UCL Université catholique de Louvain

ROYAL OBSERVATORY OF BELGIUM

MORE
Mercury Orbiter Radio-science Experiment

Libration and obliquity of Mercury from the BepiColombo radio science and camera experiments

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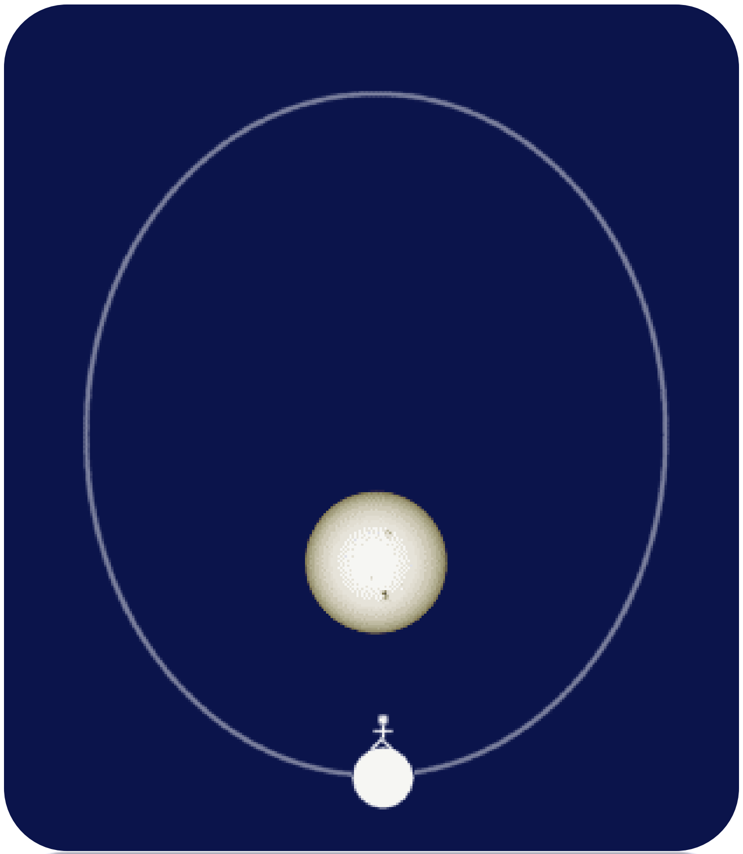
The terrestrial planets

	Mercury	Venus	Earth	Mars
Distance (UA)	0,39	0,72	1	1,52
Radius (km)	2439	6052	6371	3390
Density (g/cm³)	5,43	5,20	5,51	3,93
Rotation (days)	58,6	243,0	1,00	1,02
Revolution (days)	87,9	224,6	365,25	687,9

