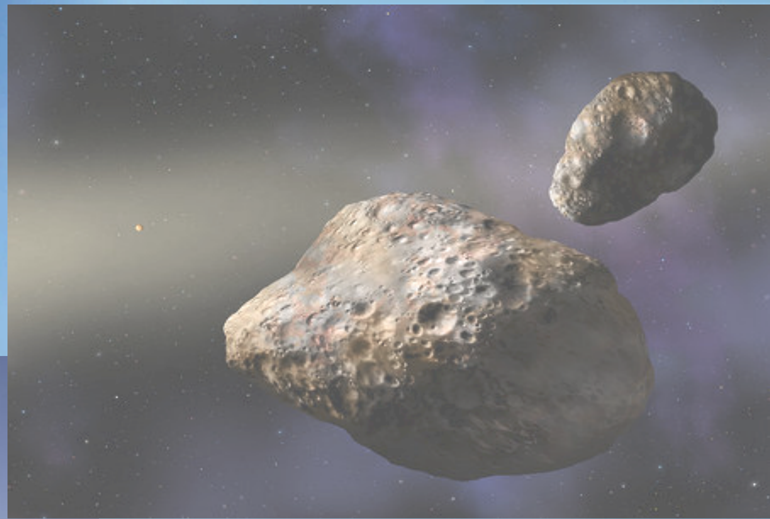
Determination of thermal properties of asteroids using IR interferometry



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PLAN

Thermal properties of asteroids

- Physical parameters
- Scientific interest

Thermophysical modeling

- Principle
- Application : Main-belt asteroids (41) Daphne and (16) Psyche

Conclusion and perspectives

Thermal properties of asteroids

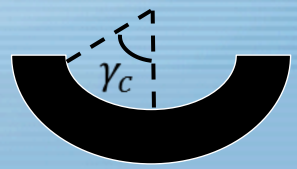
Thermal properties of asteroids : physical parameters

Thermal inertia

- Measure of the resistance of a material to a temperature change
- $\Gamma = \sqrt{\rho \kappa c}$ in SI units: $J.m^{-2}.s^{-0.5}.K^{-1}$
  - **Density**
  - **Thermal conductivity**
  - **Specific heat**

Surface roughness

- Surface parameter impacting the beaming effect (excess of emitted flux in the direction of incident radiation)
- Modeled by adding hemispherical craters



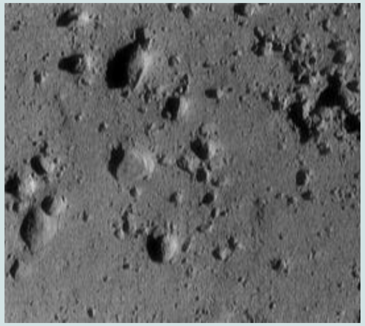
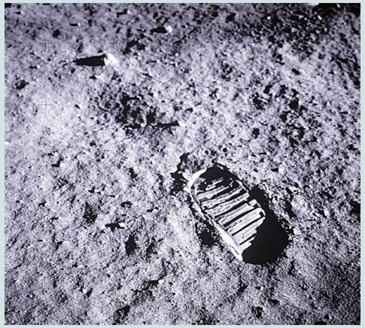
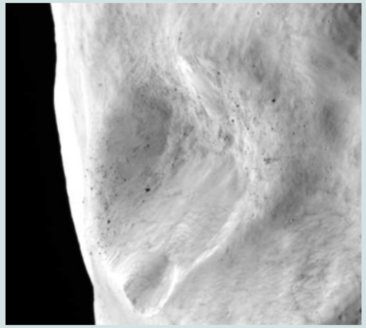
crater

