ESO/VLT/SPHERE Survey of D>100km Asteroids : First Results

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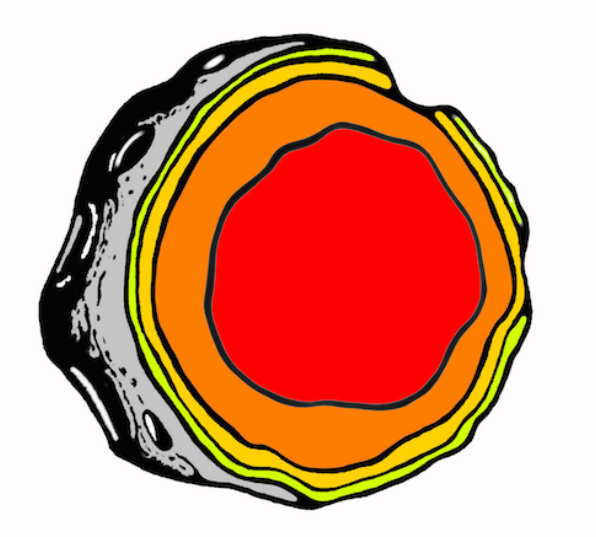
ESO Large program on VLT/SPHERE

- ESO Large Program awarded 152h on VLT/SPHERE (PI: P. Vernazza, LAM, FR)
- Purpose of the LP: High angular-resolution imaging survey of a representative sample of all D≥100 km main-belt asteroids (**~35 objects; covering the main compositional types**) throughout their rotation
- The observations are spread over 5 semesters from April 1st, 2017 till September 30, 2019
- Performed in service mode only with seeing constraint <0.8”

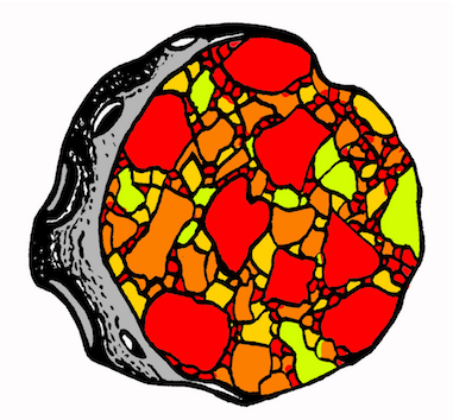
Primordial main belt asteroids: Definition

Primordial (Morbidelli et al. 2009):
D>~100km



Low macroporosity
Density: Powerfull constraint of the bulk composition

Rubble piles:
D<100km

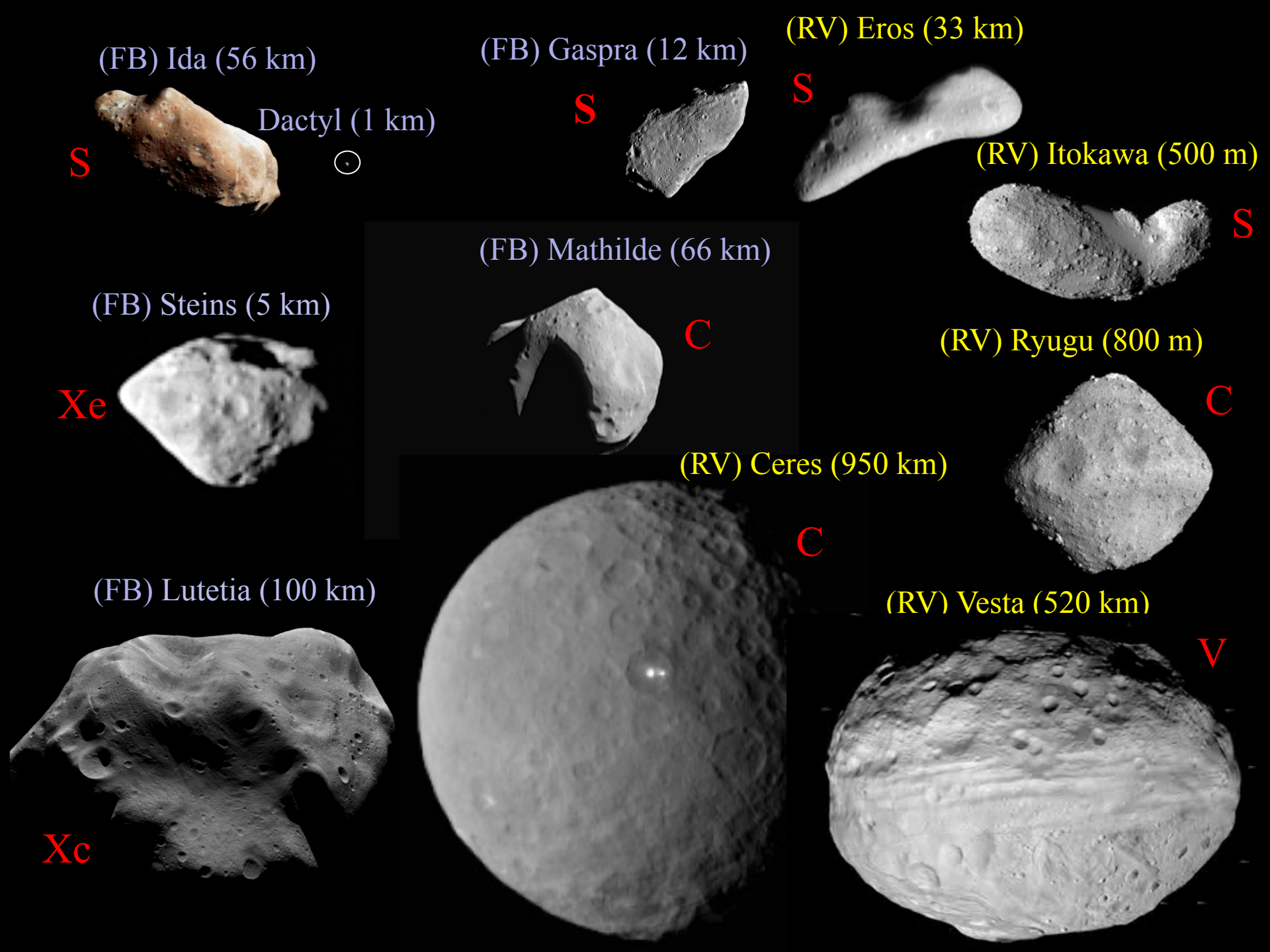


High macroporosity
Density: Weak constraint of the bulk composition

Primordial D>100km main belt asteroids: Current knowledge

- There are ~200 MBAs with D>100km (~30 MBAs with D>200km)
- For these bodies, the following properties are well characterized:
  - Orbit
  - Albedo
  - Visible and near-infrared spectrum
- For most of these bodies, mass and 3D shape/volume - hence density - are not well constrained
- For most of these bodies, a surface map of the craters does not exist

=> Few geologic constraints available for these bodies


(FB) Ida (56 km)
Dactyl (1 km)
S
(FB) Gaspra (12 km)
S
(RV) Eros (33 km)
S
(RV) Itokawa (500 m)
S
(FB) Mathilde (66 km)
C
(FB) Steins (5 km)
Xe
(RV) Ryugu (800 m)
C
(RV) Ceres (950 km)
C
(FB) Lutetia (100 km)
Xc
(RV) Vesta (520 km)
V

