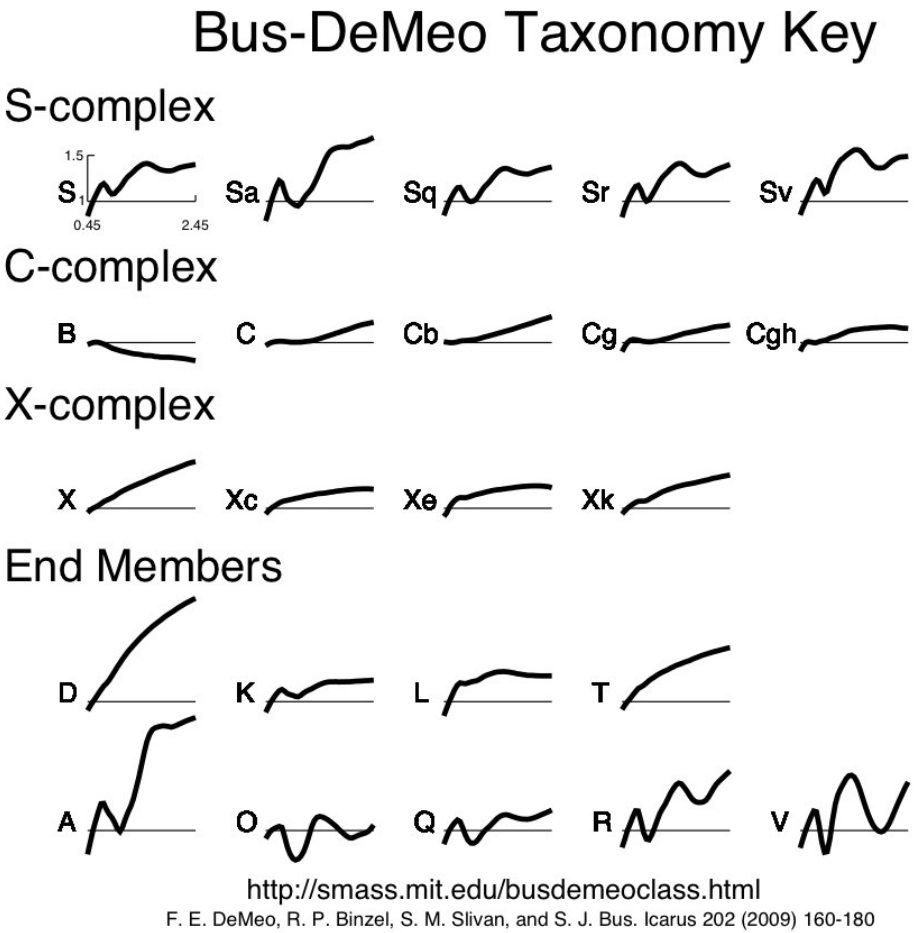


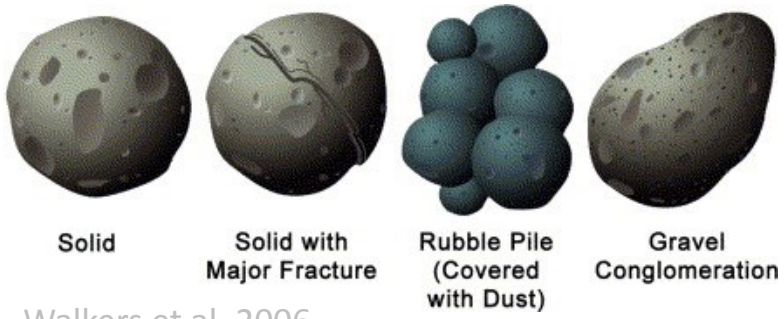




A **huge diversity**

(in terms of composition, size, density distribution, …)
is still to be explored!