γ_c : Opening angle

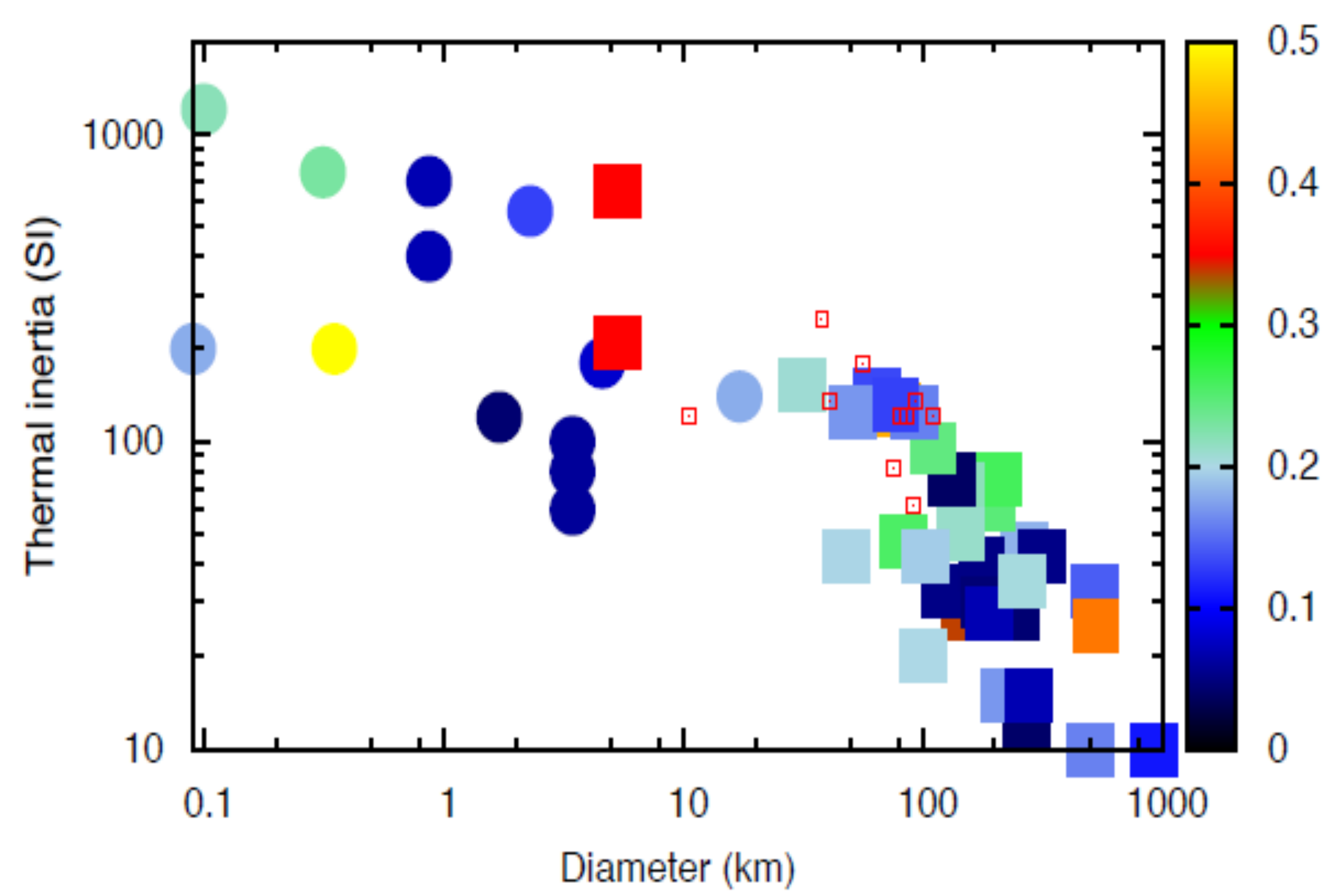
ρ_c : Crater density

Thermal properties of asteroids : scientific interest

Thermal inertia → Presence (or absence), depth and thickness of regolith, and presence of exposed rocks on the surface of atmosphere–less bodies

(25143) Itokawa	(433) Eros	The Moon	(21) Lutetia
$\Gamma = 750$	$\Gamma = 150$	$\Gamma = 50$	$\Gamma = 20$
			
