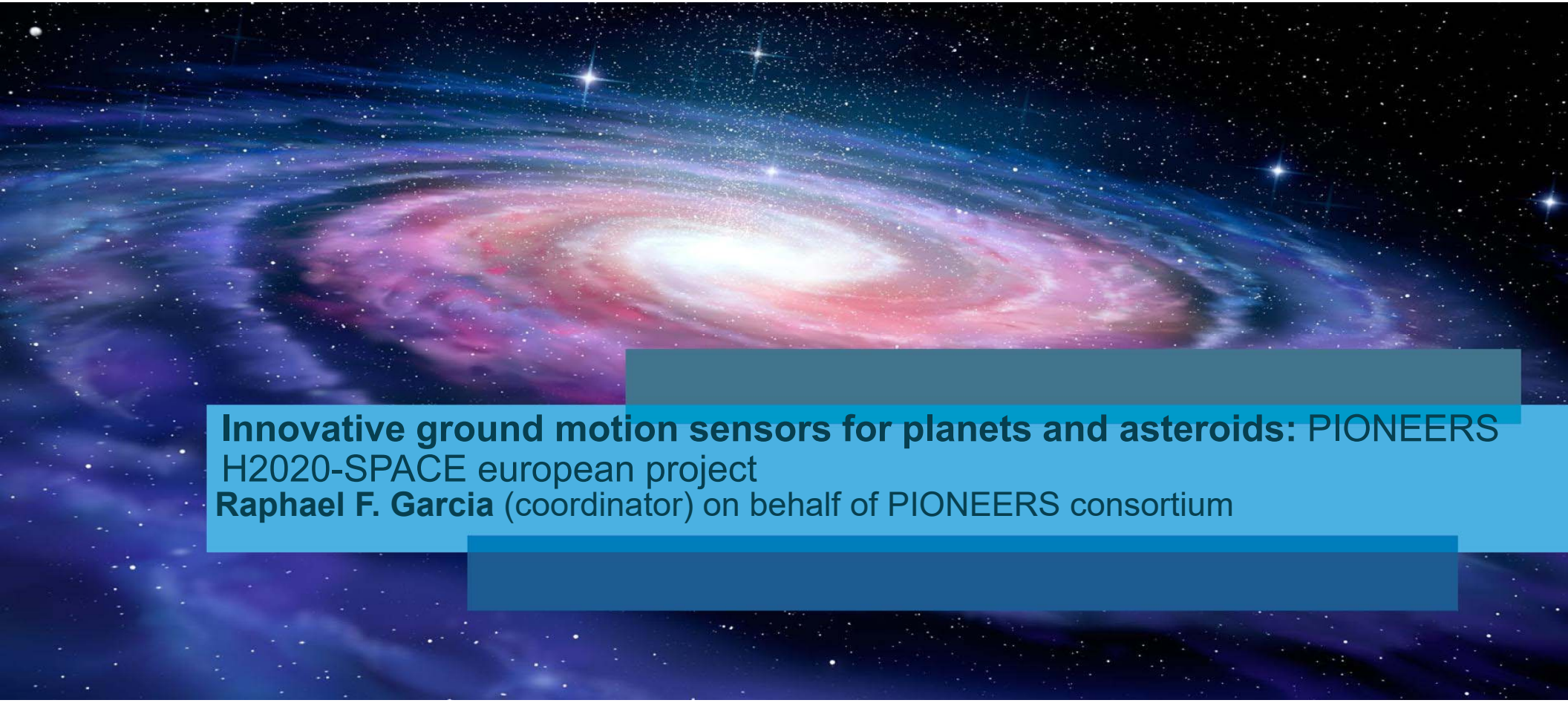