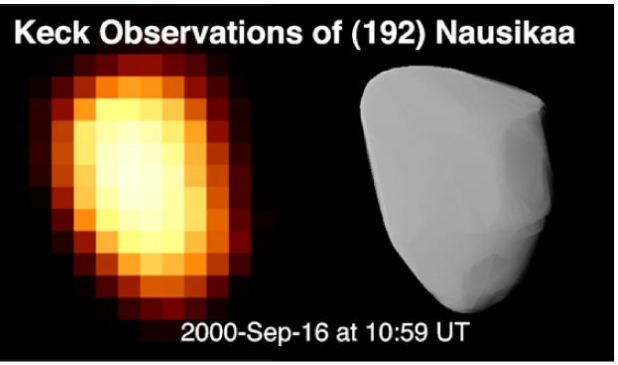


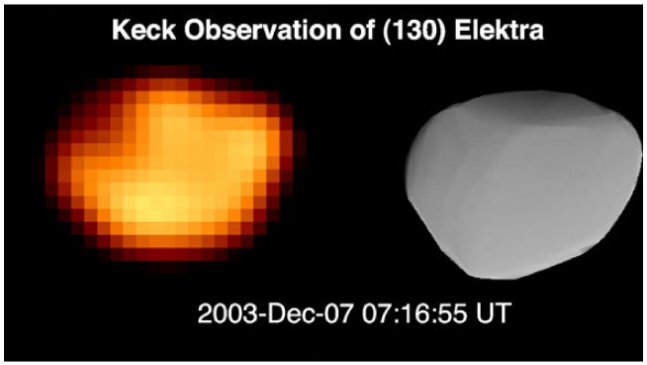


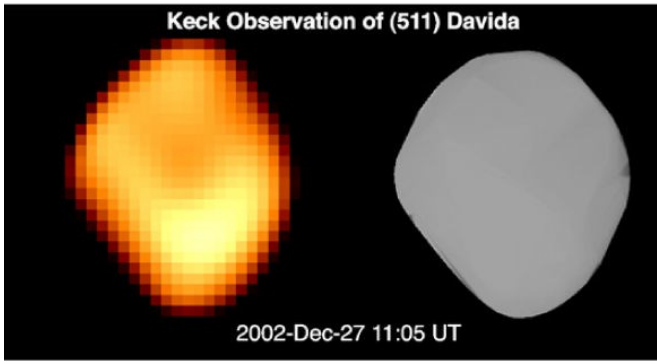
Walkers et al. 2006

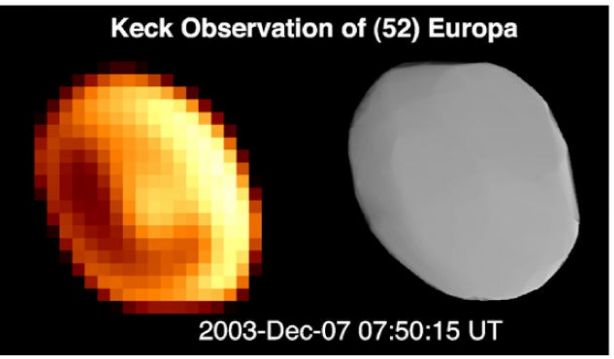
Keck/NIRC2 Survey

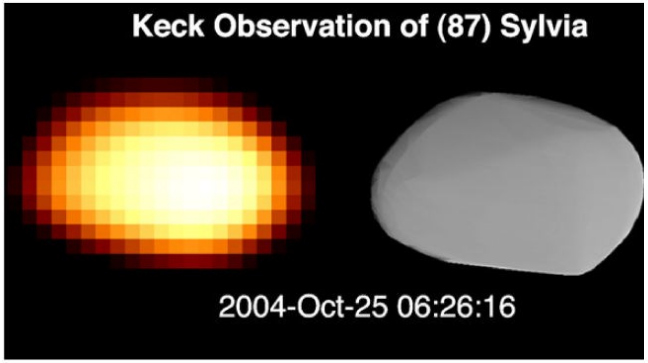
- 33 main-belt asteroids observed in 2000-2004
- vs. 3-D models from optical lightcurves

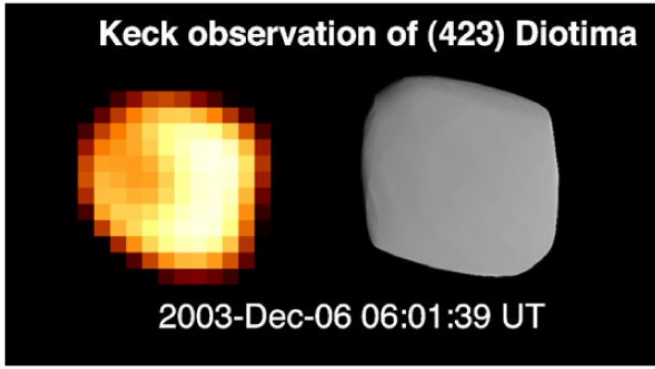












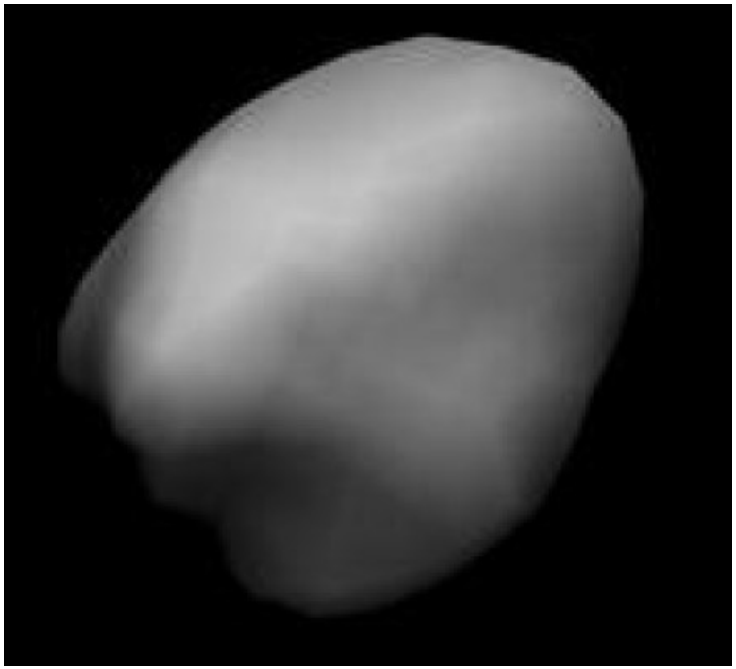
Marchis et al. 2006

The case of (21) Lutetia

- 50 lightcurves over 1962-2010
- 36 disk-resolved images over 2007-2009 (Keck/NIRC2 + VLT/NACO)