Output of the survey

- Precise 3D shapes and thus volumes for all targets (<10% error on the volume): 3D shapes produced using the deconvolved images along publicly available optical lightcurves and stellar occultation data using the ADAM algorithm (Viikinkoski et al. 2015)
- These volumes are combined with mass determinations to estimate the density of our targets
  => Constraint of the bulk composition and internal structure of our targets
- The derived 3-D shape models are used to characterize the distribution, size and profile of craters with D>30km. Such information, in turn, allows investigating the collisional history of the targets.
- Potential discovery of new satellites

Current status

- After 3 semesters of observations: 94h out of 124h allocated executed

- Good rotational coverage (≥ 4 epochs) for 30 asteroids (2 Pallas, 3 Juno, 4 Vesta, 6 Hebe, 7 Iris, 9 Metis, 10 Hygiea, 12 Victoria, 13 Egeria, 15 Eunomia, 16 Psyche, 19 Fortuna, 22 Kalliope, 30 Urania, 41 Daphne, 45 Eugenia, 51 Nemausa, 52 Europa, 63 Ausonia, 87 Sylvia, 88 Thisbe, 89 Julia, 173 Ino, 187 Lamberta, 216 Kleopatra, 324 Bamberga, 476 Hedwig, 511 Davida, 596 Scheila and 704 Interamnia)

- Publications: 4 papers published in A&A (Vernazza et al. on 89 Julia; Viikinkoski et al. on 16 Psyche, Carry et al. on 41 Daphne, Fetick et al. on 4 Vesta). 1 paper submitted to A&A (Hanus et al. on 7 Iris)

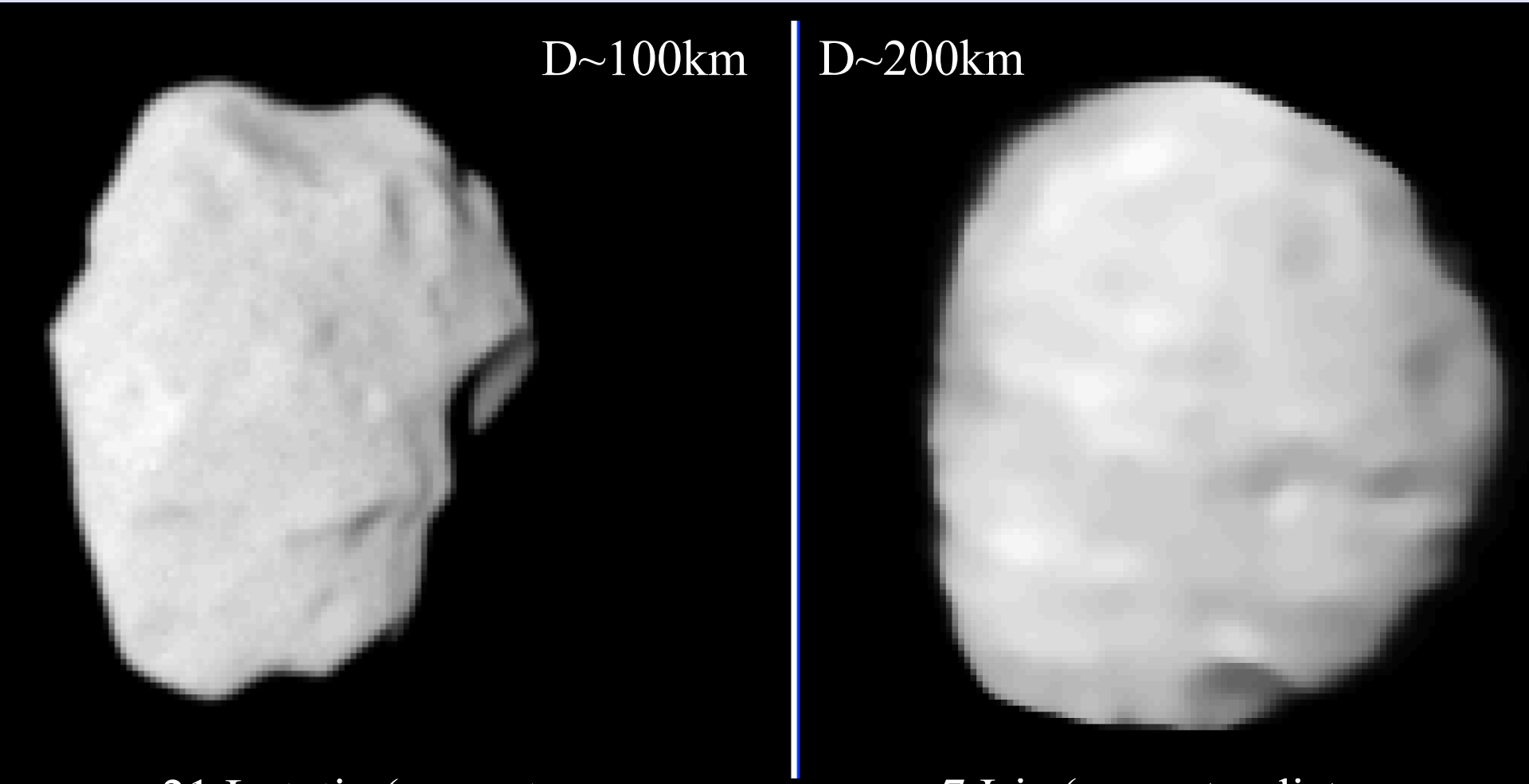
VLT/SPHERE/ZIMPOL versus VLT/NACO

2 Pallas

Angular diameter: 0.42”

Angular diameter: ~0.5”