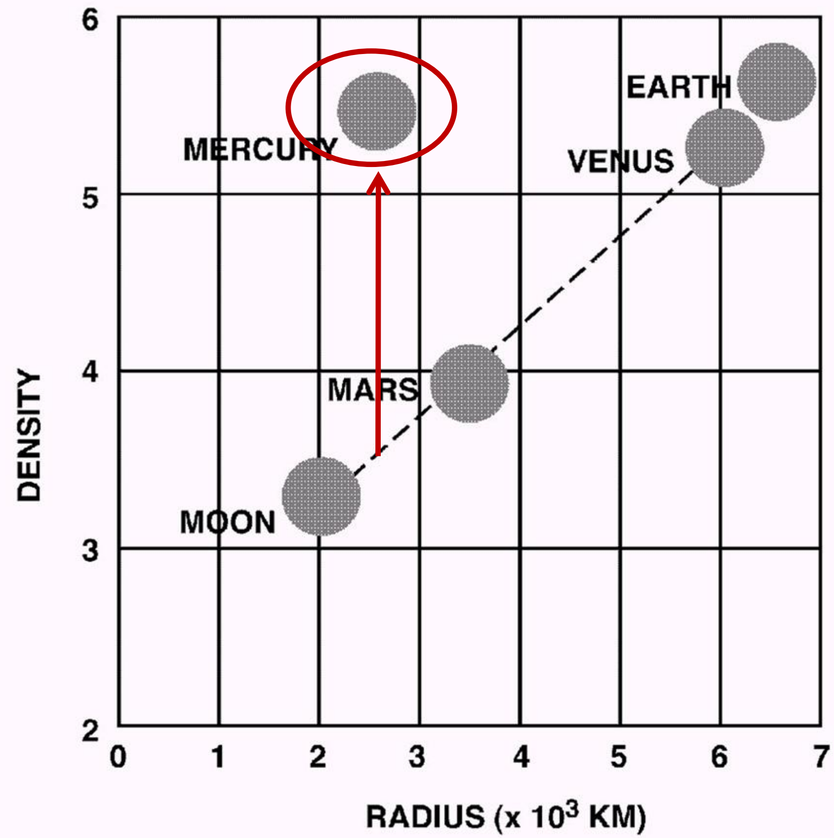
Spin-Orbit Resonance



- 3 rotations (58,6d)
- 2 revolutions (87,9d)
- 1 Mercury day = 176d
- 3:2 spin-orbit
- Unique in the Solar system

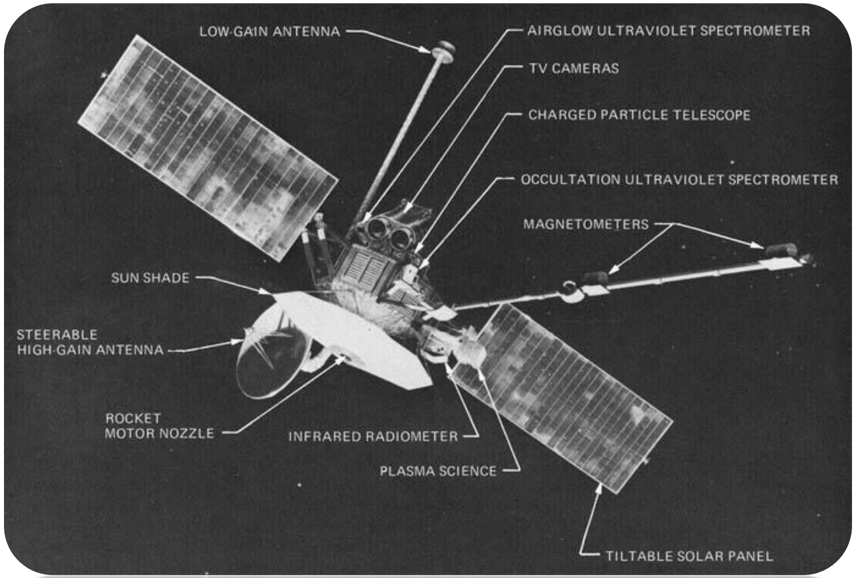
Mercury, a « special » planet

- Small but dense
- Mysterious
- High uncompressed density indicates large core



Missions to Mercury:
past & present

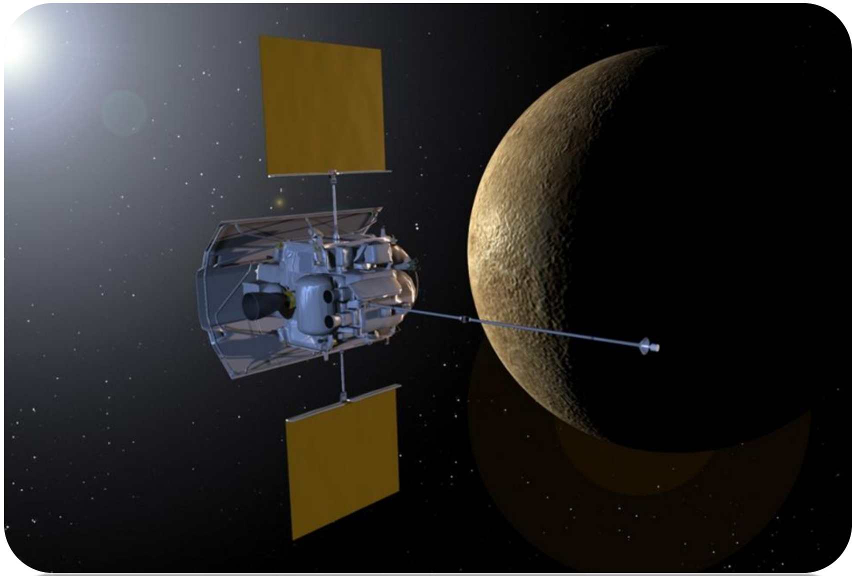
Mariner 10



Source: NASA

1974/5: 3 "fly-by"