→

3-D shape model used to plan the flyby of ESA Rosetta mission (10/7/2010)

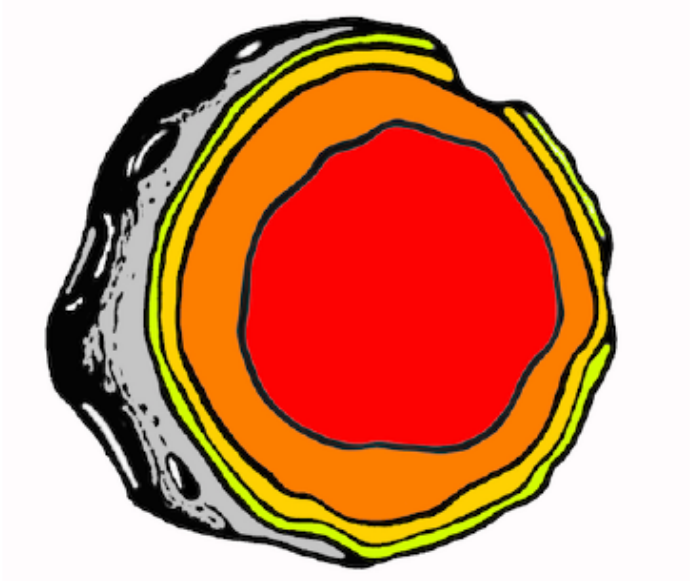


Carry et al. 2010, A&A 523, A94

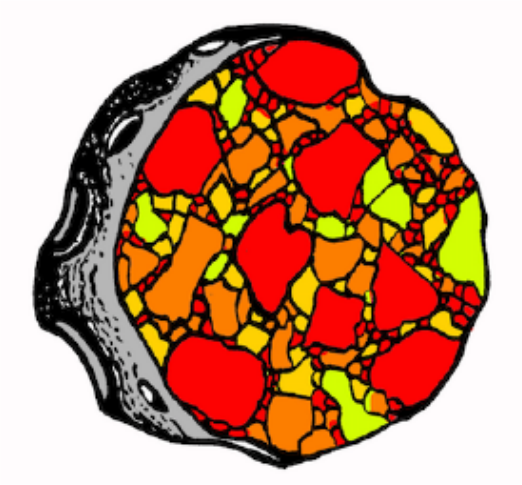
VLT/SPHERE Survey

- PI: P. Vernazza (LAM, France)
- Awarded 152h over 5 semesters (4/2017 – 9/2019)
- Targets: ~35 main-belt asteroids larger than 100 km
- Up to present, published results for 8 asteroids

