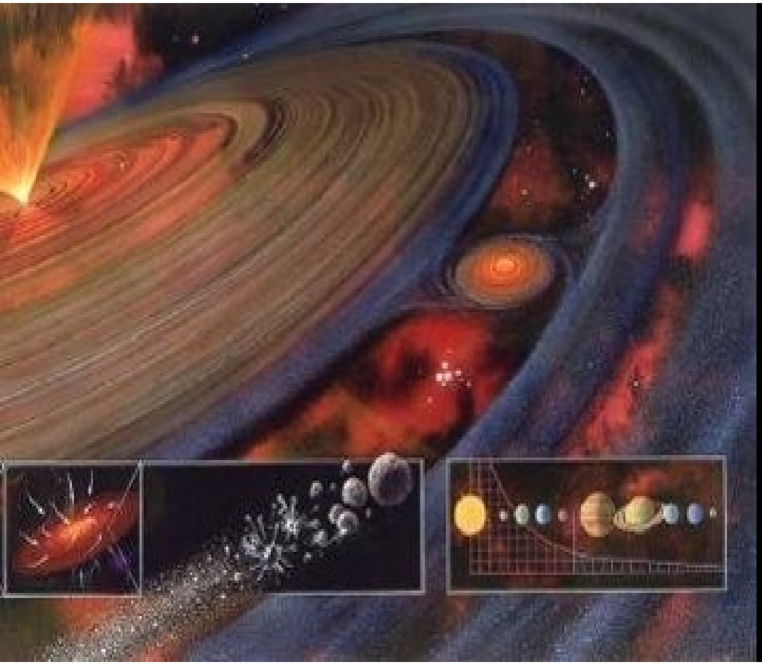
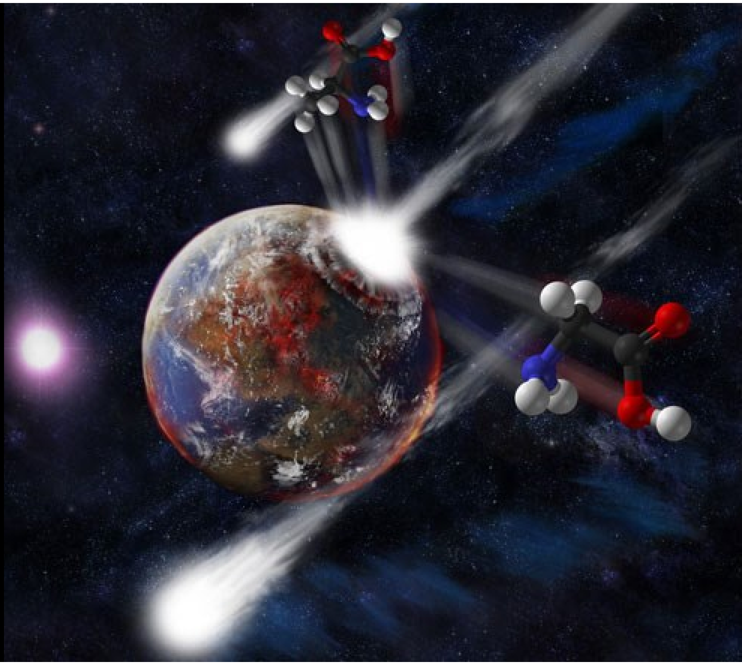
ExoBio:
Exogenous contributors of pre-Biotic material to the early Earth





Davide Perna

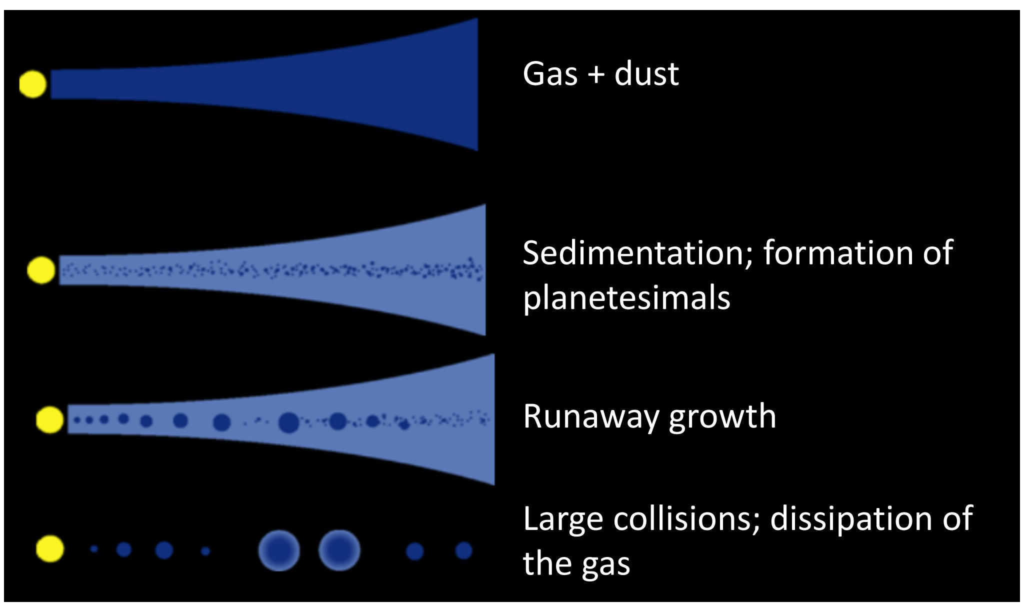
AstroFIt2 3rd Annual Meeting
INAF Headquarters, Roma, 15/10/2019