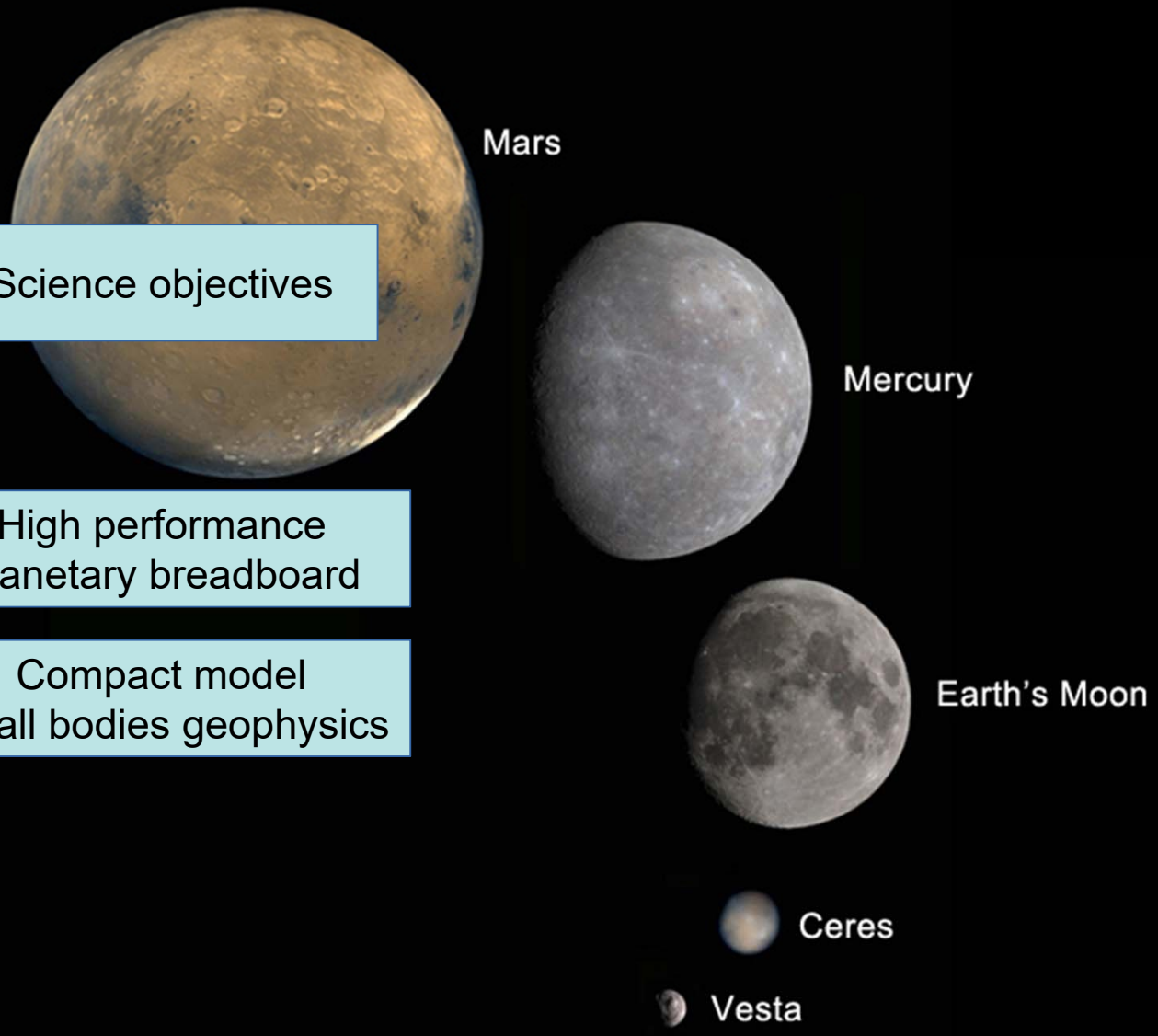