> 100 km: primordial



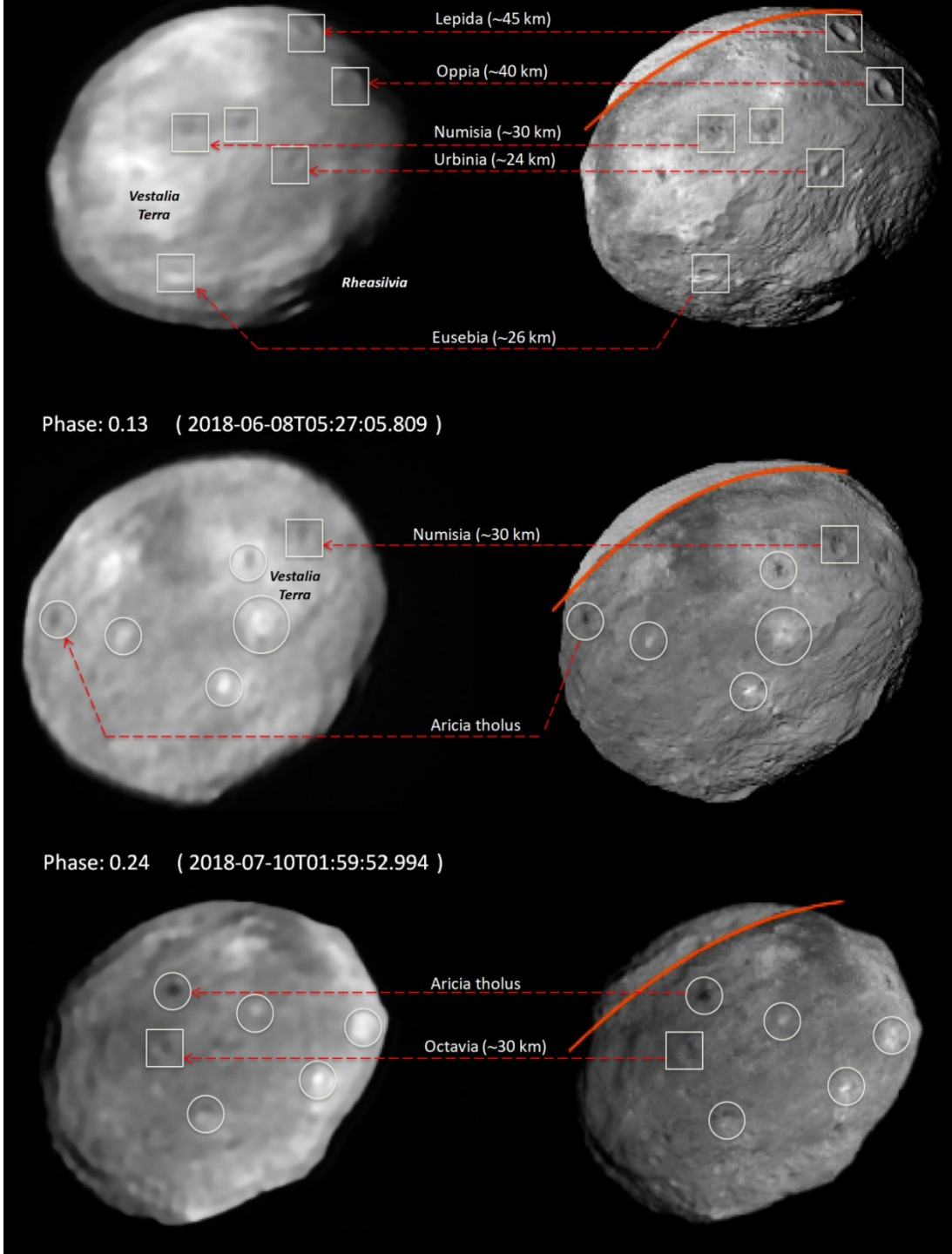
< 100 km: rubble pile



VLT/SPHERE (vs. Dawn)

(4) Vesta (~530 km)

- 30 SPHERE/ZIMPOL images over 1.5 months
  (Vesta @ ~1.2 AU from Earth)
- Parametric PSF deconvolution (Moffat profile)
- Surface features down to ~20 km
- Contour accuracy ~1 pixel (3.6 mas)



Fétick et al. (2019)