Rosetta versus VLT/SPHERE/ZIMPOL

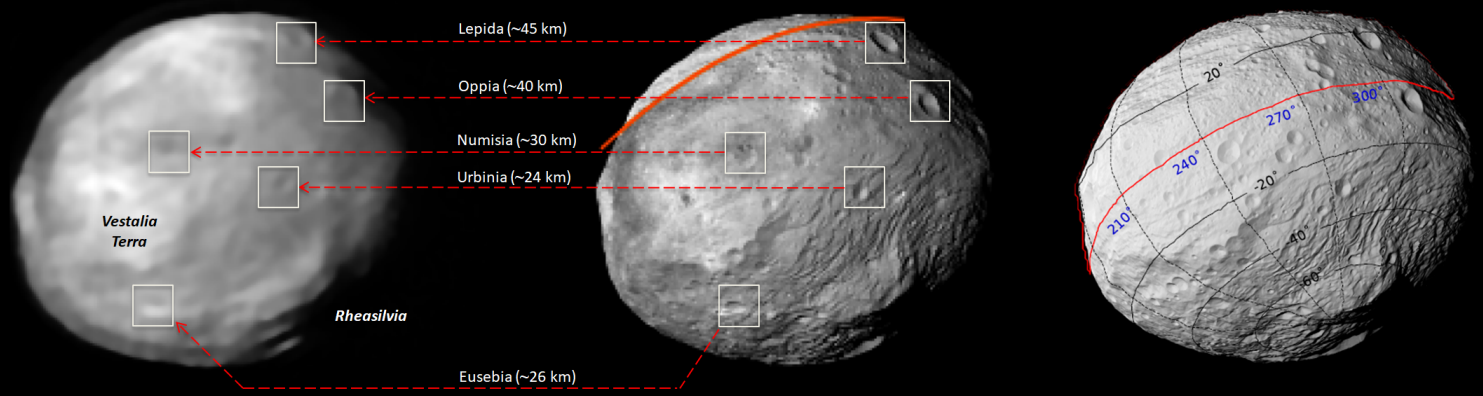


21 Lutetia (seen at a distance of ~7×10^4 km)

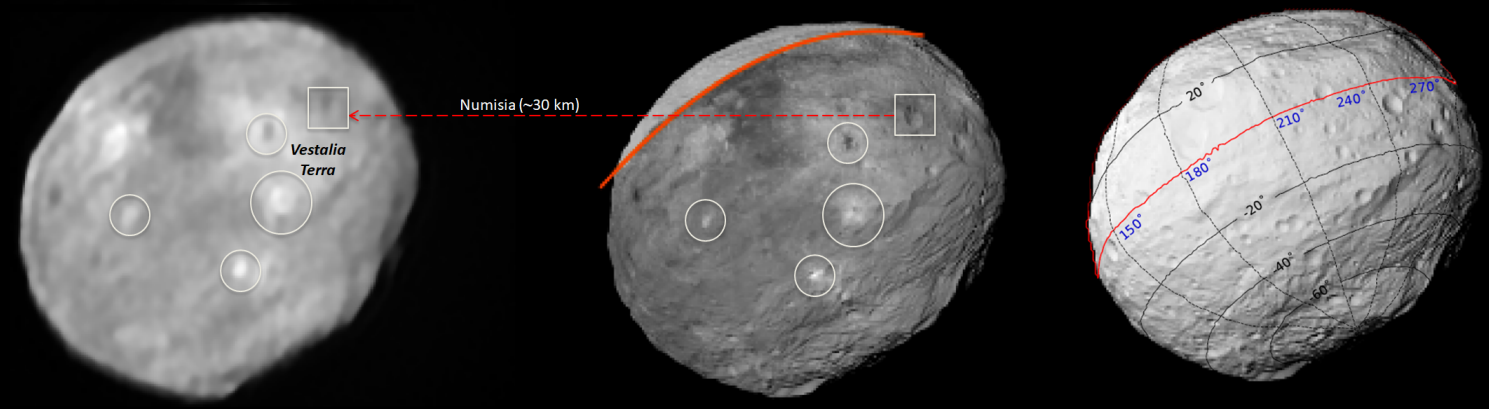
7 Iris (seen at a distance of ~1.35×10^8 km)

VLT/SPHERE/ZIMPOL versus DAWN/OASIS

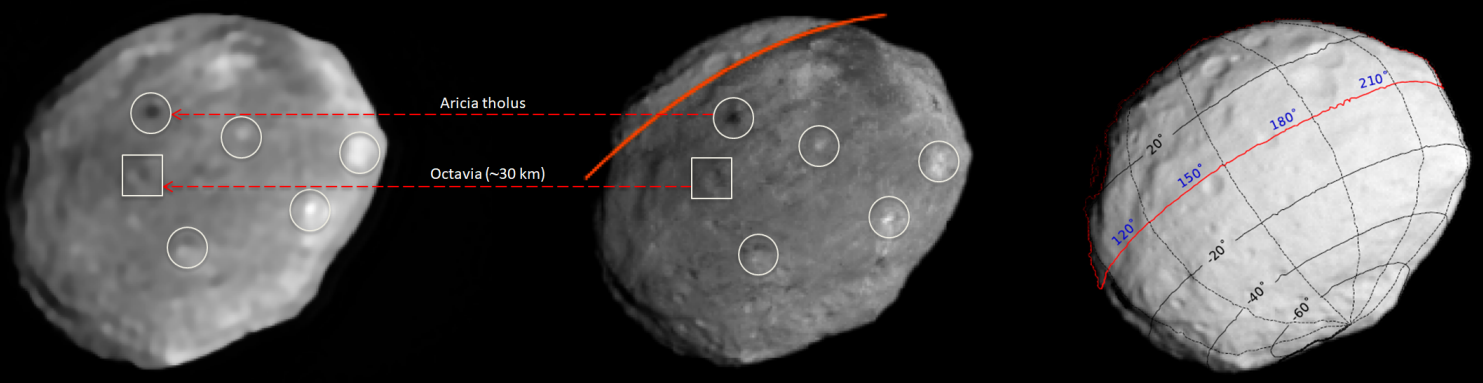
Phase: 0.00 (2018-05-20T06:41:53.277)



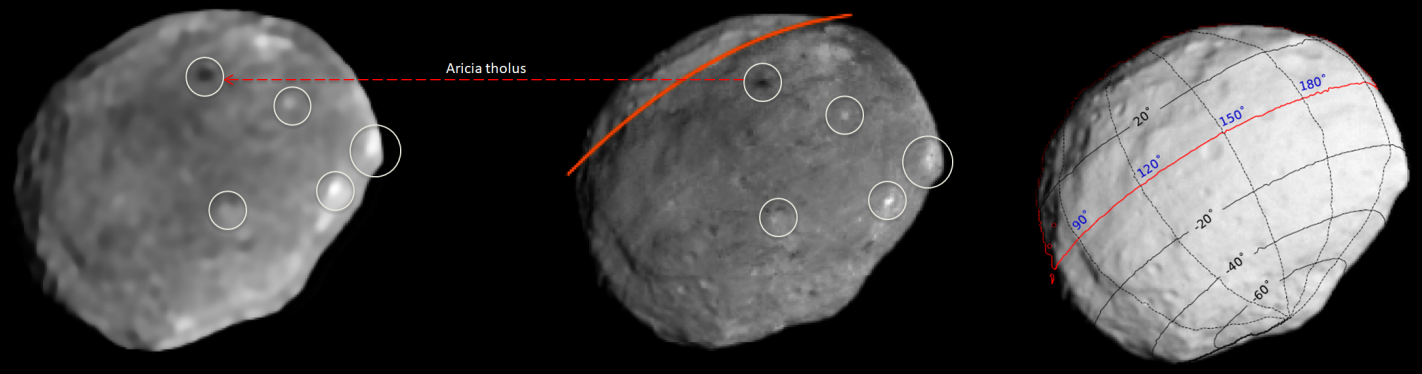
Phase: 0.13 (2018-06-08T05:27:05.809)



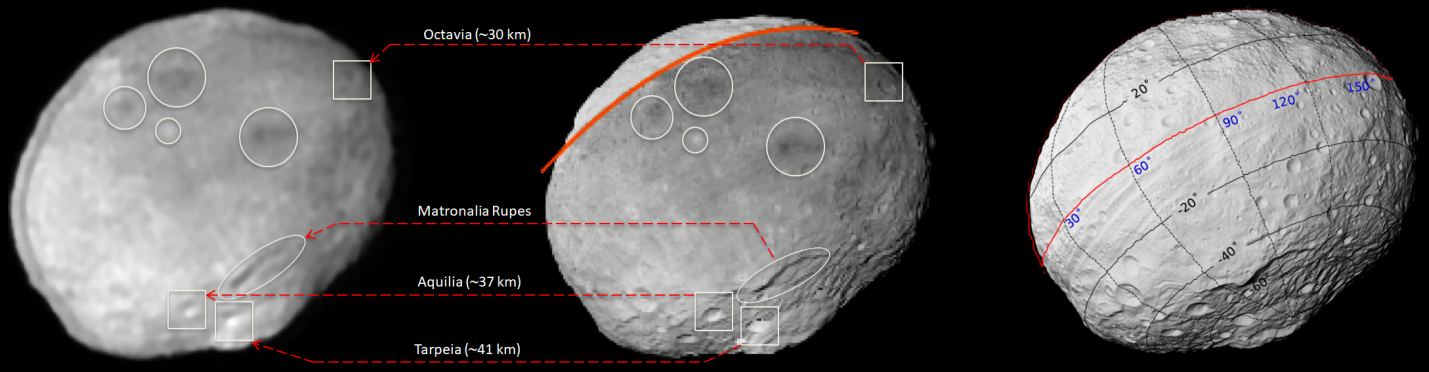
Phase: 0.24 (2018-07-10T01:59:52.994)