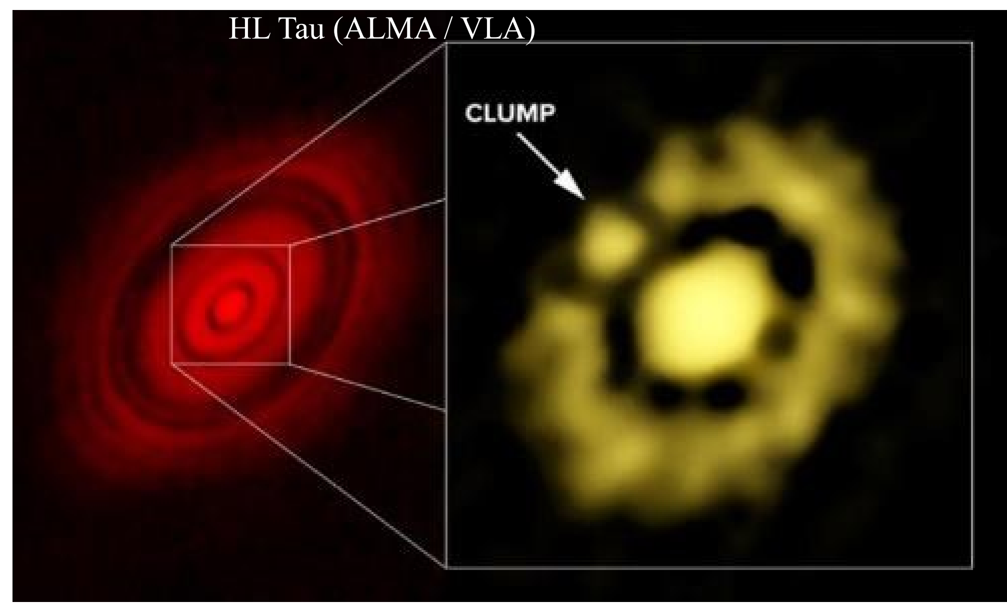
The small bodies: witnesses of the primordial solar system

Which processes have governed the formation and evolution of the primordial solar system?
What implications for the study of exoplanetary disks?

The small bodies of the solar system represent the last vestiges of planetesimals and protoplanets

The solar system as a model system that we can study in detail, and even in situ with space missions