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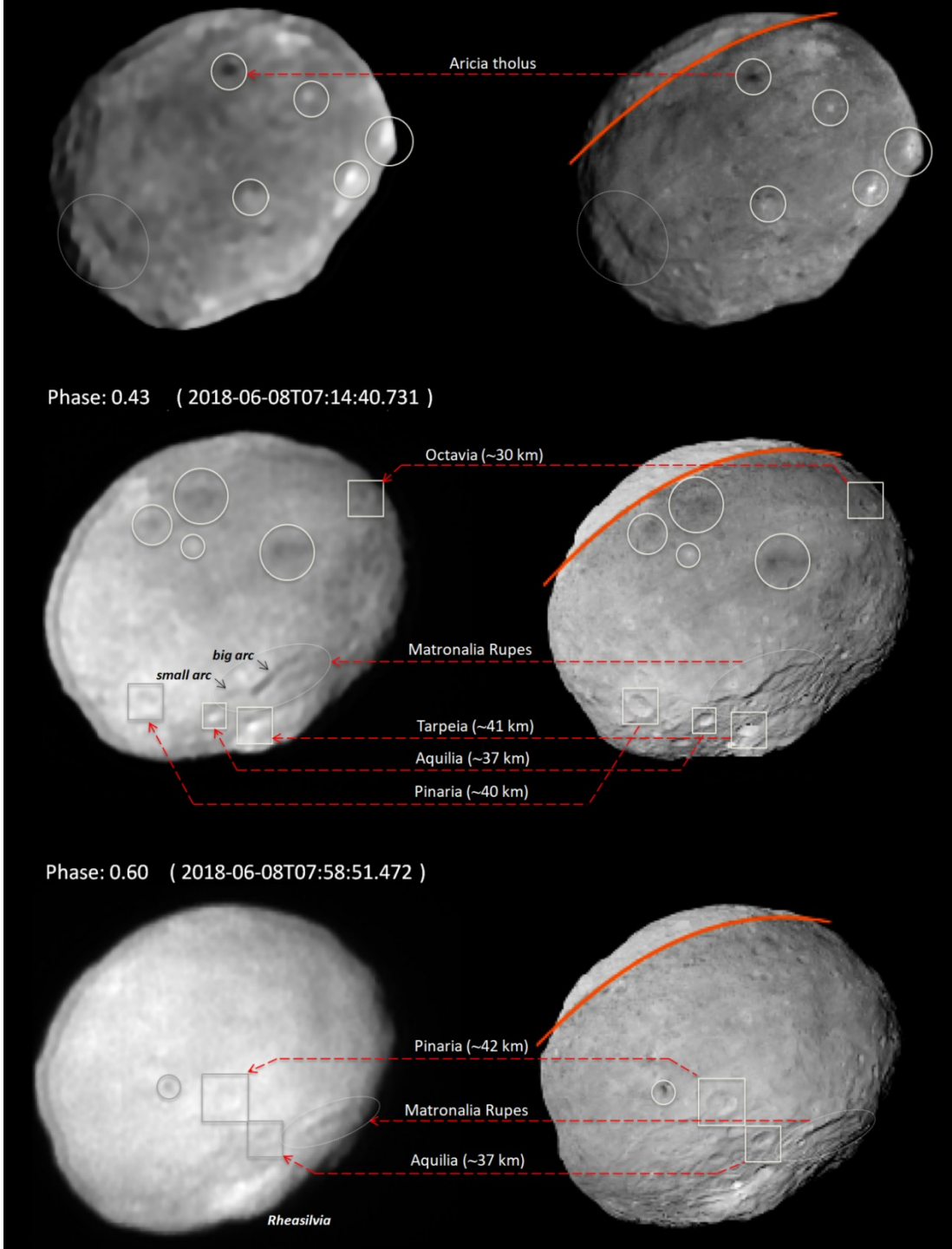
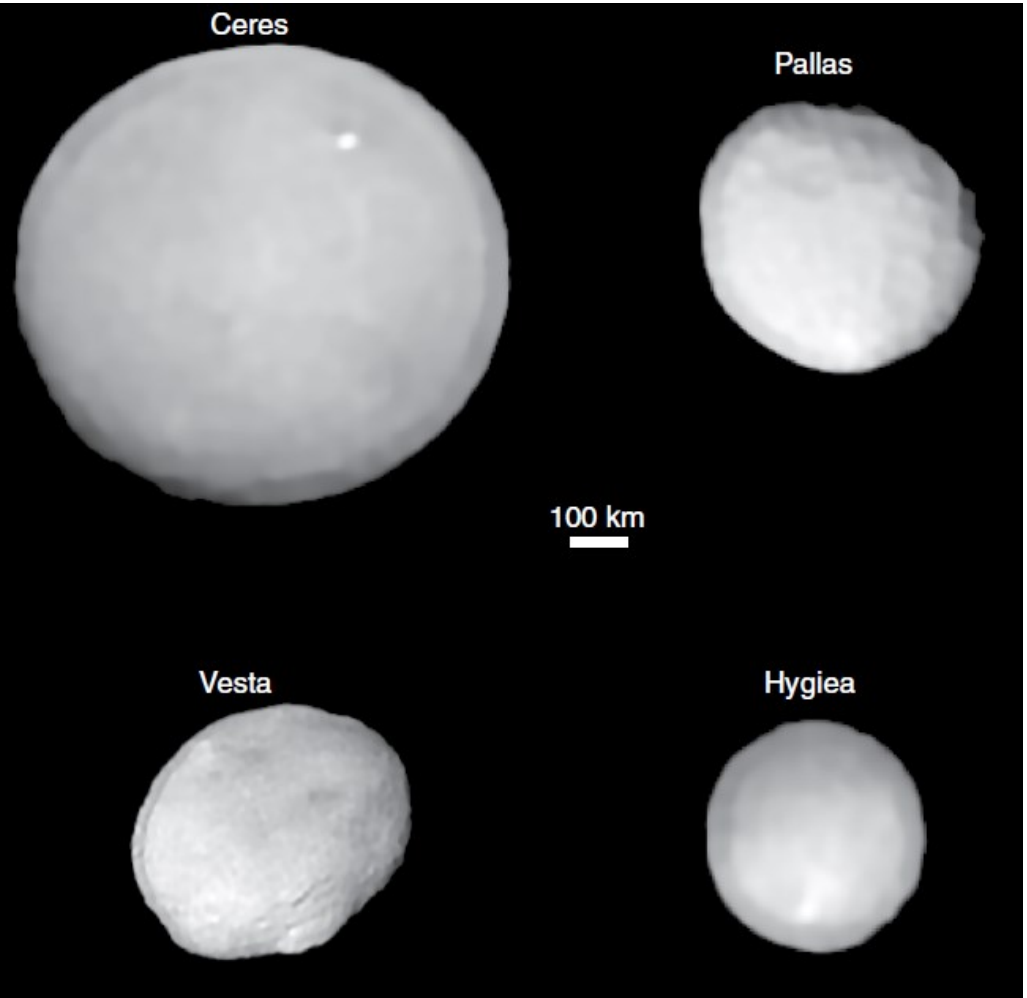
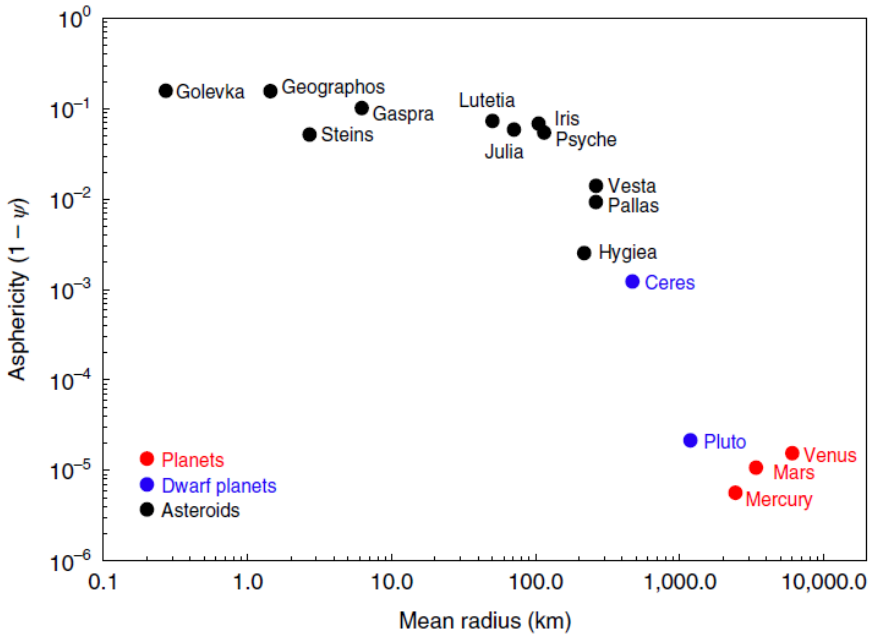