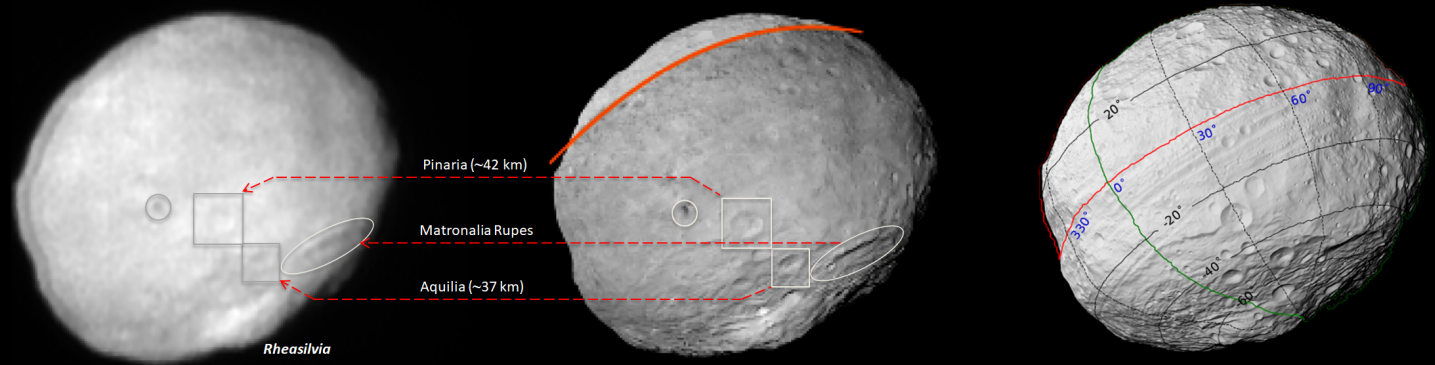
Phase: 0.30 (2018-07-10T02:16:38.723)



Phase: 0.43 (2018-06-08T07:14:40.731)

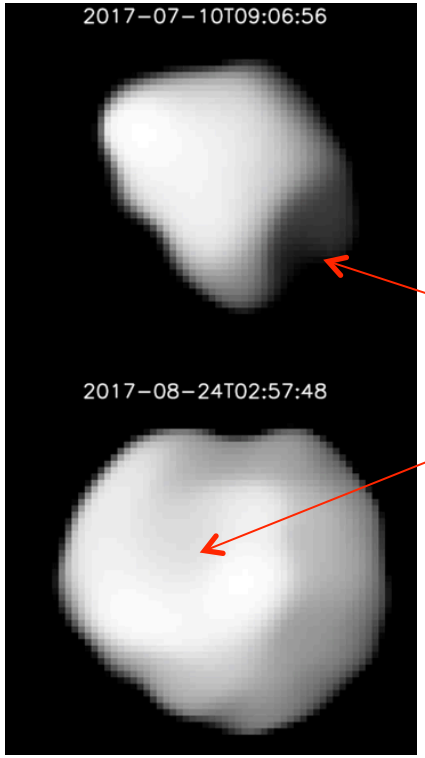


Phase: 0.60 (2018-06-08T07:58:51.472)

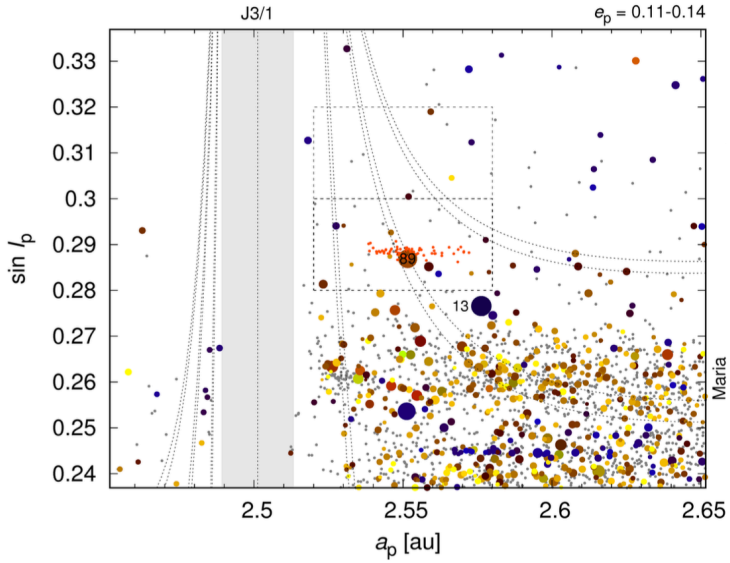


First results: The impact crater at the origin of the Julia family detected with VLT/SPHERE? (Vernazza et al. 2018)

(89) Julia
(D~140km)



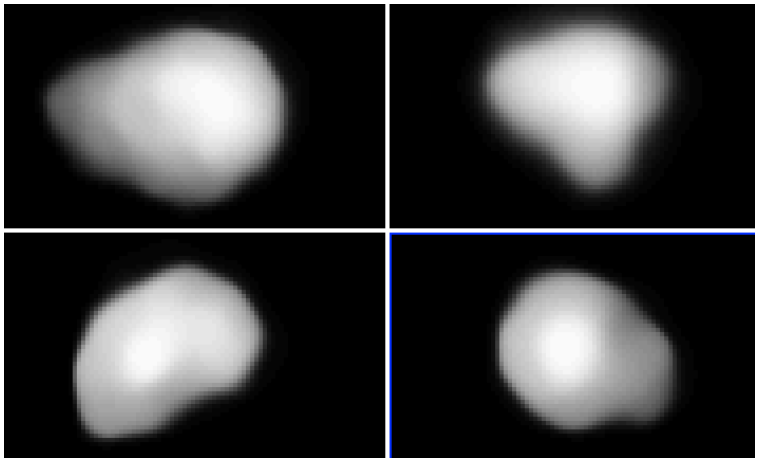
Nonza
(D~75km)