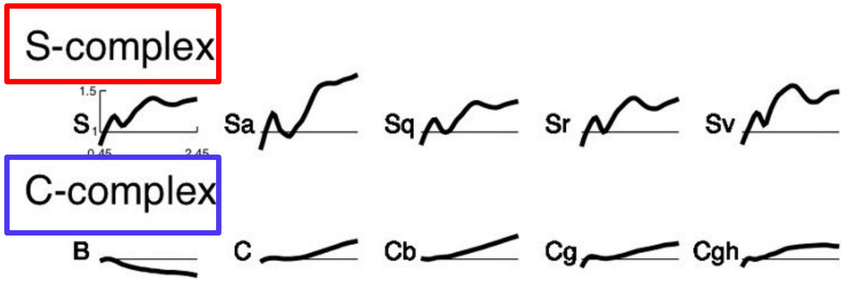


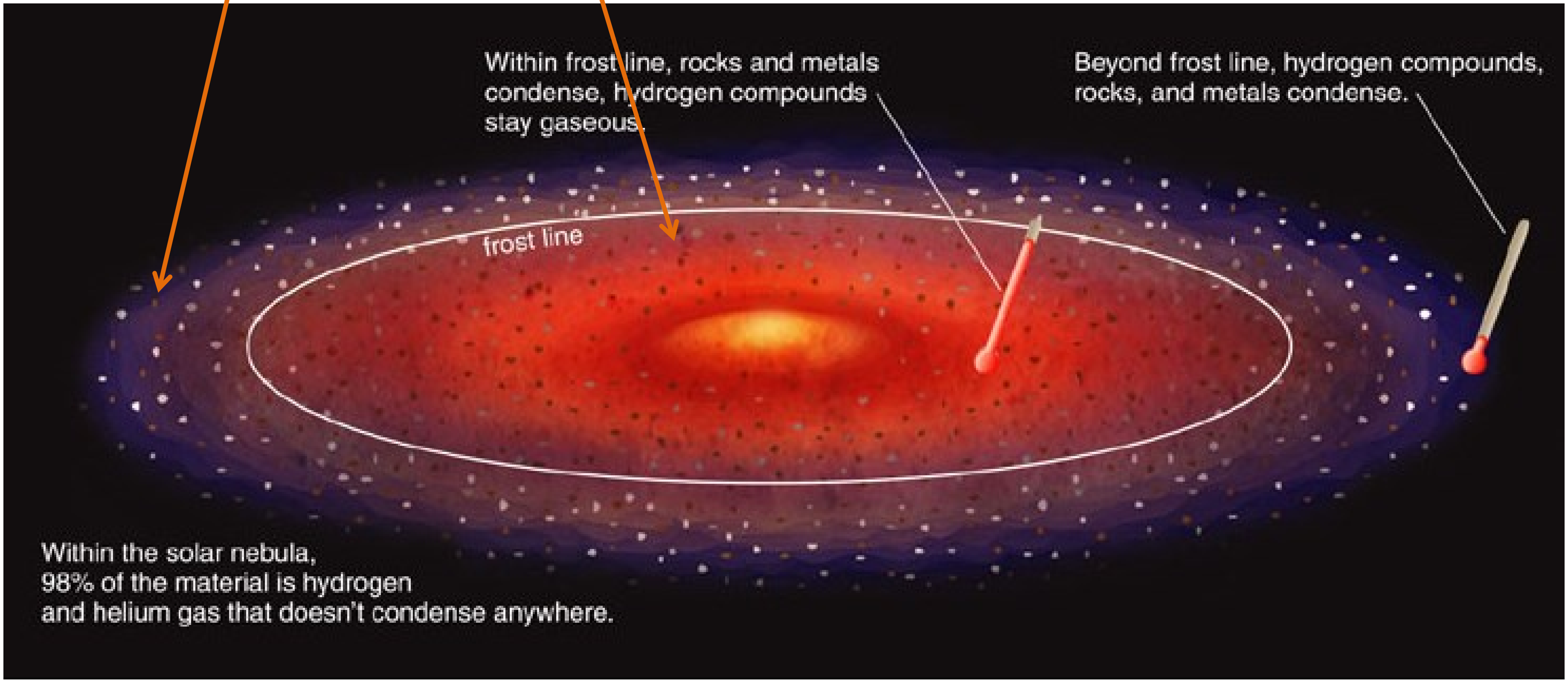


The small bodies: witnesses of the primordial solar system

"Evolved" small bodies

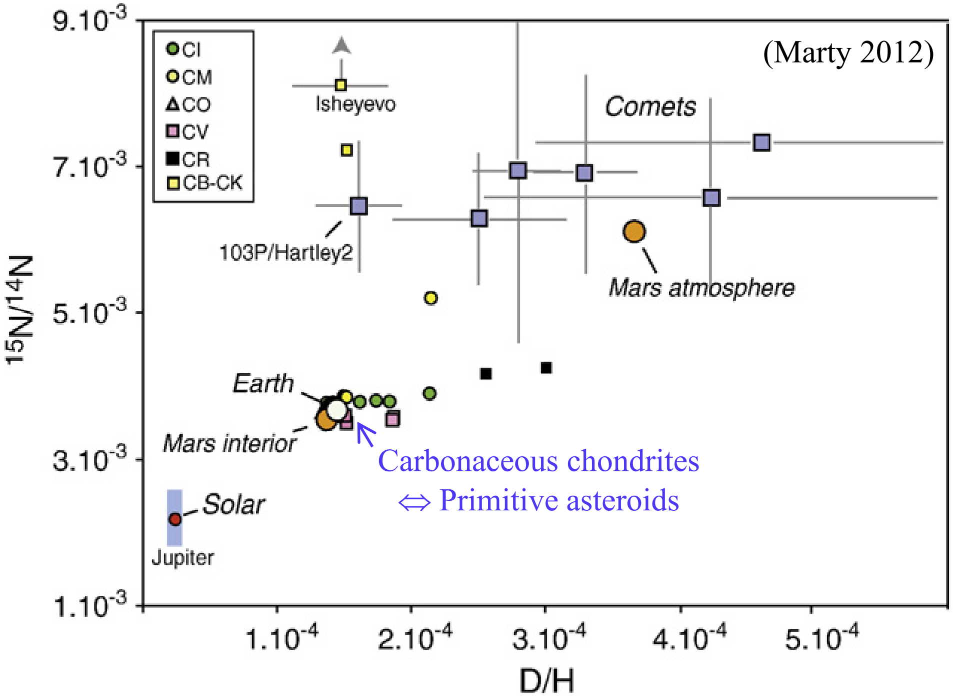
"Primitive" small bodies

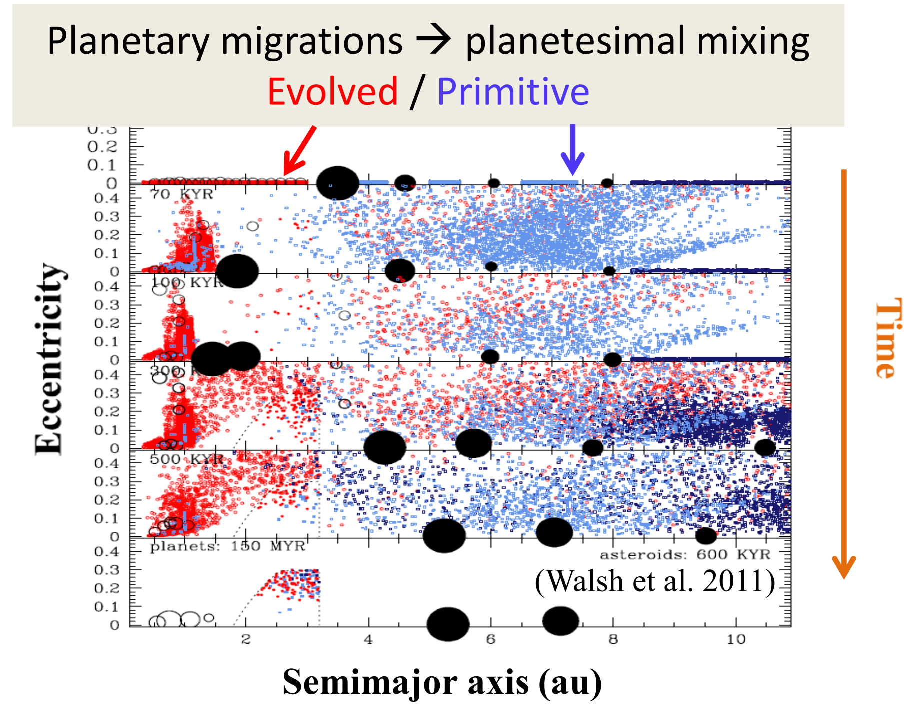


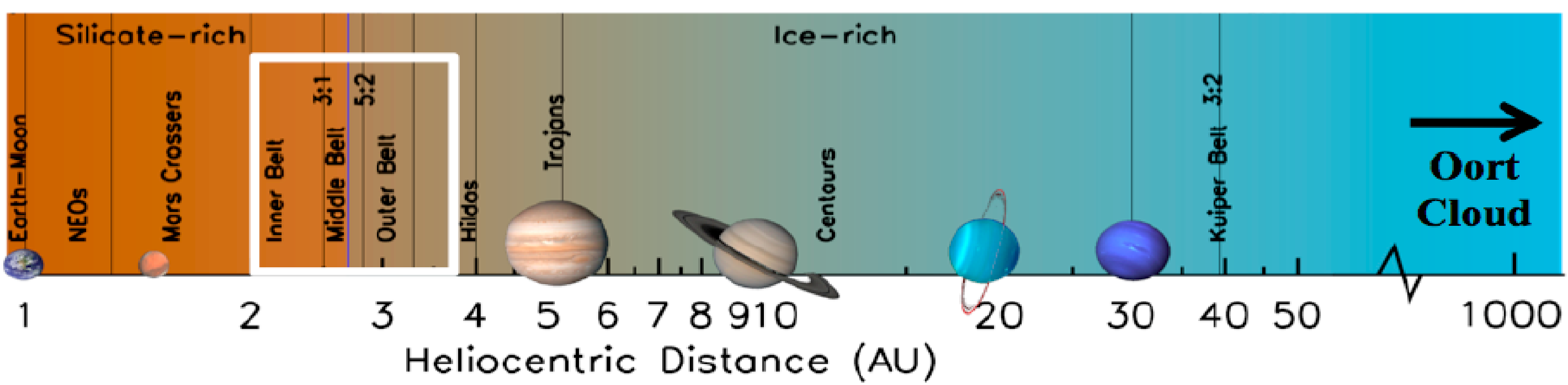


The small bodies: witnesses of the primordial solar system

What about the origin of Earth's water and other volatiles?