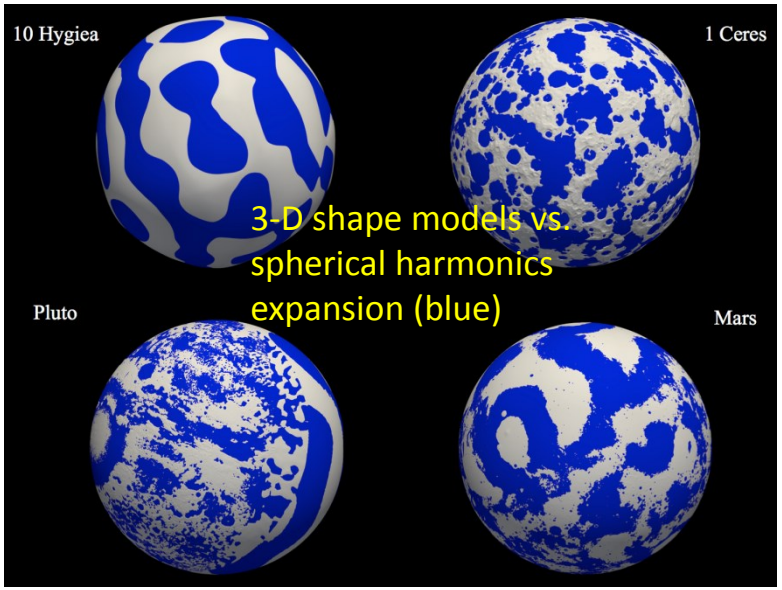
Fétick et al. (2019)

VLT/SPHERE

Is (10) Hygiea (~430 km) a dwarf planet?





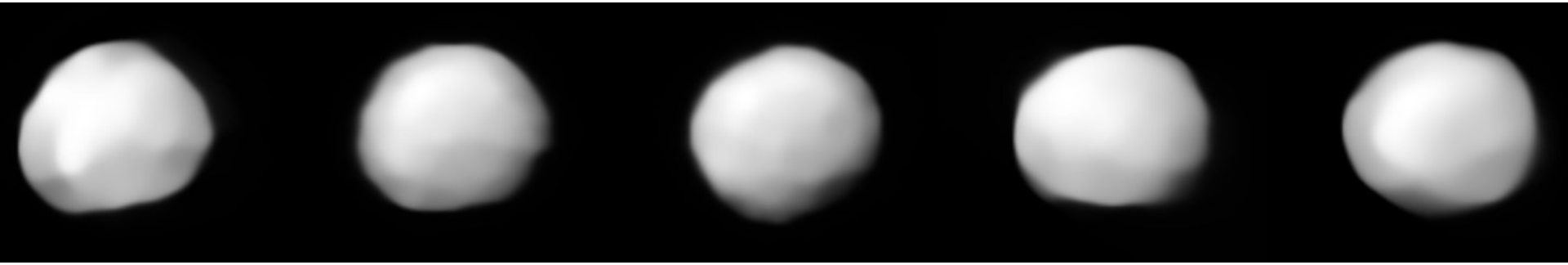


Vernazza et al. (2020)

VLT/SPHERE

(704) Interamnia (~330 km)

- One of the few asteroids in the 200-400 km size range
- Still a nearly ellipsoidal equilibrium shape
- Bulk density of ~ 2 g/cm^3, suggests high fraction of water ice
  - ✓ consistent with the paucity of apparent craters