Coarse regolith and boulders	Finer and thicker regolith	Mature and fine regolith	Very fine regolith

Thermal properties of asteroids : scientific interest



. Correlation: size decreasing ↔ thermal inertia increasing

. No correlation between thermal inertia and albedo

Thermal properties of asteroids : scientific interest

Thermal inertia ⟶ Presence (or absence), depth and thickness of regolith, and presence of exposed rocks on the surface of atmosphere–less bodies

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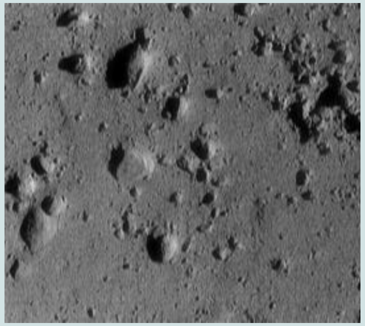
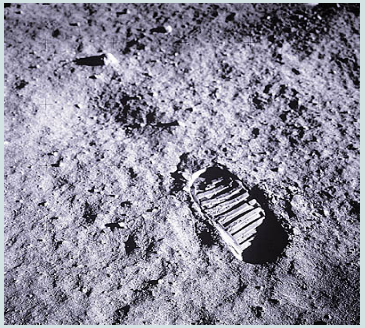
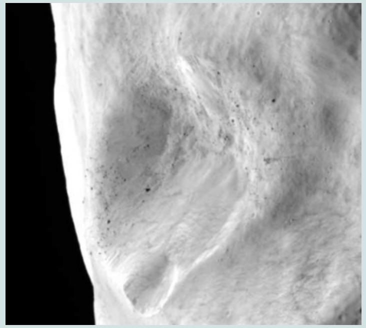
			
Coarse regolith and boulders	Finer and thicker regolith	Mature and fine regolith	Very fine regolith

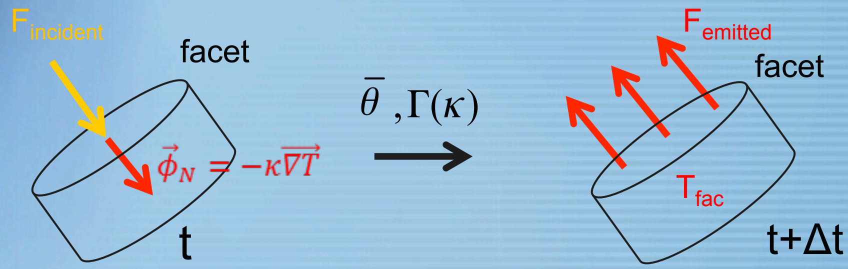
- Strenght of the Yarkovsky effect → gradual orbital drifting due to asymmetric re-emission of solar irradiation
  → source of uncertainty in the impact prediction for hazardous asteroids
- Estimation of systematic errors affecting size and albedo measured using simple thermal models

Thermophysical modeling

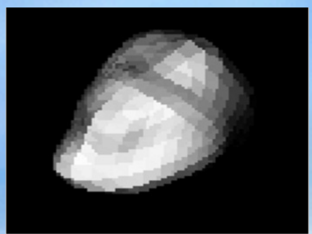
Thermophysical modeling: principle

Shape model
- distances
- rotation axis
- shape and size

Temperature calculation → flux emitted



2D mid-IR image



→ $\bar{V}(\lambda)$ et $\bar{I}(\lambda)$

Fit

$\bar{V}(\lambda)$ et $\bar{I}(\lambda)$ ⟺ $V(\lambda)$ et $I(\lambda)$

→ $\chi^2(\Gamma)$ for a given roughness

→ Size (volume), thermal inertia, roughness

(41) Daphne

- Big main-belt asteroid (D ~ 220 km)
- Spectral properties (albedo) → **C-type asteroid** ↔ primitive carbonaceous chondrite meteorites
- Presence of a small binary companion, detected by adaptive optics observation (Merline et al., 2008)