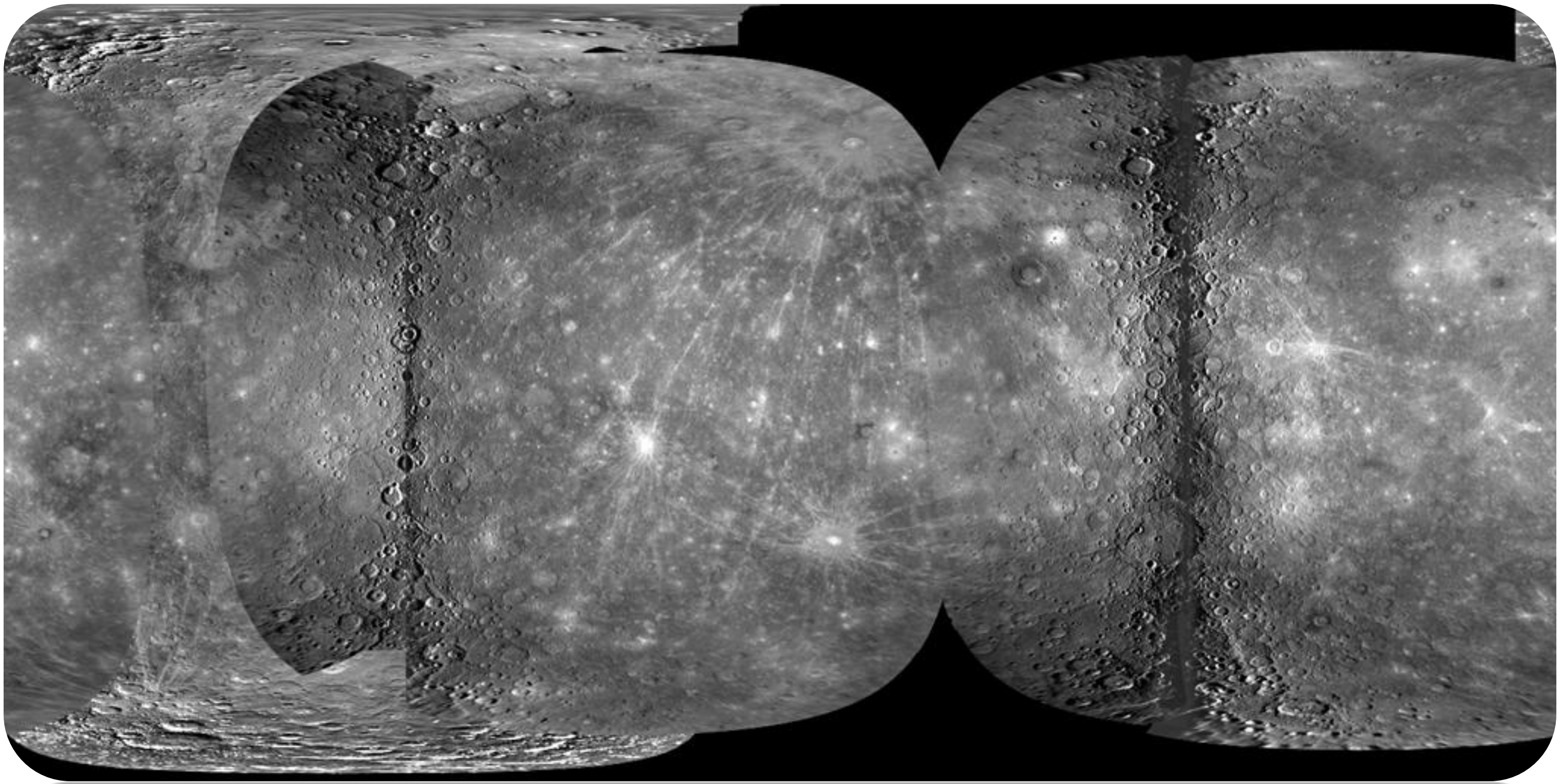
MESSENGER



Source: NASA

2008/9: 3 fly-by's
2011 : orbit insertion

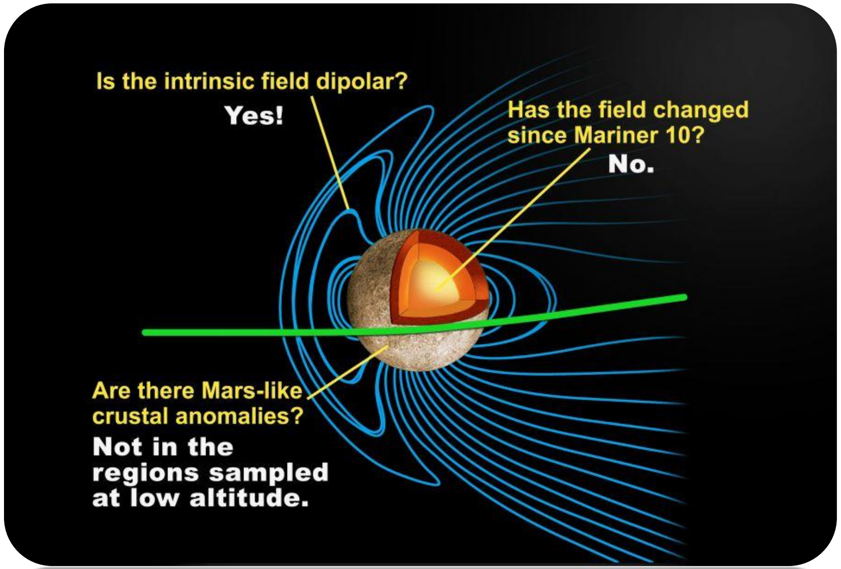
Current surface coverage by the MESSENGER mission



Source: NASA / Johns Hopkins University Applied Physics Laboratory / Carnegie Institution of Washington

Magnetic field

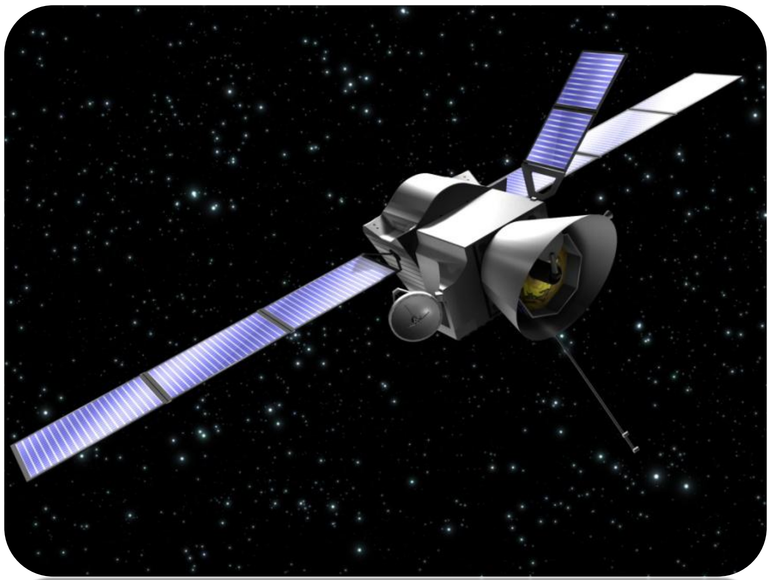