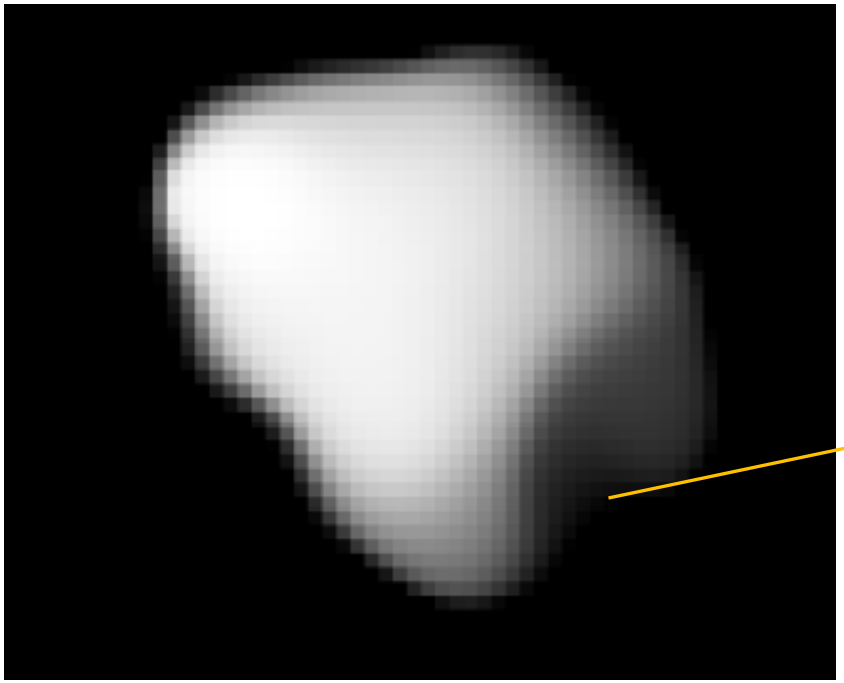
Hanuš et al. (2020)

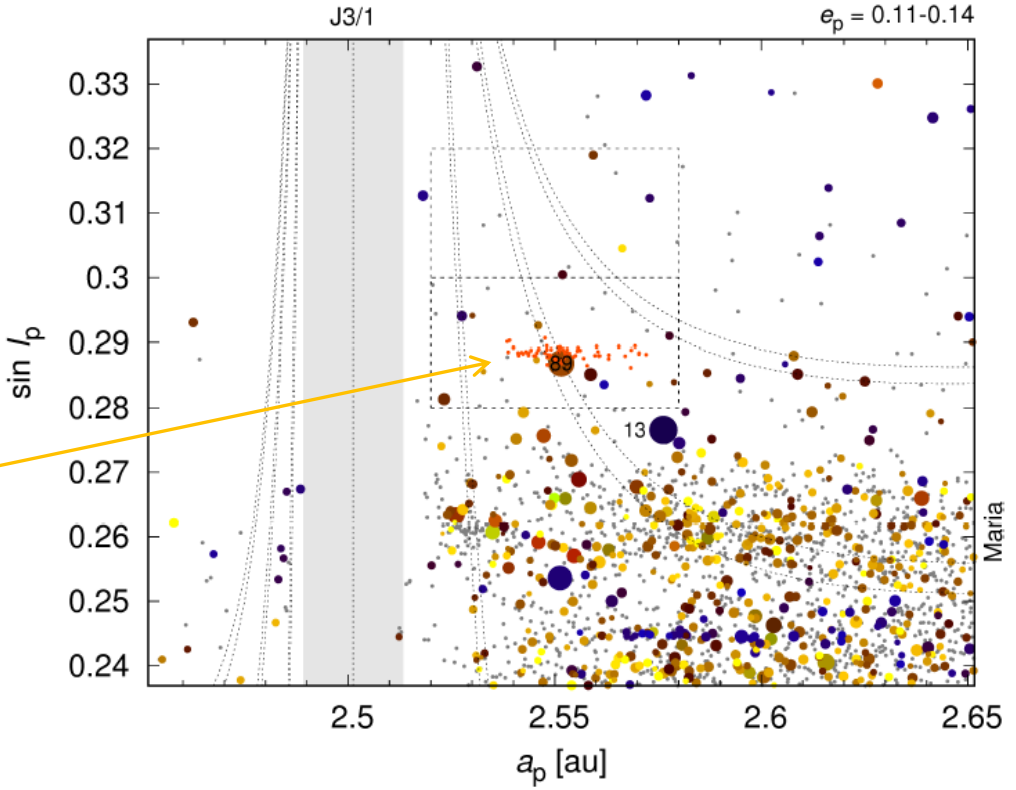
VLT/SPHERE

(89) Julia (~140 km)

- Recently proposed (Nesvorný et al. 2015) as the parent body of a small compact asteroid family (33 members)

- Crater “Nonza” compatible with such collisional event





Vernazza et al. (2018)

Beyond the state-of-the-art: the "SHARK way"

- Main belt: ~100 asteroids > 50 mas (and bright enough for AO guide)
  - Sharpest resolution with SHARK-VIS
  - With complementary (ideally, contemporaneous) observations at VIS and NIR wavelengths:
    - ✓ we solve ambiguities in building the shape model (e.g., dark terrain regions vs. concave/cratered regions) → better estimation of volume and density
    - ✓ VIS-NIR colour at different rotational phases → constrain surface composition and map its heterogeneity
      (in combination with topography → hints on formation/evolution)