Innovative ground motion sensors for planets and asteroids: PIONEERS H2020-SPACE european project

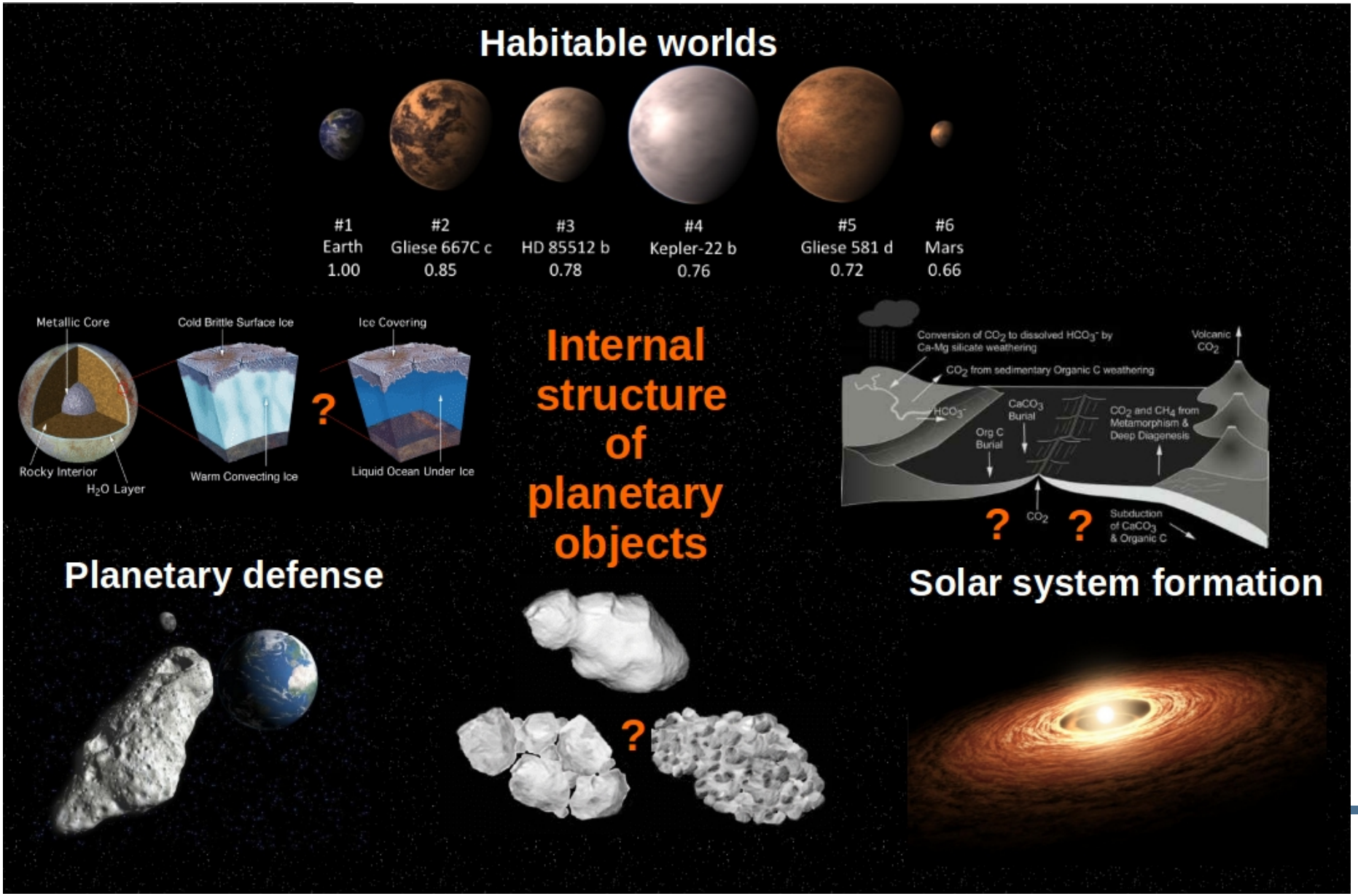
Raphael F. Garcia (coordinator) on behalf of PIONEERS consortium

Table of content



Why investigating internal structure of planetary objects?

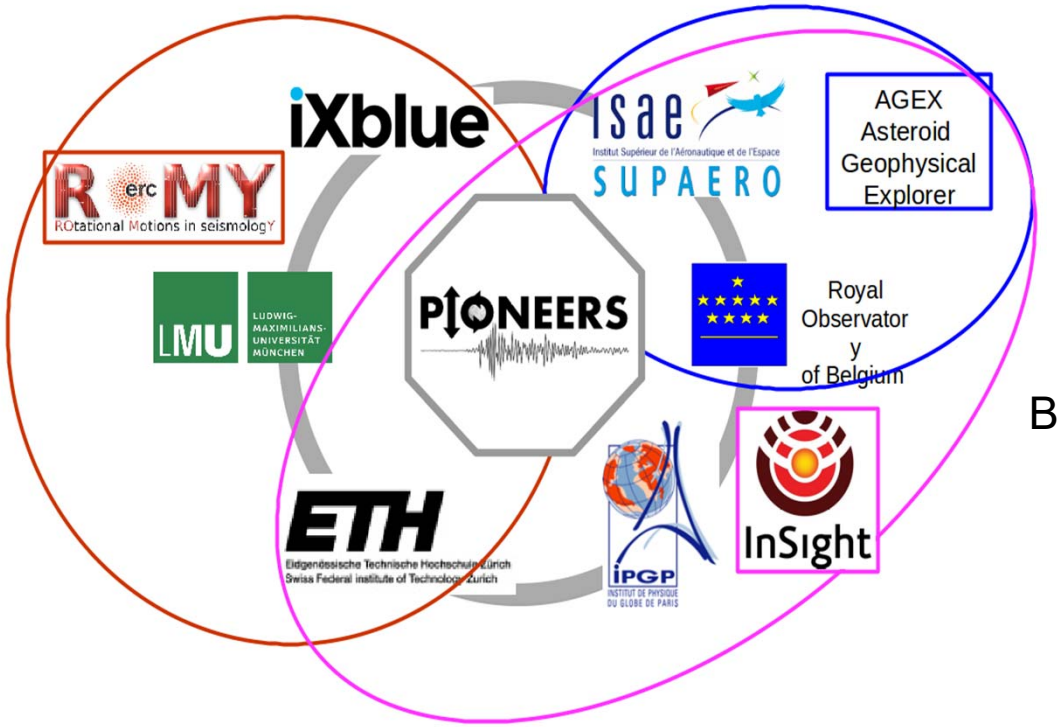
1. **Science objectives at the center of current science and exploration questions**