- Mariner 10 detected ***strong*** magentic field:
  - Dipolar, therefore not remanent
  - Generated through dynamo action?
  - Mercury has a liquid core ?
  - MESSENGER observed **the same** magentic field!



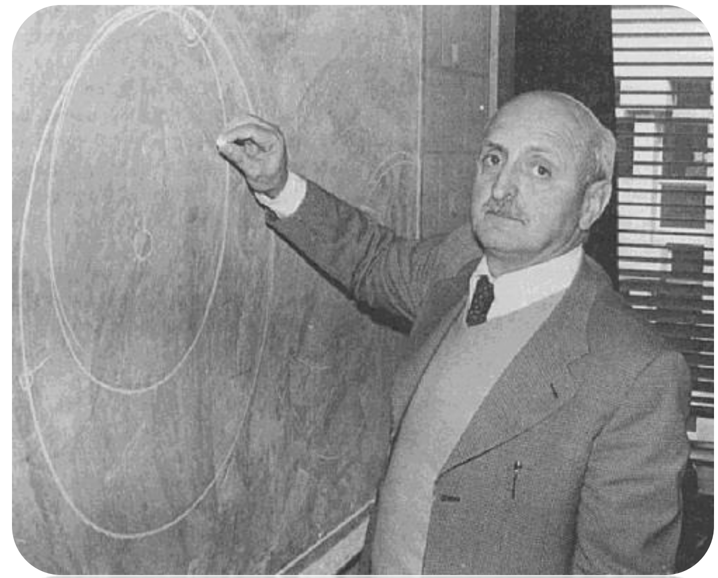
Source: NASA / Johns Hopkins University Applied Physics Laboratory / Carnegie Institution of Washington