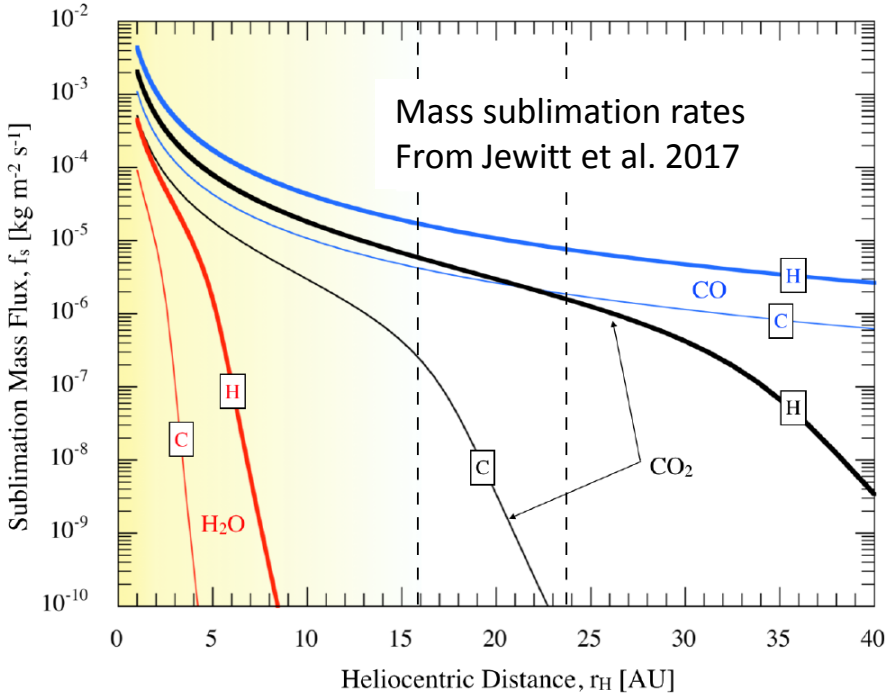
Beyond the state-of-the-art: the “SHARK way”

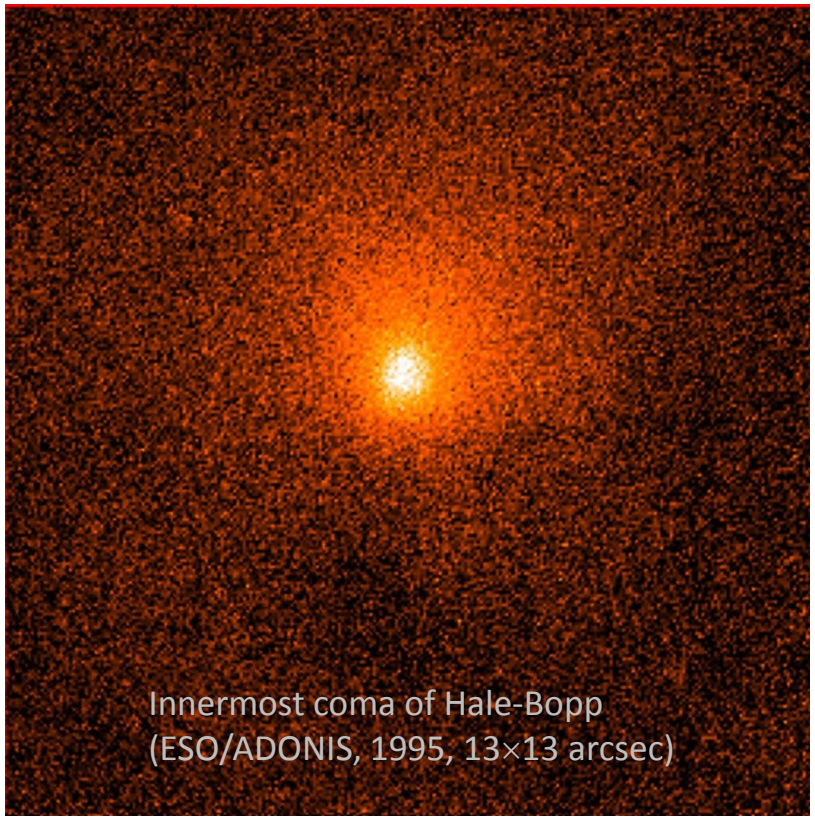
- Eris, Haumea, Makemake (beyond Pluto):
  - Angular size > 40 mas
  - Possible atmosphere (local? transient?) → sublimation/deposition/geological processes

- Quaoar, Orcus, Salacia, 2007 OR10 (angular size ~ 30 mas)
- Smaller TNOs, search for satellites

Beyond the state-of-the-art: the “SHARK way”

- Active small bodies (comets, centaurs)
  - Nucleus size
  - Composition
  - Emission processes
  - …





From “dots” to disk-resolved images…

…new-generation adaptive-optics instruments
(and 30-40 m telescopes in the near future) will allow a
“ground-based exploration”
of a significant number of small bodies,
opening a new frontier in planetary sciences!

shark-vis