ExoBio:
Exogenous contributors of pre-Biotic material to the early Earth (6/2017-5/2020)

Astro FIt 2 Astronomy Fellowships in Italy

- The first-ever spectroscopic survey of the “small” near-Earth asteroids
  - ✓ Completed during Year 1
  - ✓ Main result: primitive asteroids more abundant among small-sized bodies (Perna et al. 2018, P&SS 157, 82)
- Sample return missions from primitive near-Earth asteroids
- A long-term survey of mid/outer solar system small bodies

ExoBio:
Exogenous contributors of pre-Biotic material to the early Earth (6/2017-5/2020)

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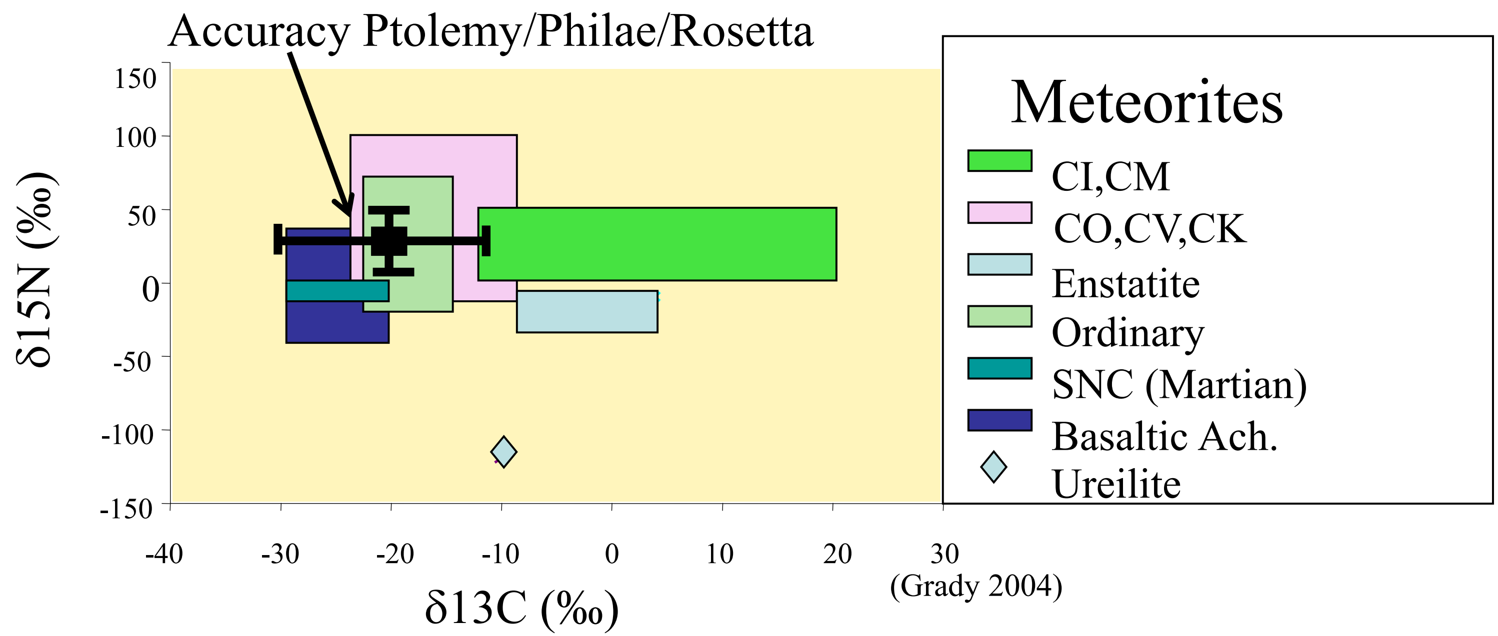
- A long-term survey of mid/outer solar system small bodies

- "Near-Earth Space Trekker" proposal for the 2018 ESA "Fast mission" call

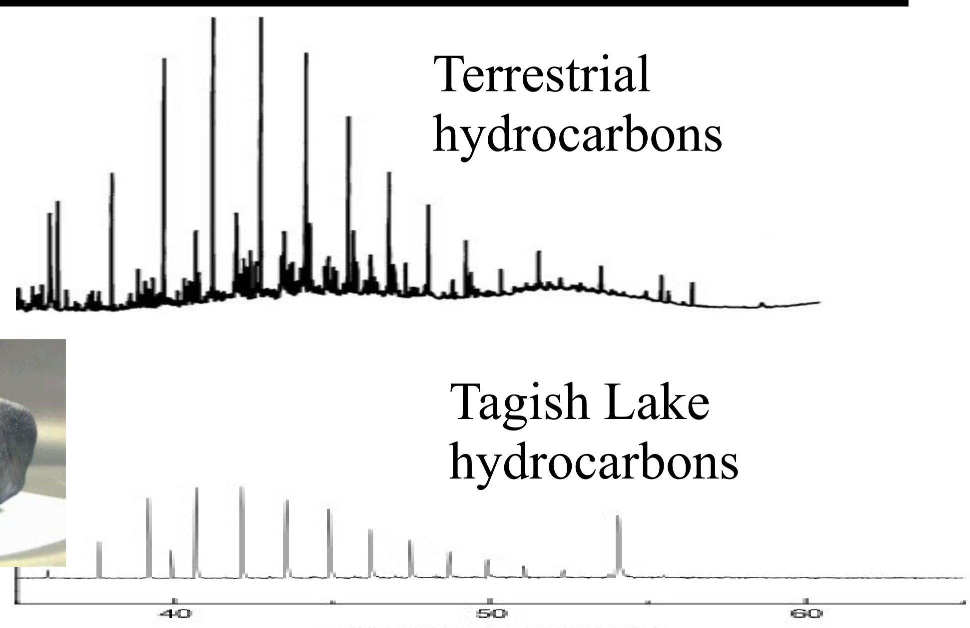
Sample return missions from primitive near-Earth asteroids

"Why do you need to return samples when you can just land on the surface?"