Consortium and heritage

1. **European leading teams in planetary seismology, rotational sensors and rotation dynamics of planetary objects**
2. **Teams already involved in the development of state of art instruments (SEIS/INSIGHT, BlueSeis)**

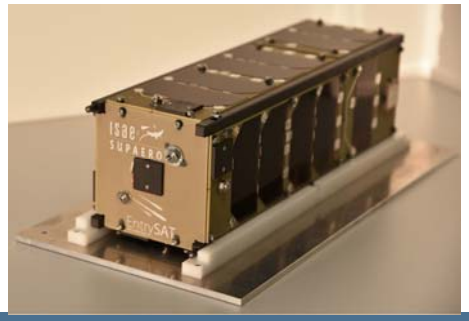
Consortium partners
and their links through already existing projects



SEIS/InSight

BlueSeis-3A
BlueSeis/iXblue

EntrySat
ISAE-SUPAERO



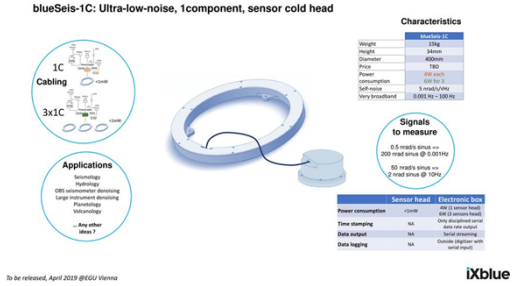
Project objectives

- **Objective 1 : Improve the European experience in planetary geophysics through innovation**

SEIS on Mars

- **Objective 2 : Improve competitiveness of industrial partners on the market of scientific instrumentation**

iXblue scientific instruments



- **Objective 3 : Provide 6 DoF instrum ions**

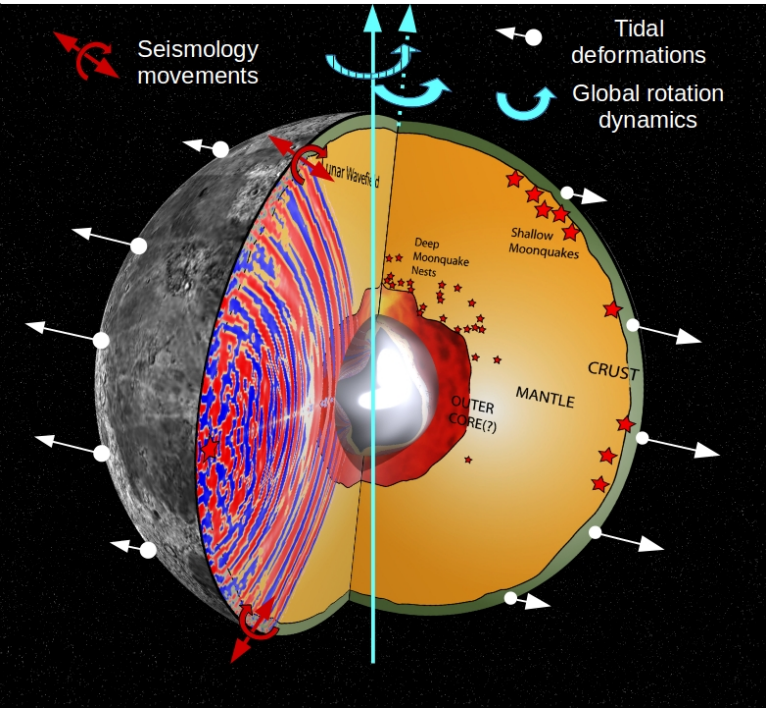
Planetary targets

Small bodies targets

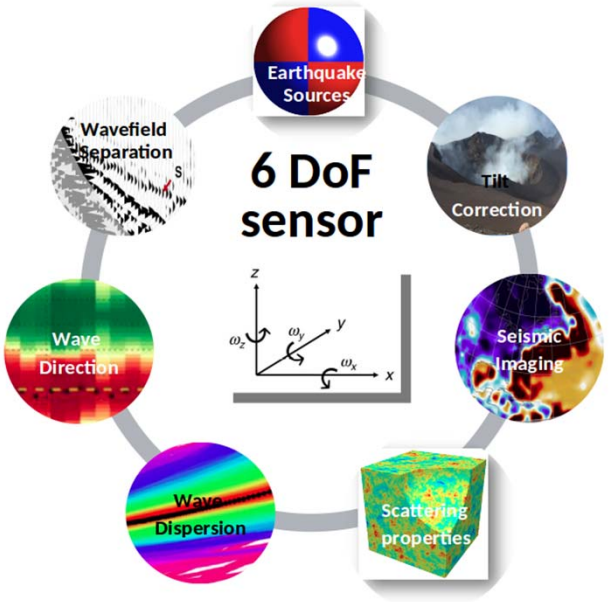
Science objectives

1. **6 Degrees of Freedom seismology for internal structure imaging**
2. **Global rotational dynamics of planetary objects (MoI, forced librations…)**
3. **lander/ground interactions for sub-surface mechanical properties**
4. **lander/rover navigation for ground properties and local gravity field variations**