Lightcurves observations and disk-resolved observations

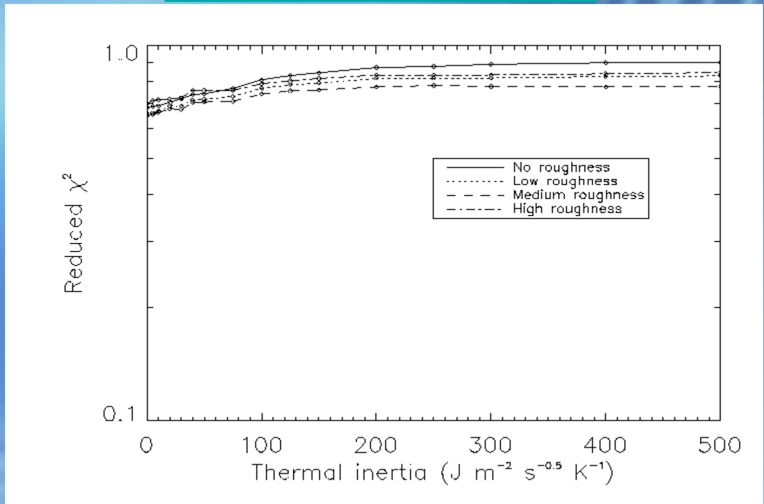
Shape model →

Non-convex model (Carry, 2009)

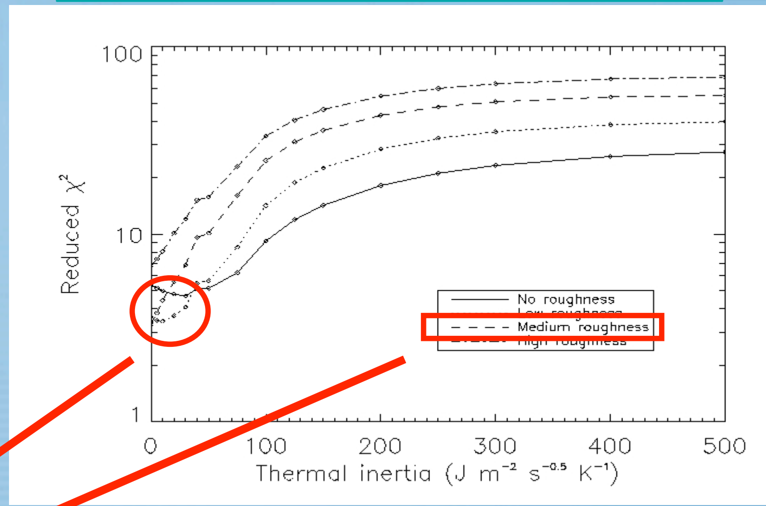
→ Observing campaign performed in March 2008 with ATs (baseline = 16m) (four mid-IR visibility and flux measurements)