"Why do you need to return samples when we have meteorites?"

(University of Western Ontario, University of Calgary)



Hayabusa2@Ryugu

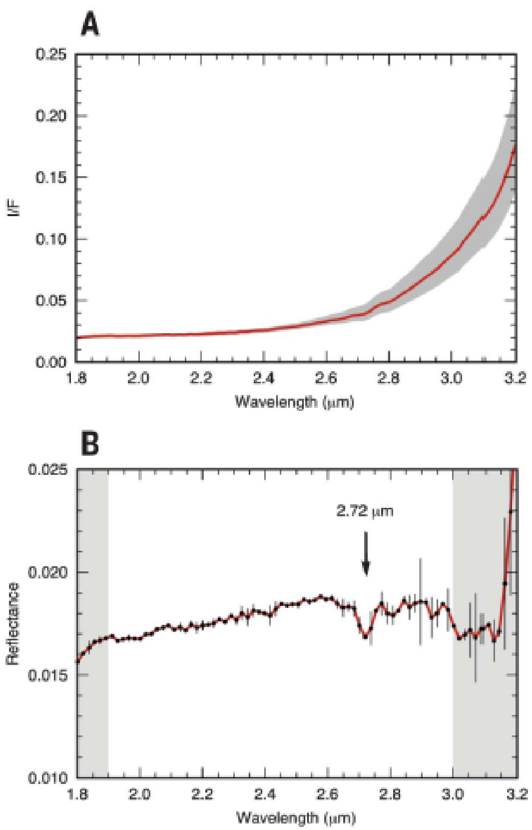
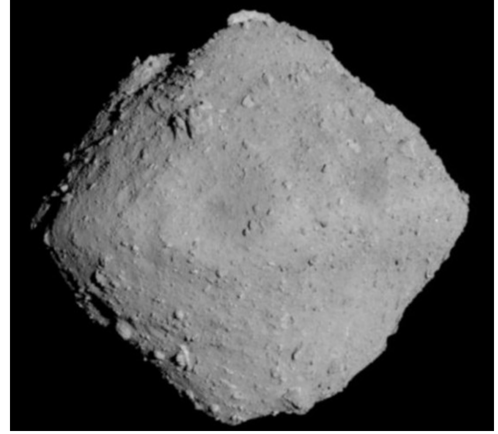


Fig. 1. NIRS3 near-infrared spectra of Ryugu. (**A**) Reflectance spectra, including thermal emission. The range of variation in spectra acquired from the equatorial scan on 10 July 2018 is shown (gray) along with the average spectrum (red). *I/F* is the measured radiance divided by the solar flux. (**B**) Example of a thermally corrected spectrum (observation date and time: 10 July 2018 06:02:22 UTC). Error bars are calculated based on the uncertainties in the element-to-element radiometric calibration (9). Shaded areas indicate regions with large calibration residuals. The absorption band indicated by the arrow at 2.72 μm is due to OH.