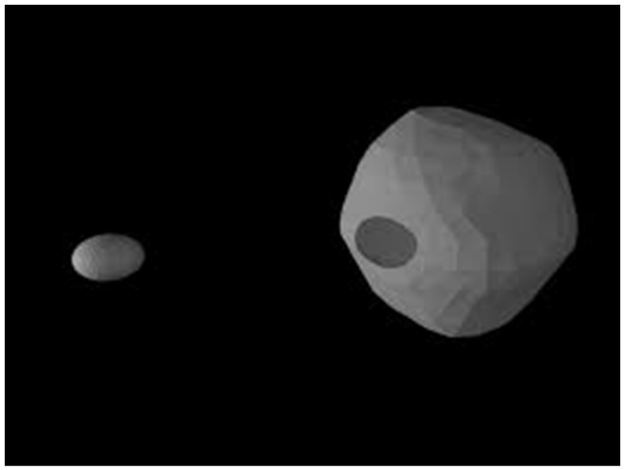
Expected measurements



Expected improvements from 6 DoF measurements



Rotational dynamics (forced librations, tides...) in binary systems

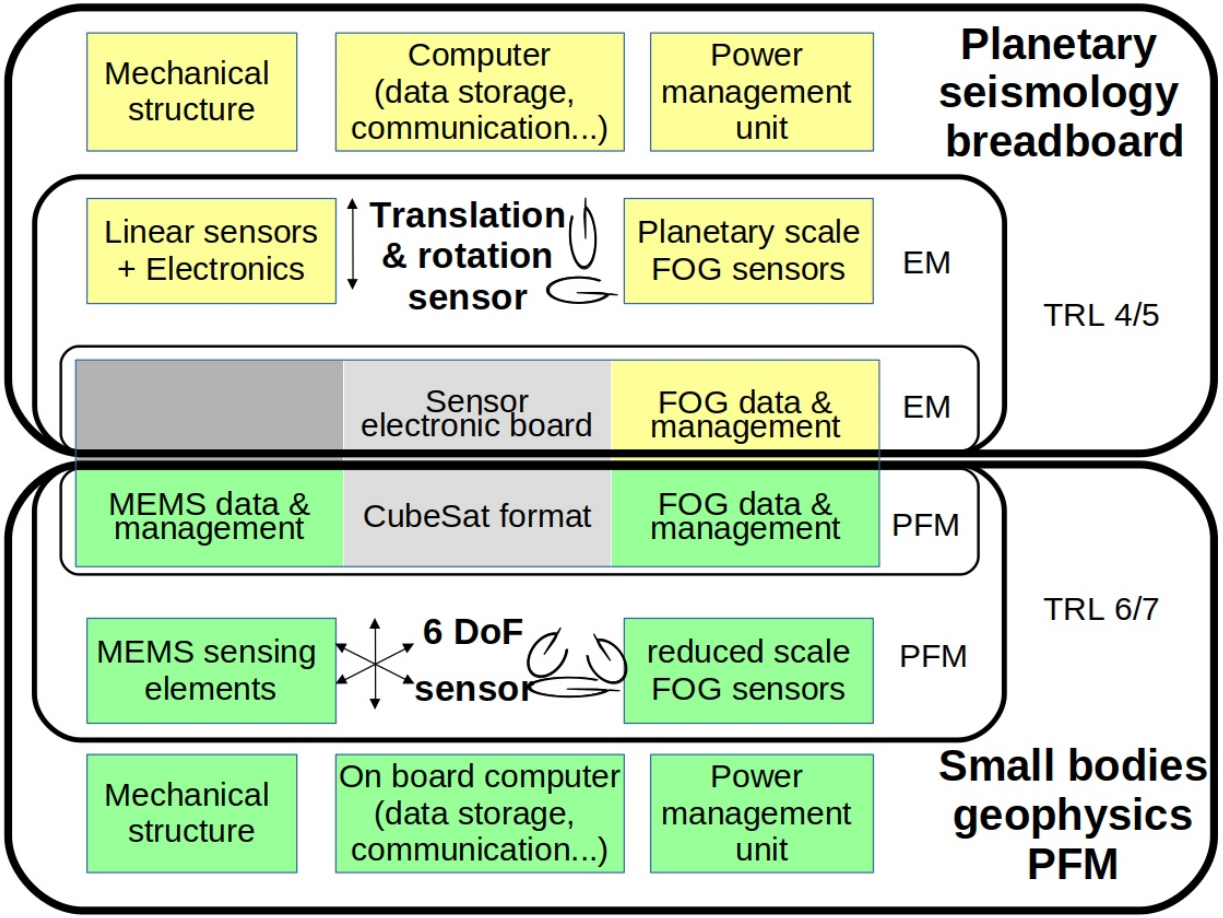


2 Instruments

1. **Two different instruments will be developed at different performance levels, different final TRL and for different targets**
2. **The fiber optic gyroscopes of these instruments will share the same electronic board**