Missions to Mercury:
future

BepiColombo



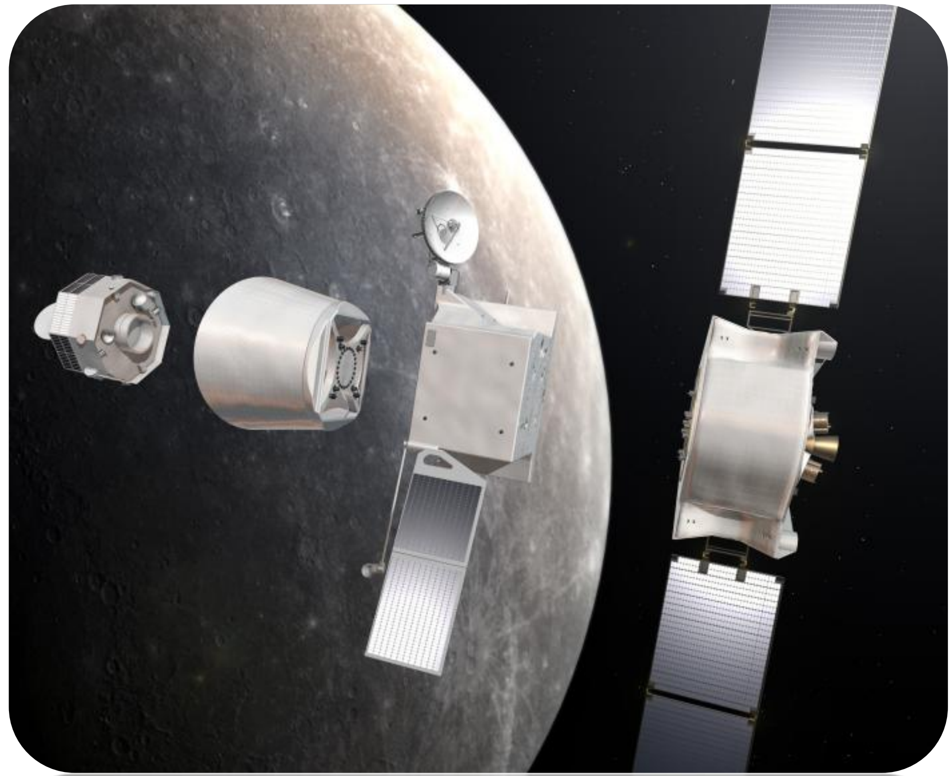
2014: launch
2020: orbit insertion



Giuseppe “Bepi” Colombo
(1920-1984)

The BepiColombo mission

- Mercury Magnetospheric Orbiter
- Solar shield
- Mercury Planetary Orbiter
- Solar-electric propulsion module