JAXA Hayabusa 2
Ryugu orbit: 2018-2019
Samples back to Earth: 2020

- Kitazato et al. 2019, Science 364, 272
- Barucci et al. 2019, A&A 629, A13

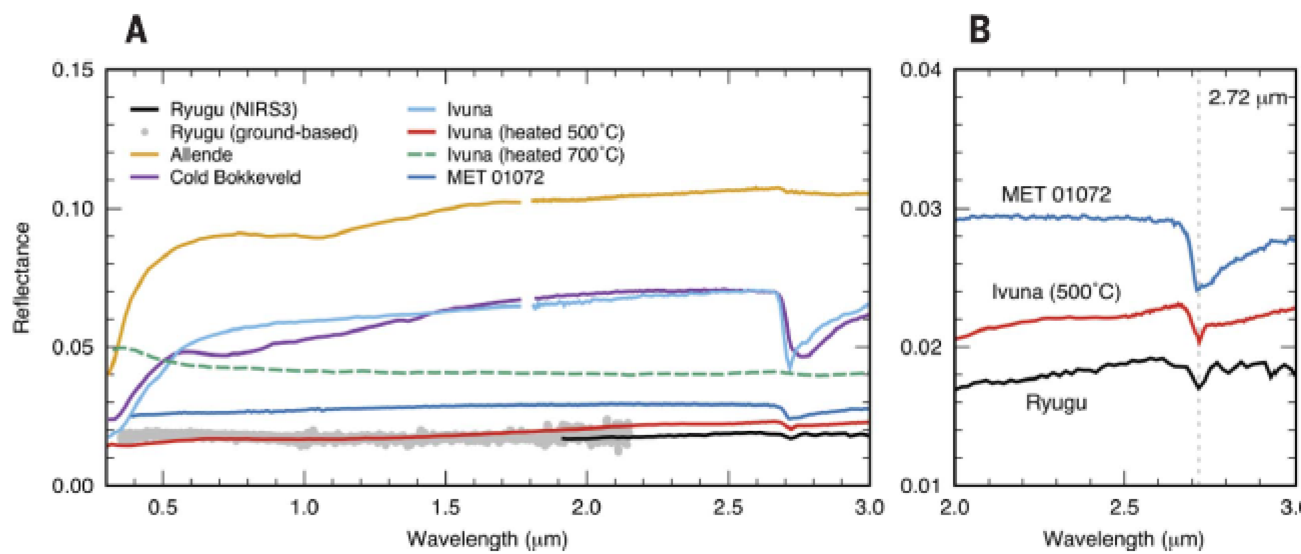


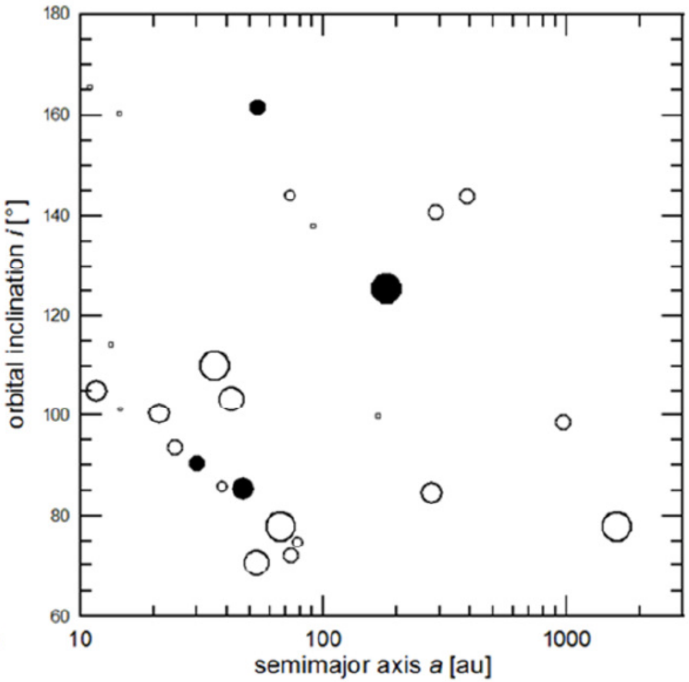
Fig. 3. Comparison of Ryugu with meteorite spectra. (**A**) Globally averaged NIRS3 spectrum of Ryugu compared with laboratory spectra of meteorite samples: Ivuna (CI1), Cold Bokkeveld (CM2), MET 01072 (shocked CM2), and Allende (CV3). Details and references for the meteorite spectra are listed in table S1. A ground-based visible and NIR spectrum of Ryugu (6) is also plotted. (**B**) Enlargement of the NIRS3 wavelength range in (A).

Mid/outer solar system small bodies

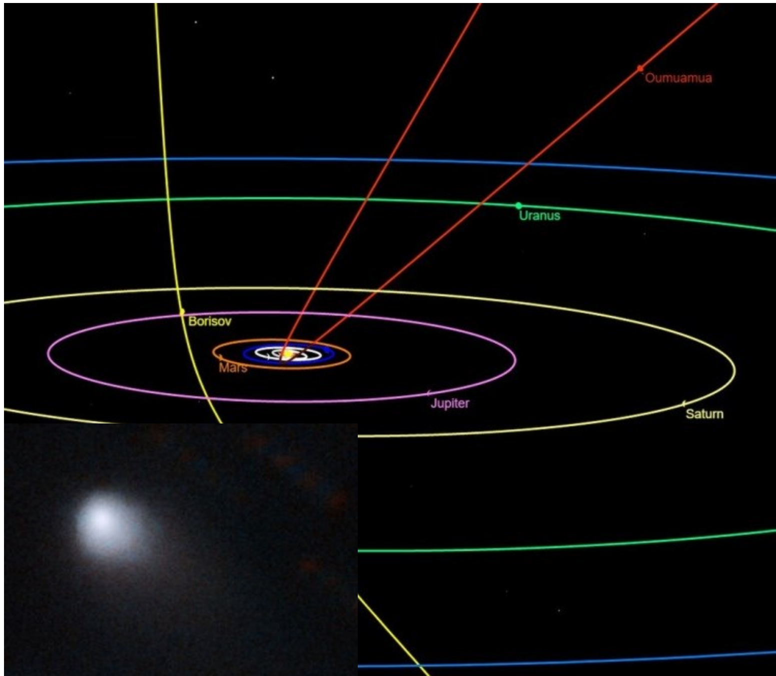
✓ Long-term ongoing work, but 7 papers already published

- Ieva et al. 2018, MNRAS 479, 260
- Perna et al. 2018, MNRAS 475, 974
- Hromakina et al. 2018, MNRAS 474, 2536
- Mazzotta Epifani et al. 2018, A&A 620, A93
- Fulvio et al. 2018, P&SS 164, 37
- Ieva et al. 2019, MNRAS 487, 2335
- Hromakina et al. 2019, A&A 625, A46

✓ Ongoing observations at LBT:



- "Extreme a,i" TNOs (Oort cloud origin)
- 2I/Borisov (first interstellar comet)