High perfomance, planetary grade, at breadboard level

Compact model (1U CubeSat), for small bodies, up to flight model



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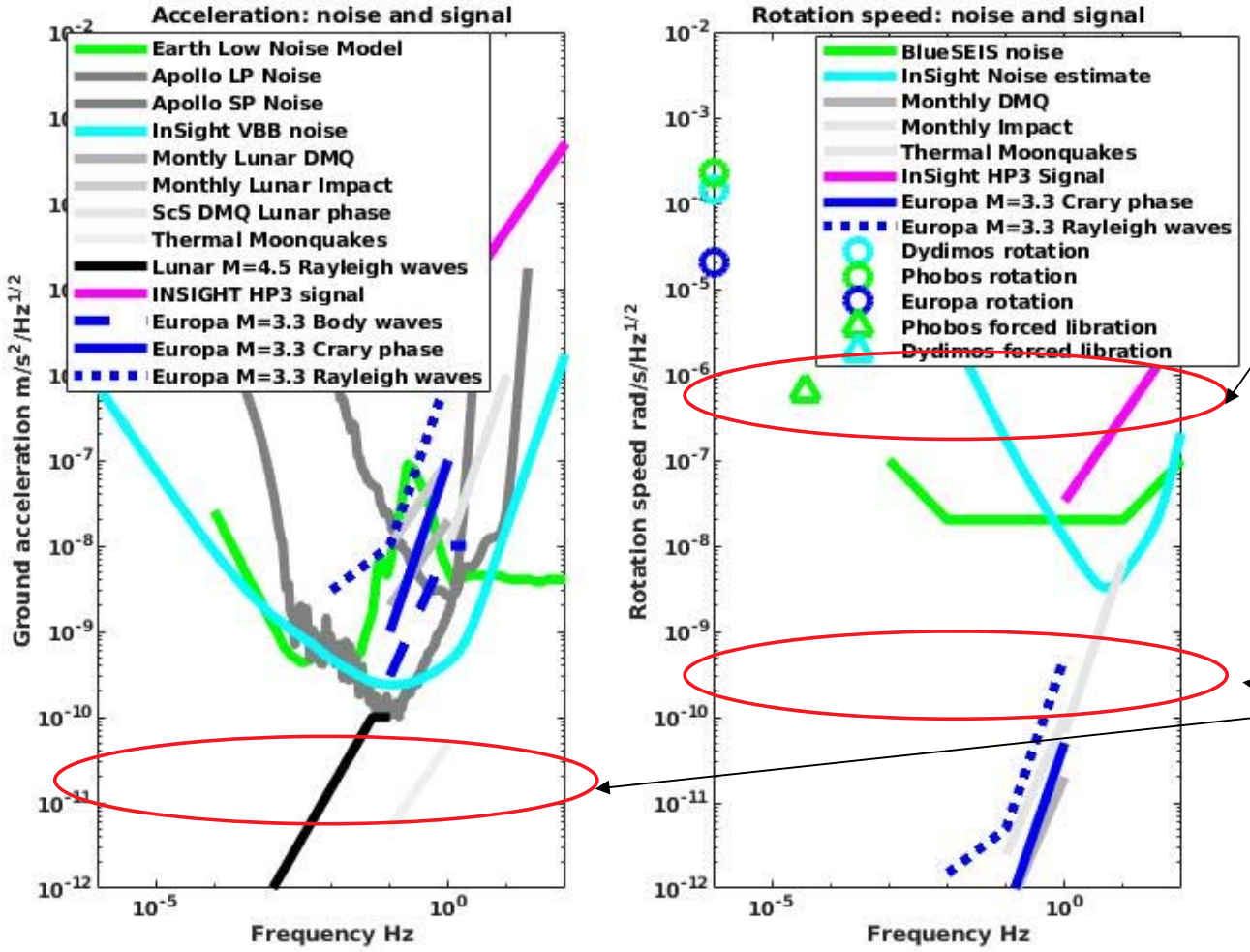