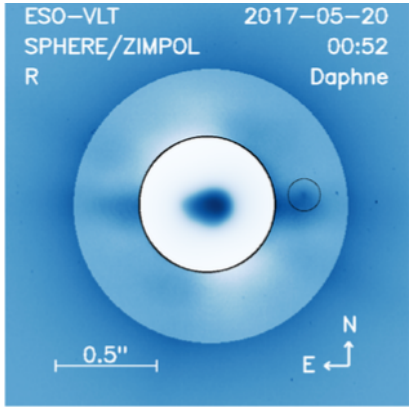


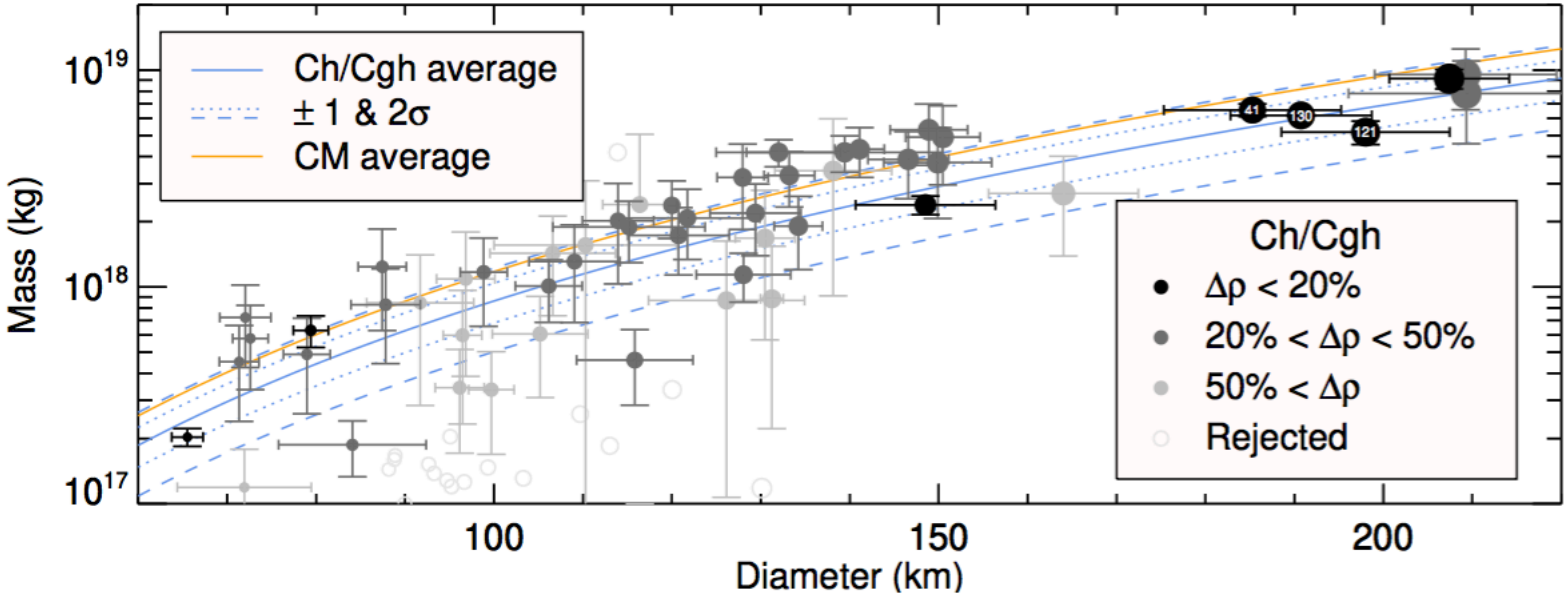
Julia family:

- 66 members with 1km<D<2.5km
- Age: 30-120 Myrs
- Size of the impact crater: D>60km
- Size of impactor: D~8km

First results: The homogeneous internal structure of CM-like asteroid (41) Daphne (Carry et al. 2019, A&A)