The “Fast” mission call in ESA’s Science Programme

Activity	Date
Release of the Call for F mission	16 July 2018
Phase-1 proposal submission deadline	25 October 2018 – 12:00 (noon) CEST
Phase-1 proposal assessment	November 2018
Workshop for Phase-2 proposers	11 December 2018 (TBC)
Phase-2 proposal submission deadline	20 March 2019 – 12:00 (noon) CET
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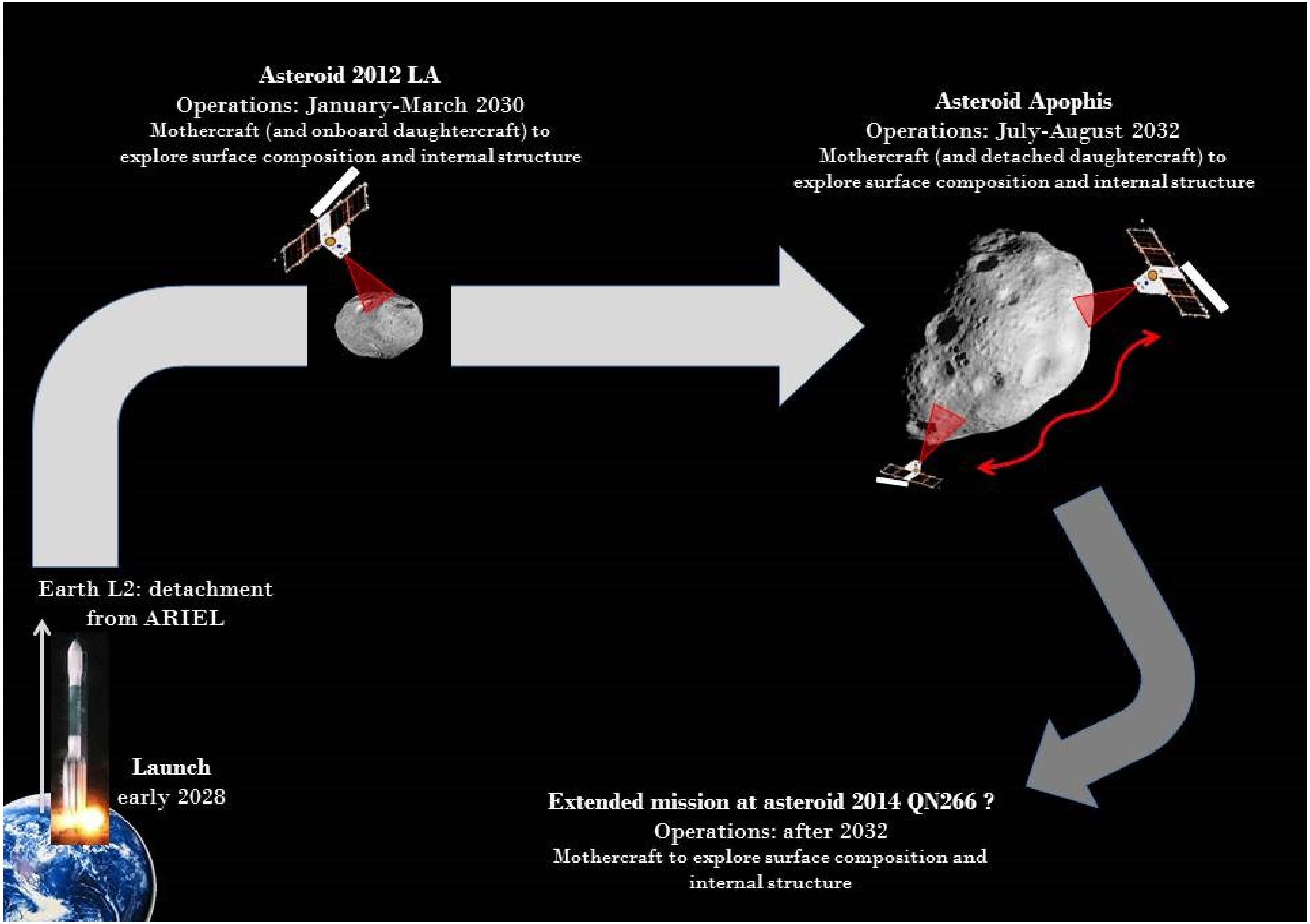
Proposal evaluation and scientific ranking	April – July 2019
Phase 0 study	July – December 2019
Selection of candidate mission	February 2020
Phase A/B industrial kick-off	September 2020
Mission adoption	November 2022
Mission CDR	June 2024
Spacecraft launch readiness	December 2027

- Launch to Sun-Earth L2 Lagrange point as a co-passenger to the ARIEL M mission
- Cap of 150 M€ to the ESA Cost at Completion (CaC)
- NEST proposal among the 6 out of 23 Phase-1 proposals recommended for Phase-2 after the technical and scientific screening by ESA

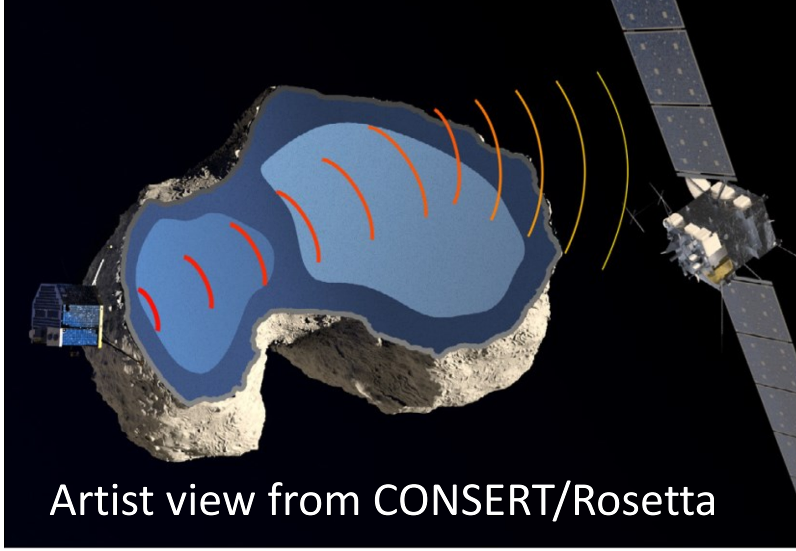
NEST in a nutshell

- **Rendez-vous with multiple NEAs** (operations at each target: a few months)
  - Baseline targets: **2012 LA** (10-m-sized) and **Apophis** (350-m-sized)
  - Extended mission target: **2014 QN266** (20-m-sized)



NEST science goals

- Smallest asteroids ever visited
- First radar investigation of asteroid interiors
  - → To constrain latest theories about planetary systems formation