High TRL Compact model
For small bodies
Geophysics =>

Noise target of small bodies
compact model
at CubeSat format

High Performance
Planetary
Breadboard =>

Noise target of
high perfomance
Planetary instrument

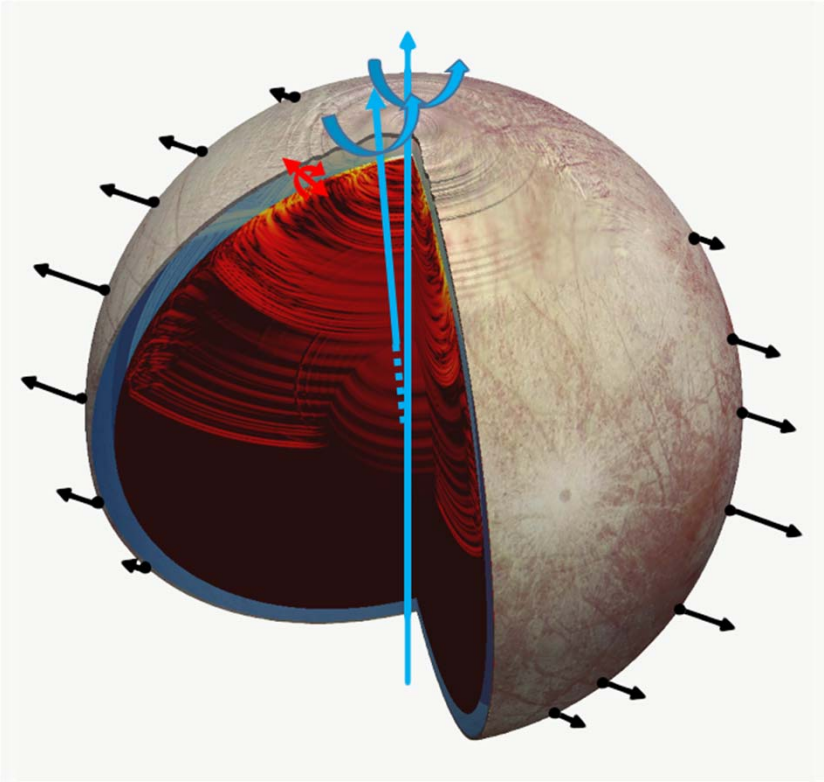
High performance planetary breadboard

1. **Two sensors :**
   - Translational sensor based on optical interferometry readout
   - Giant Fiber Optics Gyroscope for high performance rotation sensing

2. **Development up to breadboard for :**
   - Technology demonstration of performances
   - Demonstration of scalability of performances
   - Identification of key difficulties

3. **Science targets :**
   - Background seismological noise of large planetary objects
   - Precise global rotation dynamics of large planetary objects
   - Improvement of planetary seismological methods

   by adding rotation (environment noise removal, network analysis, scattering characterisation...)