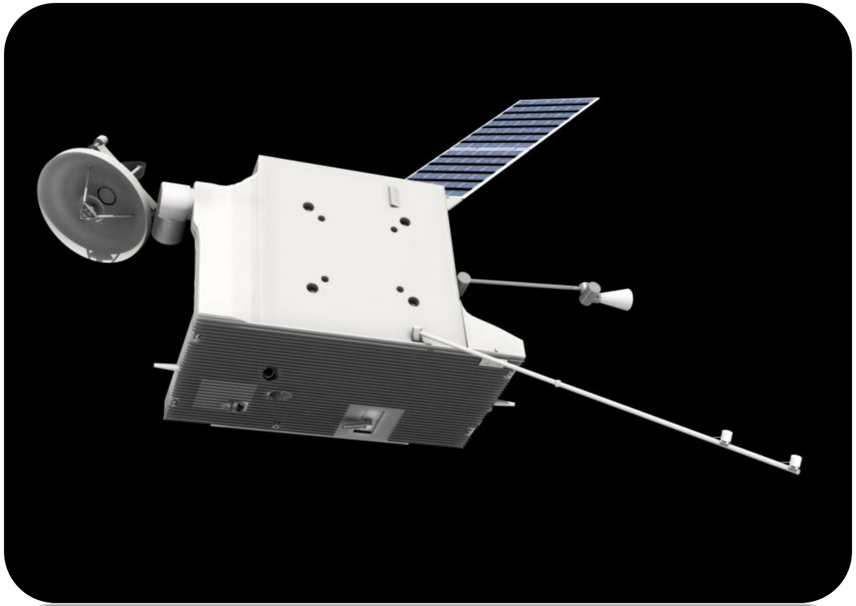


Les composants de la mission BepiColombo. **Source**: ESA

BepiColombo: Mercury Planetary Orbiter

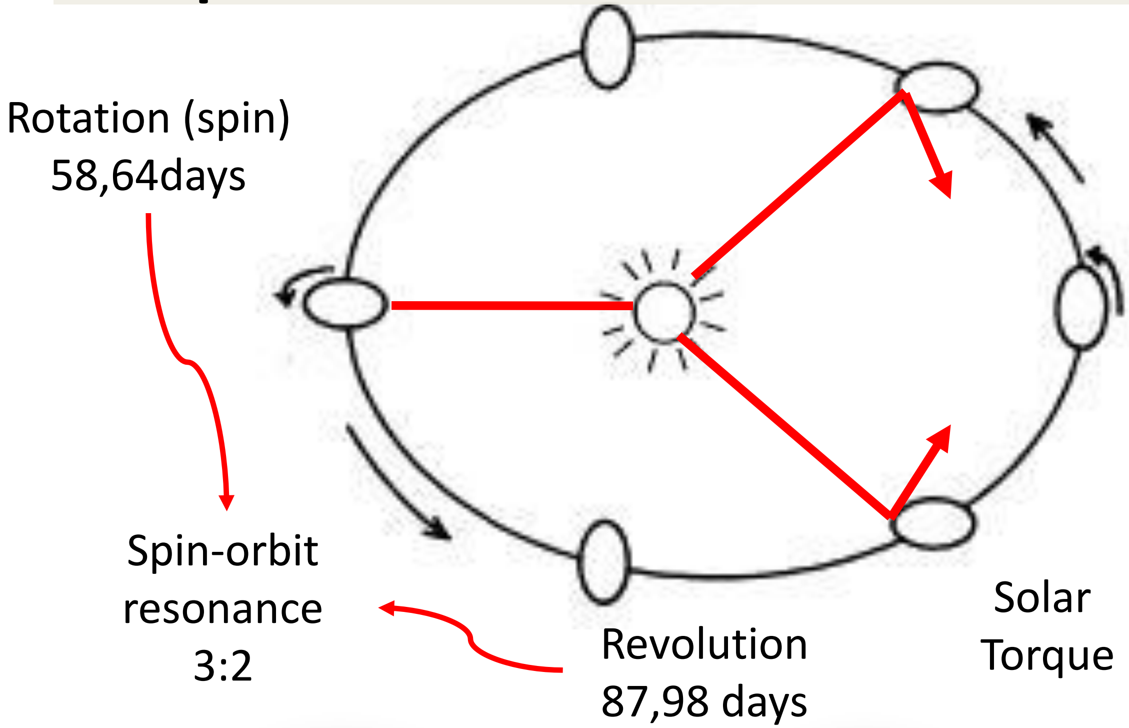
- Instruments :
  - Cameras
  - Spectrometers
  - Laser altimetre
  - …

- Main objectives:
  - Surface mapping
  - Surface composition
  - Internal structure
  - Gravitational field