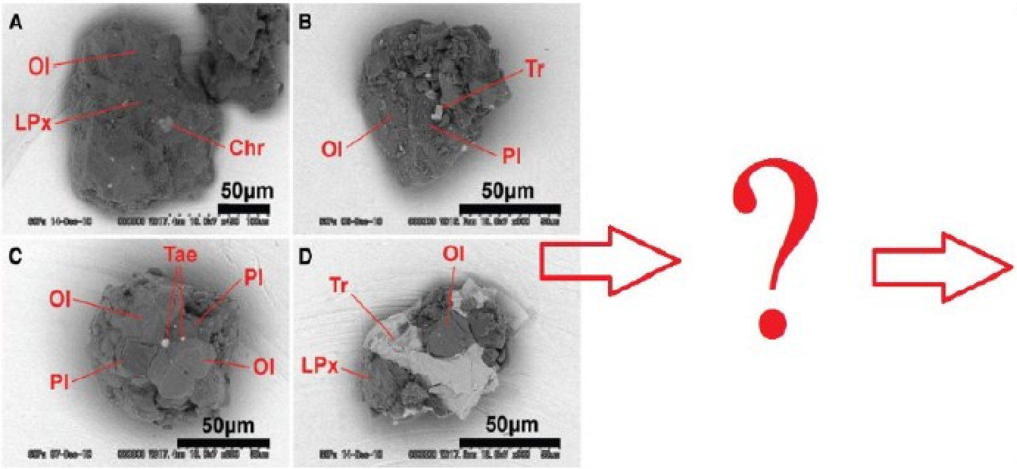


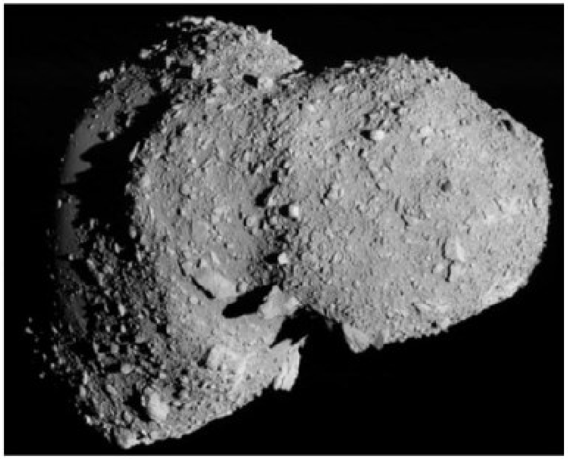
NEST: Key Questions

1. Which were the conditions of the protoplanetary disk and which are the mechanisms underlying the formation of terrestrial planets?

2. What are the internal structure and surface properties of asteroids in different size regimes, and how this reflects different formation and early evolution?

3. Which is the nature of the "potentially hazardous asteroid" Apophis, which has multiple potential impact solutions during the course of the next century?





NEST

Core Team members	
Davide PERNA (Lead Proposer)	INAF – Osservatorio Astronomico di Roma, Italy
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Maria Antonietta BARUCCI	LESIA – Observatoire de Paris, France
Lorenzo CASALINO	Politecnico di Torino, Italy
Vania DA DEPPO	CNR – IFN, Italy
Vincenzo DELLA CORTE	INAF – IAPS, Italy
Elisabetta DOTTO	INAF – Osservatorio Astronomico di Roma, Italy
Sonia FORNASIER	LESIA – Observatoire de Paris, France
Alain HERIQUE	IPAG – Université Grenoble Alpes, France
Daniel HESTROFFER	IMCCE – Observatoire de Paris, France
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Jean-Luc JOSSET	Space Exploration Institute, Switzerland
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Patrick MICHEL	CNRS – OCA, France
Alessandro MURA	INAF – IAPS, Italy
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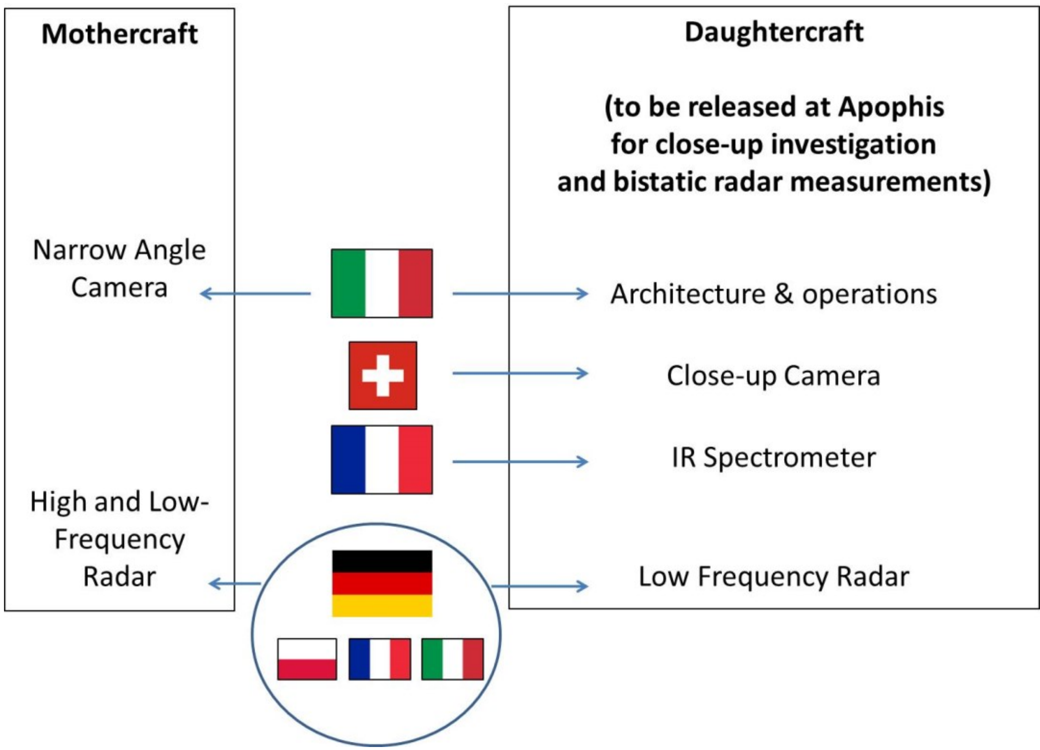
Yves ROGEZ	IPAG – Université Grenoble Alpes, France
Alessandro ROSSI	IFAC – CNR, Italy
Giovanni B. VALSECCHI	INAF – IAPS, Italy
Marco ZANNONI	Università di Bologna, Italy



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- NEST proposal didn't pass Phase-2 technical screening: evaluated as "incompatible with the boundary conditions of the call"

- Extremely positive Phase-1 scientific assessment!
  →
  Next larger-class mission opportunities (more targets, more instruments…)

Supervising and dissemination activities

- ✓ 2 PhD and 1 Master students supervised
- ✓ European Researchers' Nights and other events at INAF-OAR
- ✓ Several television/radio/web interviews and participations

Thank you!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement n. 664931