Thermophysical modeling : (41) Daphne

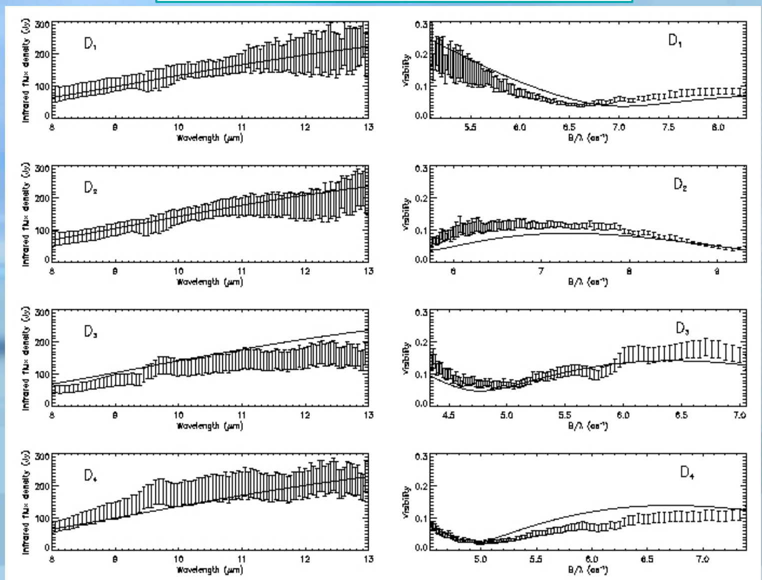
Mid-IR Flux → TPM



Mid-IR Visibility + Flux → TPM



Visibilities and fluxes



Thermal inertia < 30 J.m^{-2}.s^{-1}.K → very fine regolith

(**Moon ≈ 50 J.m^{-2}.s^{-1}.K** and **(1) Cérès ≈ 15 J.m^{-2}.s^{-1}.K**)

Moderate roughness → high rough terrains discarded

(Moon and (1) Ceres → high roughness)

Matter et al., 2011

Thermophysical modeling : (16) Psyche

(16) Psyche

- **Main-belt asteroid**

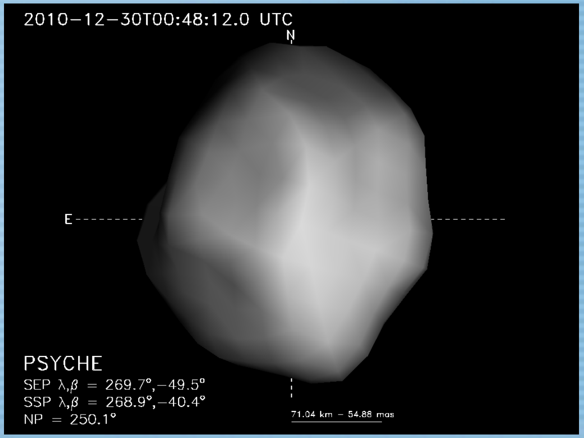
- Visible and near-IR spectral properties (albedo) → **M-type asteroid** ↔ iron-nickel meteorites (Hadersen et al., 1995)

- **size estimates (~ 230-260 km)**→ densities **≤ 3 g/cm³ (silicate-rich)** or densities **≥ 3.5 g/cm³ (metal-rich)** (Baer et al., 2008; Drummond & Christou, 2008)

Is M-type (16) Psyche a dense metal-rich asteroid ?
Origin: fragment of a differentiated body iron core ?

Lightcurves observations and disk-resolved observations → Shape model →

Non-convex model (Carry, 2011)