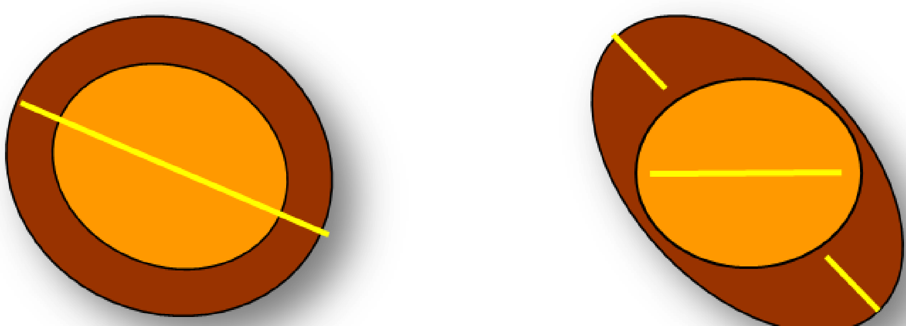
Source : ESA

3:2 resonance & internal structure dependence of the libration amplitude

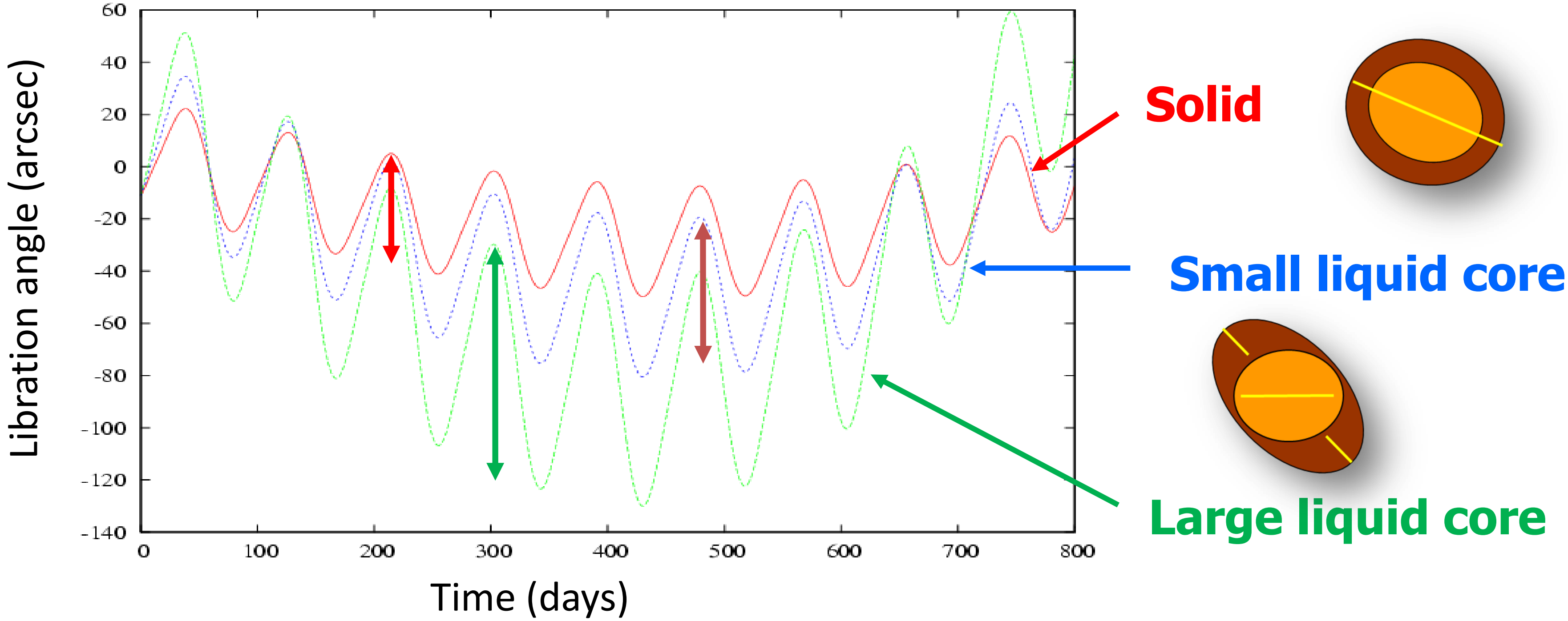


$$\gamma = \frac{3}{2}\frac{B-A}{C_m} f(e)\sin nt$$

- Libration amplitude increases
- Mantle moment of inertia decreases
- Core moment of inertia increases
- Radius of the core increases
- % light element increases



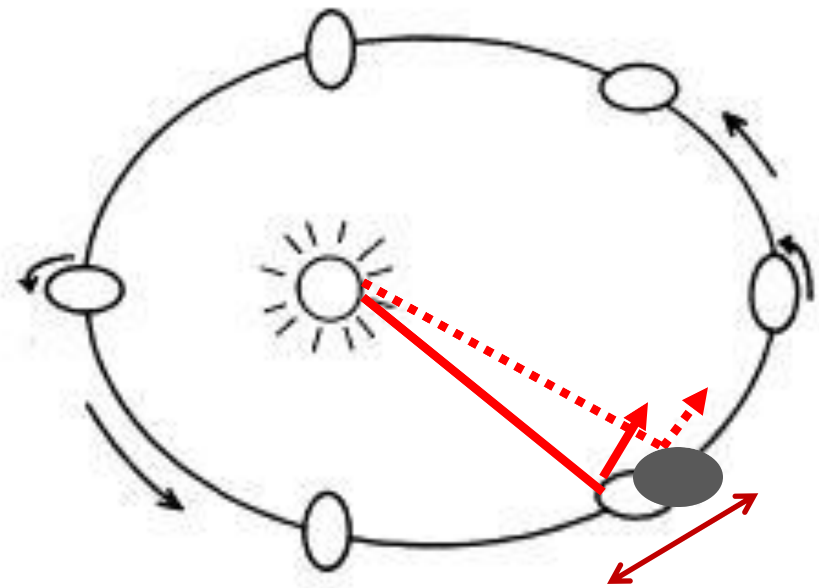
Libration amplitude and internal structure



Source: Nicolas Rambaux

Planetary induced librations

- Mecanism ?