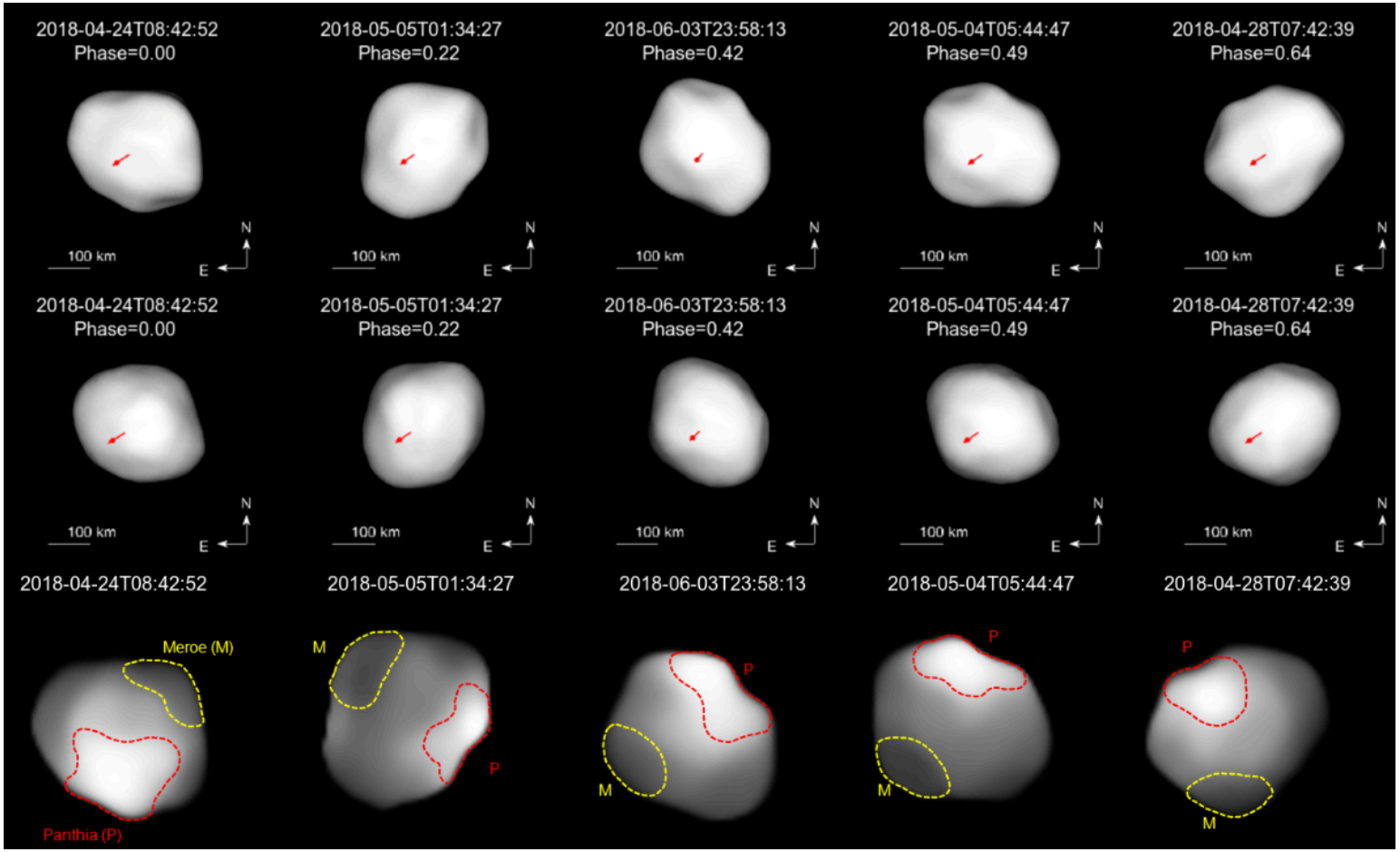




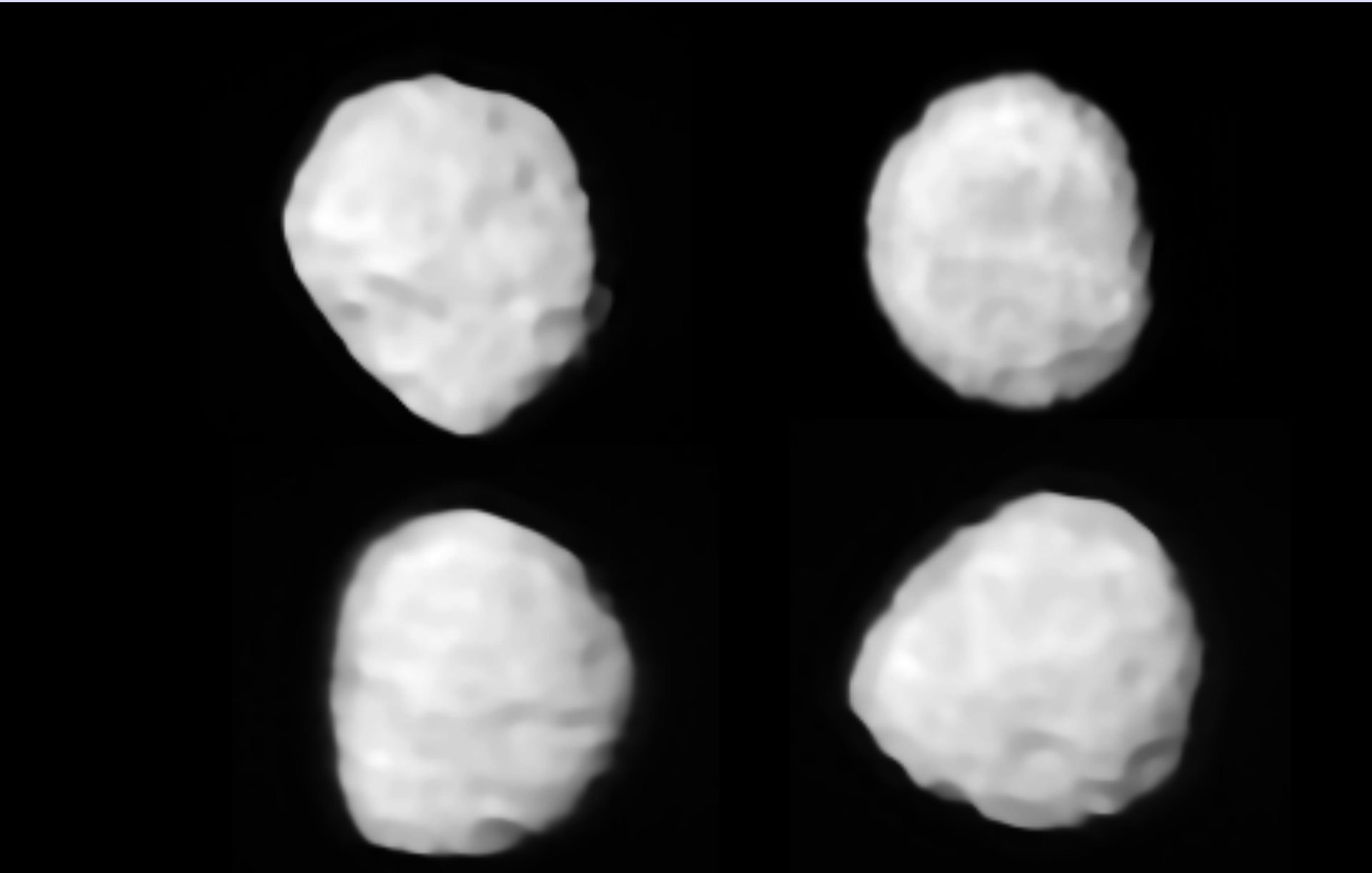


First results: (16) Psyche: A mesosiderite-like asteroid?
(Viinkinkoski et al. 2018)

Density of Psyche: 3.99 ± 0.26 g/cm^3
Density of mesosiderites: 4.25 ± 0.05 g/cm^3
Density of iron meteorites: ~7-8 g/cm^3

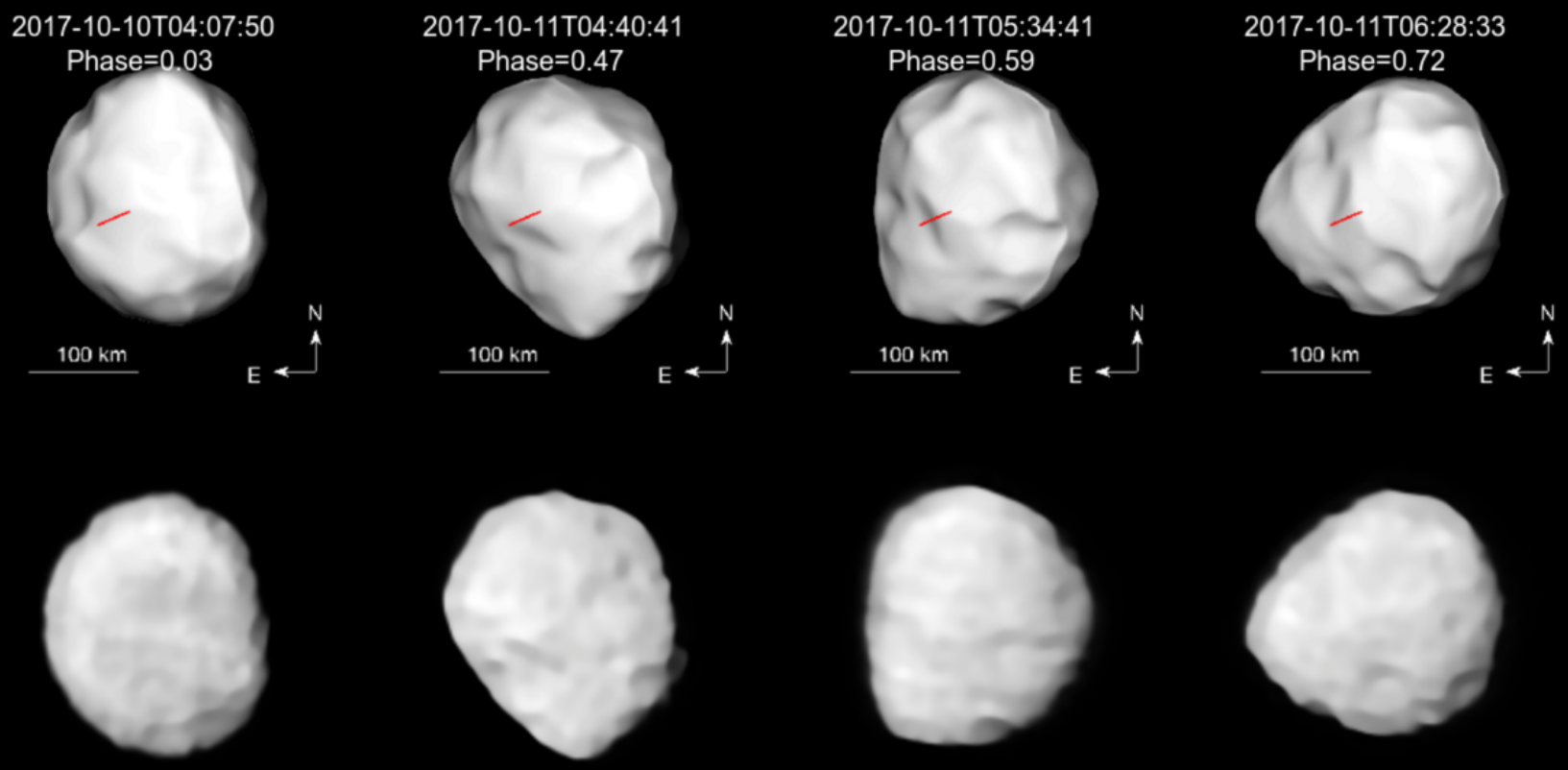


First results: (7) Iris's shape as evidence of an ancient large impact? (Hanus et al., submitted to A&A)