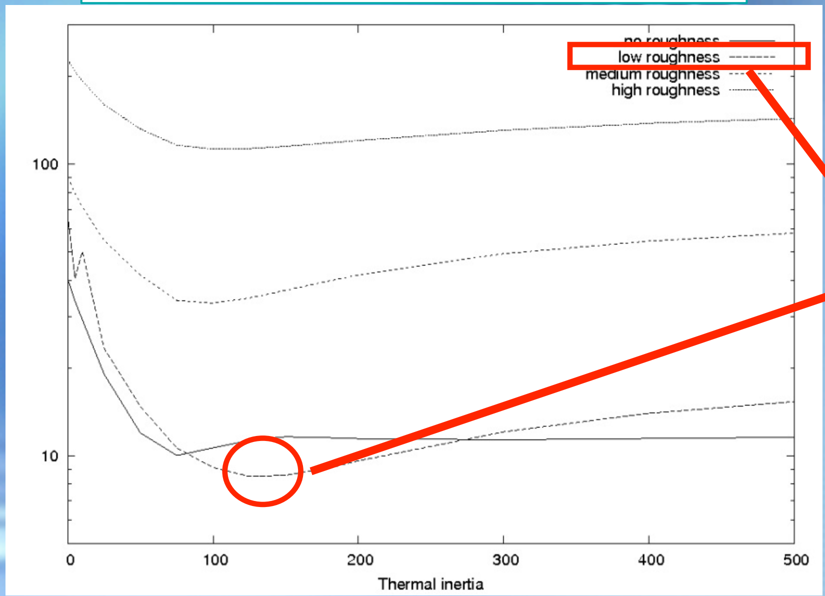


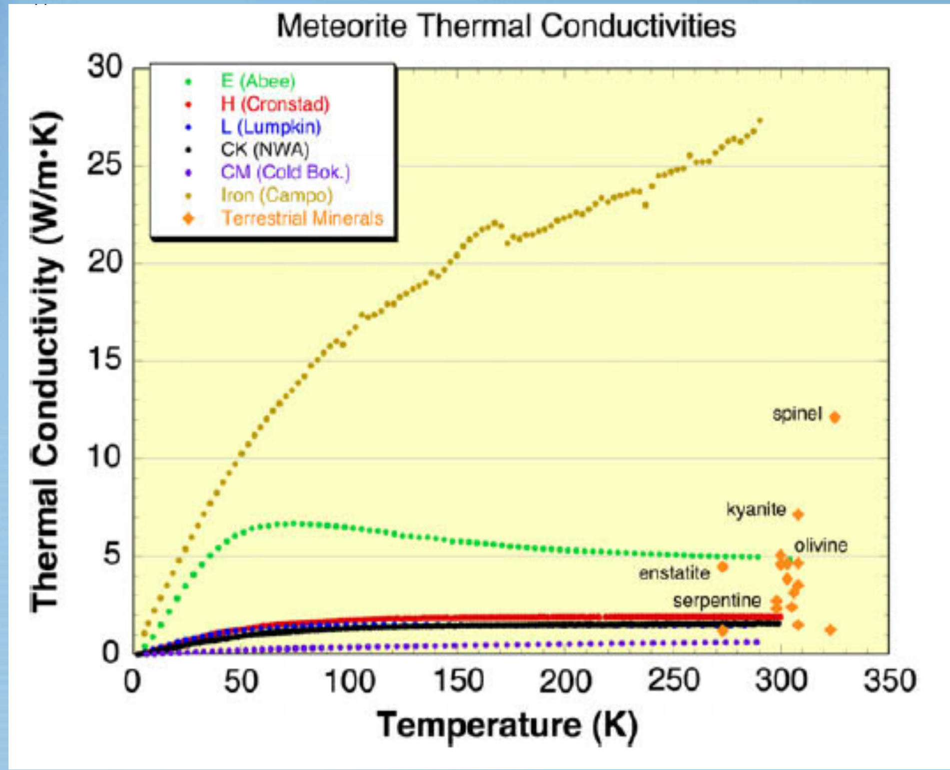
→ New observing campaign performed in December 2010 with ATs (baseline = 16m) (five mid-IR visibility and flux measurements)