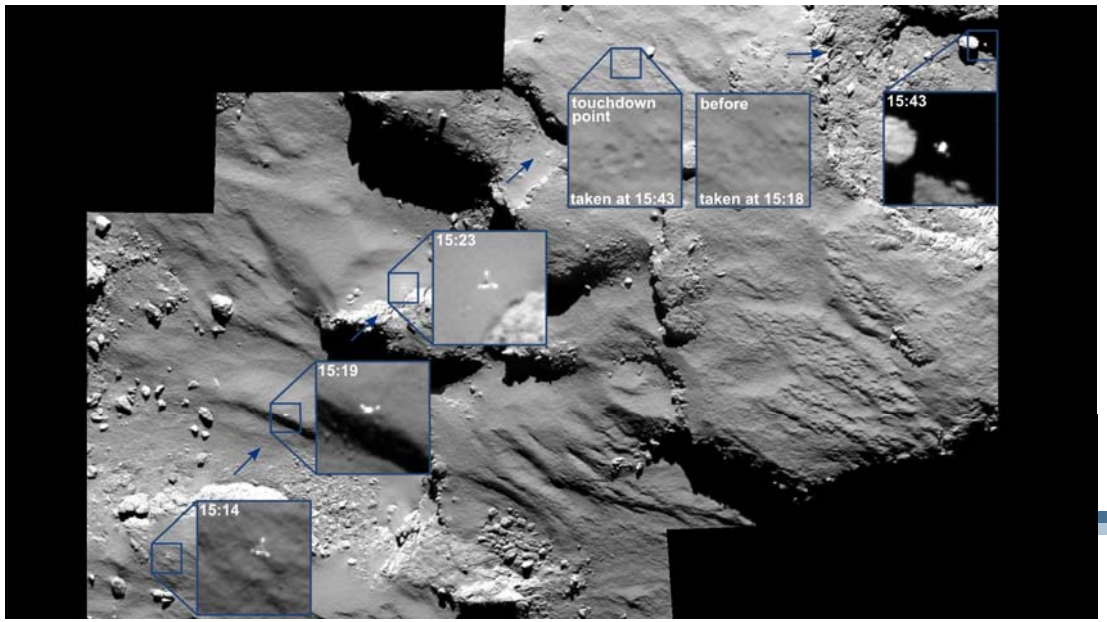


Type of signal targeted by the instrument

High TRL compact model for small bodies geophysics

1. **Two triade of sensors :**
   - High performance accelerometers (translations)
   - Small fiber optics gyroscopes (rotations)
2. **Development up to flight model :**
   - CubeSat format
   - Space qualification
   - Keep ITAR Free and cost improvement in mind
3. **Science targets :**
   - Interactions between lander and ground for small bodies
   - Local gravity field determination from rebounds and trajectories
   - Rotation dynamics of small bodies (rotation rate, forced librations…)
   - Active seismology

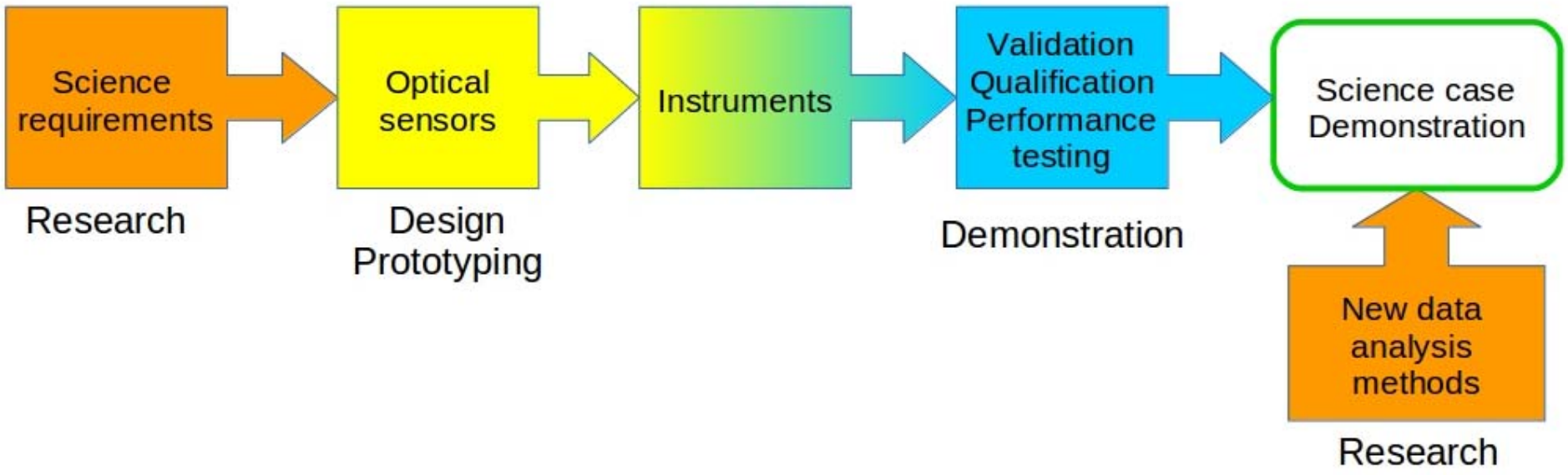
Rebounds of Philea lander (credits ESA)



Asteroid binary system

Methodology

1. **Instrument development from science requirements to validation and performance testing**
2. **Earth analog and data analysis methods developed in parallel to reinforce the science case**



Schedule / Milestones

1. **2019 :**
   - Science requirement definition review
   - Preliminary Definition review of sensors/sub-systems
   - Final science requirements delivery
2. **2020 :**
   - Development of performance testing facilities
   - Critical design review of sensors/sub-systems
   - Preliminary design review of instruments
3. **2021 :**
   - Validation of new 6 DoF data analysis methods with Earth analog data
   - Qualification review of sensors
   - Critical design review of instruments
4. **2022 :**
   - Instrument performance testing and validation
   - Qualification review of instruments

Conclusions

1. **Develop the next generation of planetary ground motion sensors including translations and rotations**
2. **Rely on european leading teams in this field**
3. **Target improvement of seismology investigations, but also geodetic studies**
4. **Target both large planets and small bodies with two different instruments with different performances and different development time scales, but sharing the same electronics for fiber optics gyros.**

More information at
https://pioneers.oma.be

Conclusions / Prospect

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1. **Target missions/objects :**
   - **Compact model => MMX ? HERA ?**
   - **Planetary model => Future Moon seismological sensors ? Planets with atmospheres ?**
2. **A new type of mission ?**
   - **Compact model is able to monitor the Asteroid rotations => visit many NEOs, and leave there long lived landers monitoring their rotation (missing parameter for orbit predictions)**

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°821881