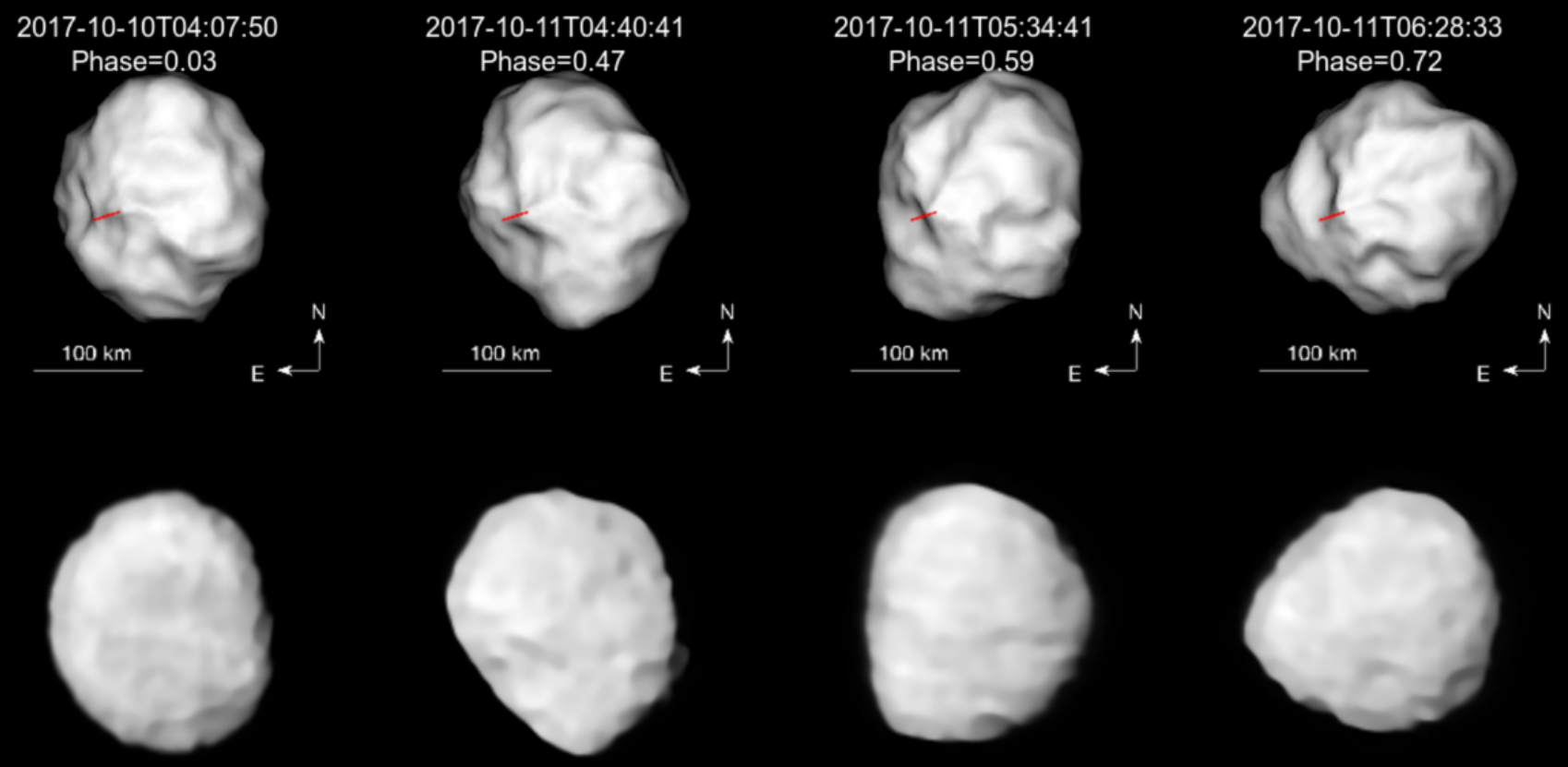
First results: (7) Iris's shape as evidence of an ancient large impact? (Hanus et al., submitted to A&A)

- High-resolution model (ADAM software), only southern hemisphere is reliable, the ridge is a modeling artifact
- Density: 2.7 g/cm^3 (compatible with LL condrites and ~16% macroporosity)



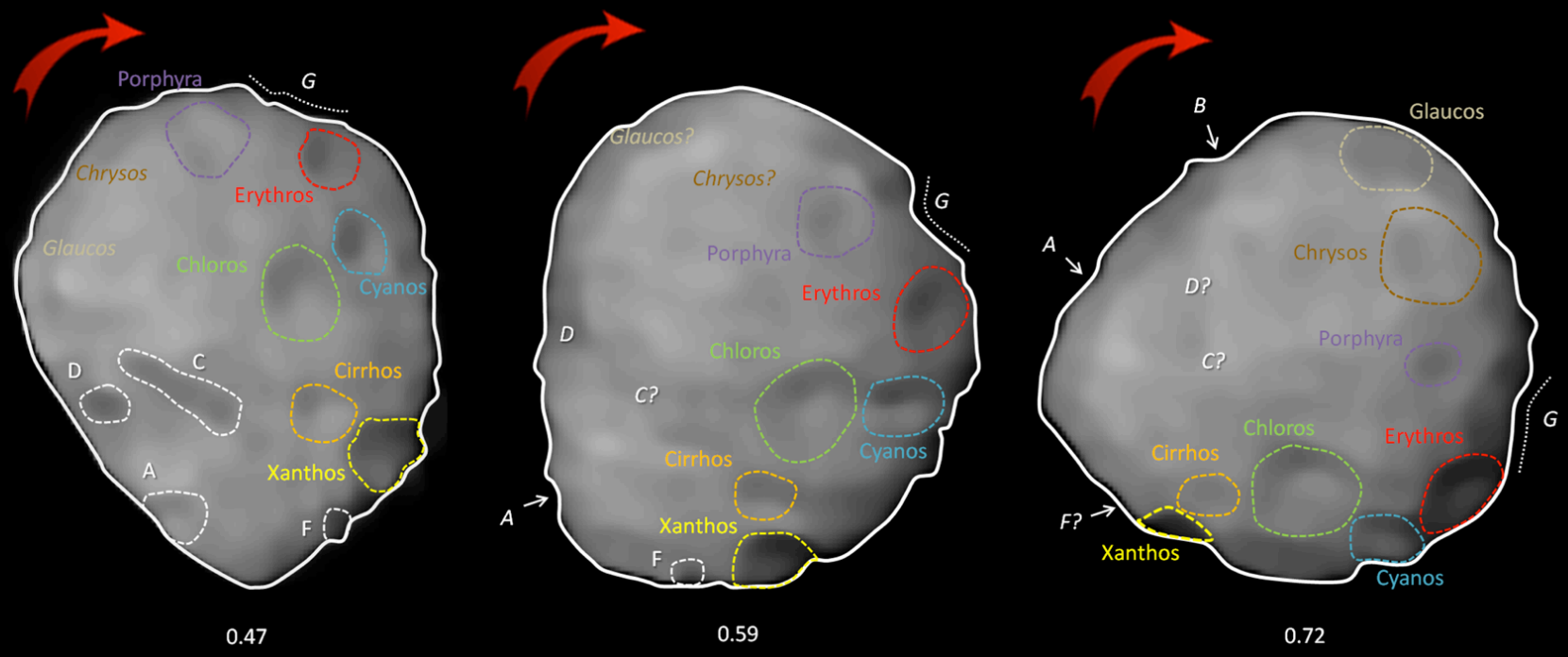
First results: (7) Iris's shape as evidence of an ancient large impact? (Hanus et al., submitted to A&A)