Thermophysical modeling : (16) Psyche

Visibilities and fluxes

Mid-IR Visibility + Flux → TPM





. Preliminary results

Thermal inertia > 100 J.m^{-2}.s^{-1}.K

→ little porosity → likely metallic surface composition

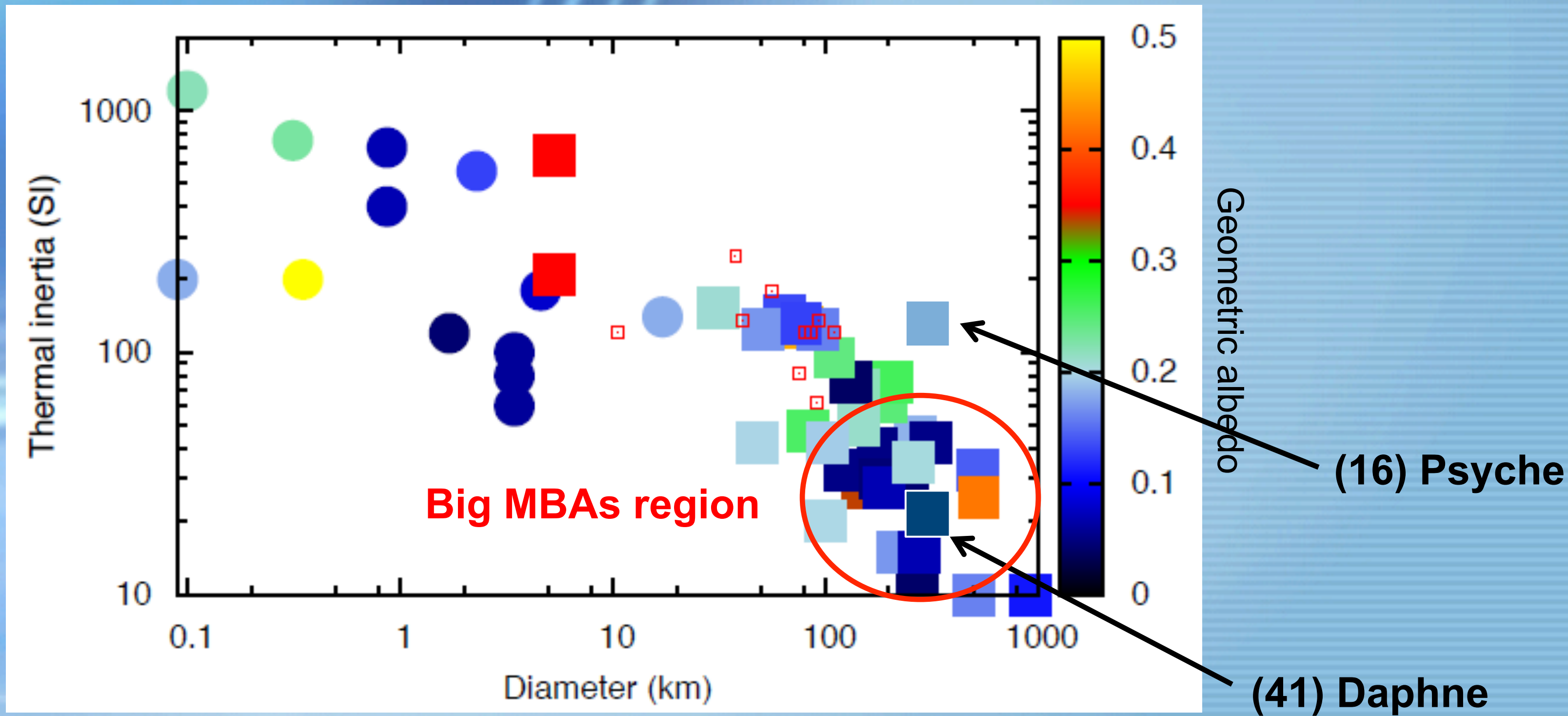
Volume equivalent diameter → ~ 235 km

→ density ≥ 3.5 g/cm^3 → indication of metal-rich composition

. In progress : refinement of the shape model + use of IRAS and WISE data

Thermophysical modeling : Summary

Existing measurements of Thermal inertia of asteroids



Conclusion and perspectives

Conclusion and perspectives

Summary

• First application of IR interferometry to the study of thermal properties of asteroids

→ (41) Daphne : **. First constraints on thermal inertia and surface roughness** (Matter et al., 2011)

→ (16) Psyche : **. Preliminary results on size and thermal inertia → metallic composition**

↳ **In progress**

Perspectives

↓

Off-axis mode of PRIMA

↓

Larger panel of asteroids observable with MIDI
(expected gain of about 3 magnitudes in V)

Thermal properties **Internal structure**

Thank you for your attention

Work in progress

October 2011 → MIDI observation of two binary asteroids previously detected by transit
→ Aim: direct measurement of the semi-major axis of the system

(1313) Berna

- Secondary detected in 2004 by Roy et al.
- Binary system period = 25 h
- Expected N band flux ~ 0.7 Jy

↓

- Fringes found but measured without tracking
- Correlated flux very likely to be ≤ 0.2 Jy

↓

Data reduction in progress

(939) Isberga

- Secondary detected in 2006 by Molnar et al.
- Binary system period = 27 h
- Expected N band flux ~ 1 Jy

↓