Radar model of Ostro+ 2010, only southern hemisphere was sampled



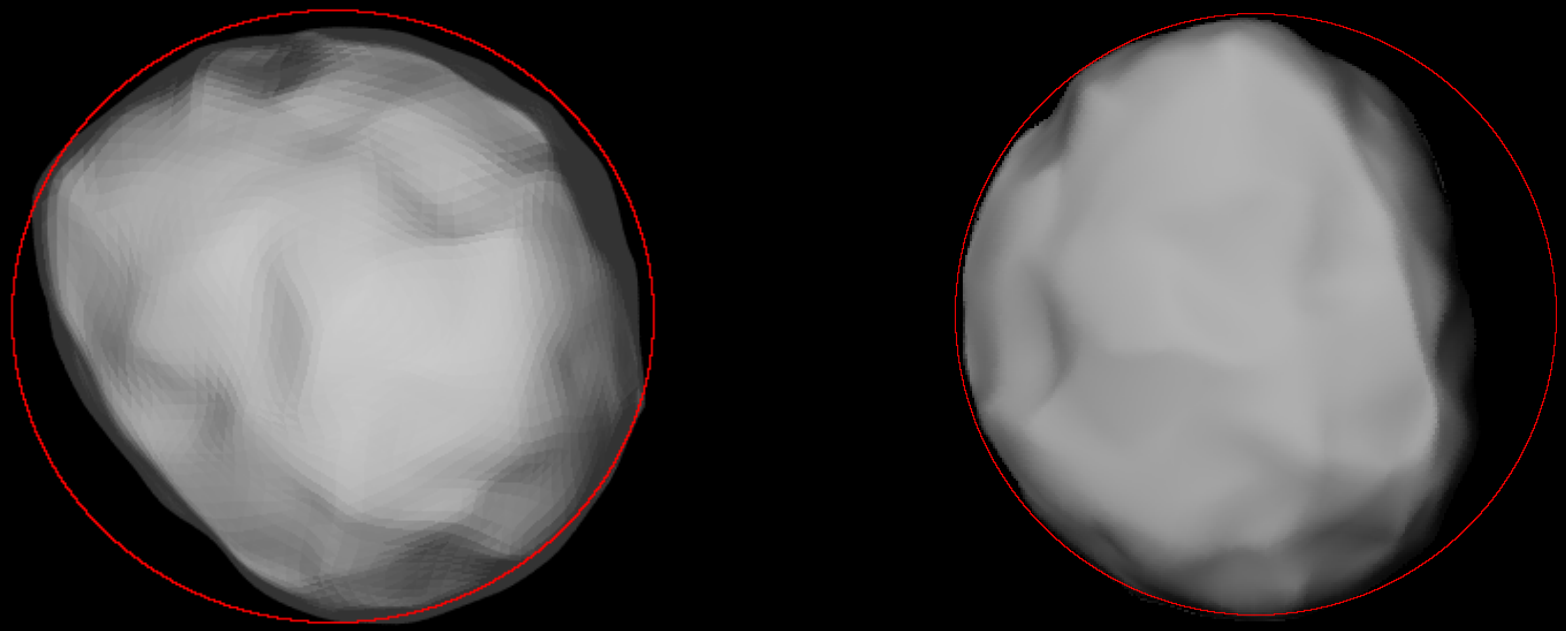
First results: (7) Iris's shape as evidence of an ancient large impact? (Hanus et al., submitted to A&A)

- Several consistent features – impact craters
- 20-40 km in diameter (8)
- We measured the depth from images (e.g., Xanthos)
- Depth/size ratio (~0.4) larger than for other rocky asteroids



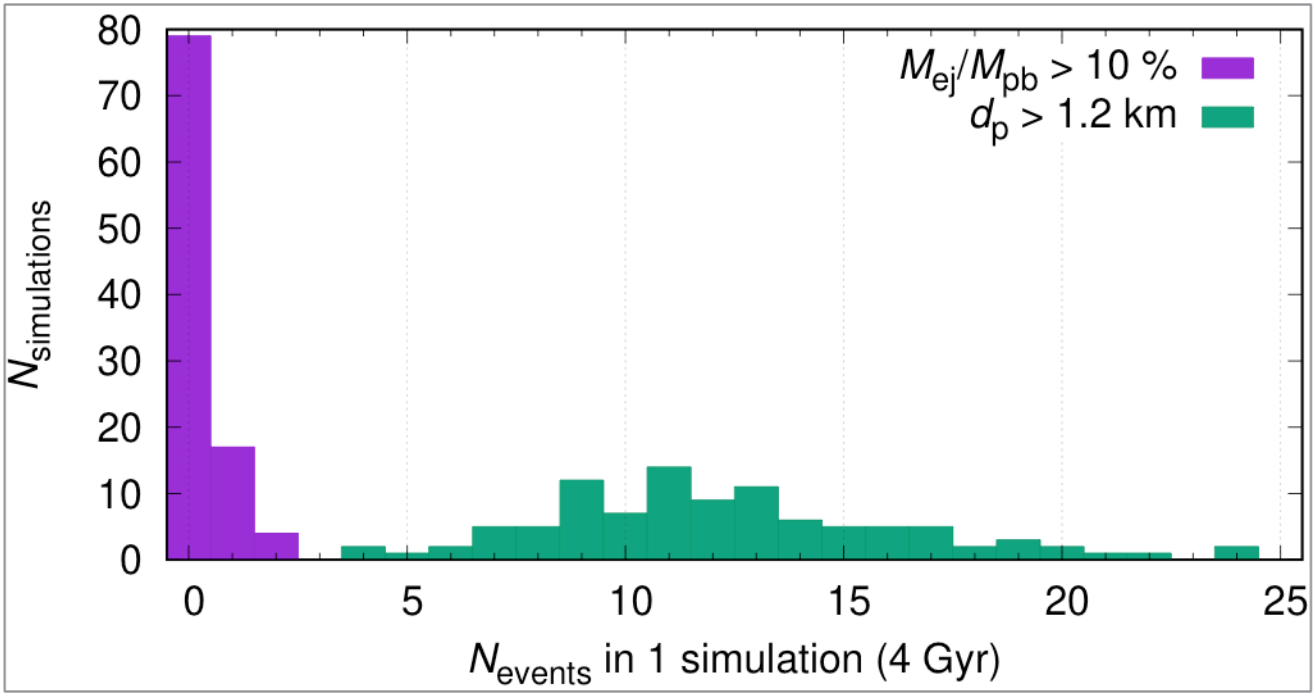
First results: (7) Iris's shape as evidence of an ancient large impact? (Hanus et al., submitted to A&A)

- Oblate spheroid with a large equatorial excavation (~10% of the volume)
- Ancient impact? Or a near miss collision (hit-and-run)?
- No recent family, preserved small craters



First results: (7) Iris's shape as evidence of an ancient large impact? (Hanus et al., submitted to A&A)

- 100 collisional evolutions of Iris simulated for 4 Gyr by the Boulder code (Morbidelli et al. 2009)
- We count the largest impacts (0-2) and impacts creating craters >20 km (5-20)
- We have ~8 craters on the southern hemisphere, which seems consistent with the collisional model



Conclusions

New doors into ground-based asteroid exploration, namely geophysics and geology, are being opened thanks to the unique capabilities of VLT/SPHERE.

In the fields of geophysics, geology, and asteroid family studies, the future will only get brighter with the forthcoming arrival of 30–40m class telescopes like ELT and GMT.

As soon as papers are accepted for publication, we make the corresponding reduced and deconvolved AO images and 3D shape models publicly available: http://observations.lam.fr/astero/