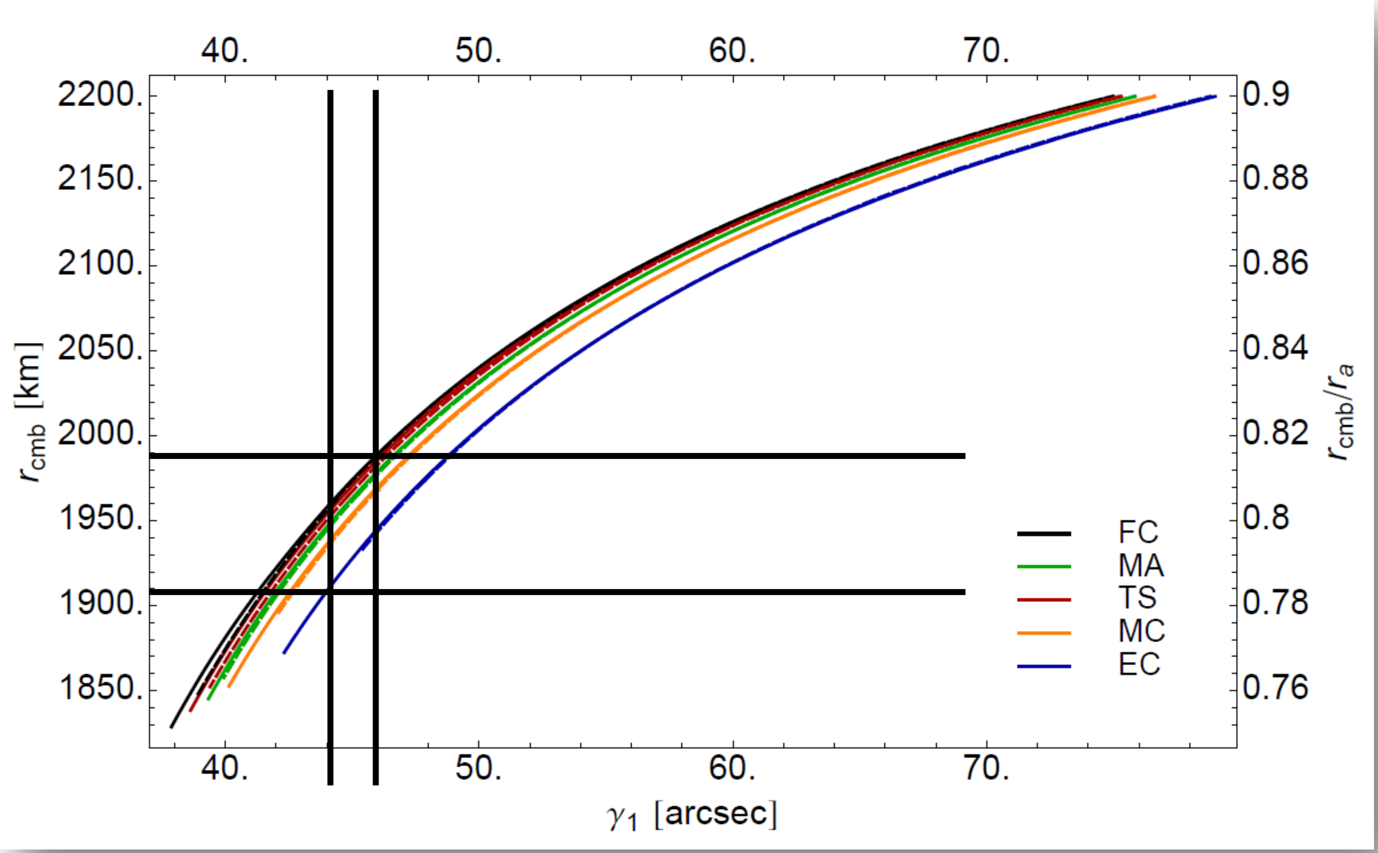


- Most important:
  - Jupiter (11.86 a)
  - Venus (5.66 a)

Link between libration amplitude and internal structure

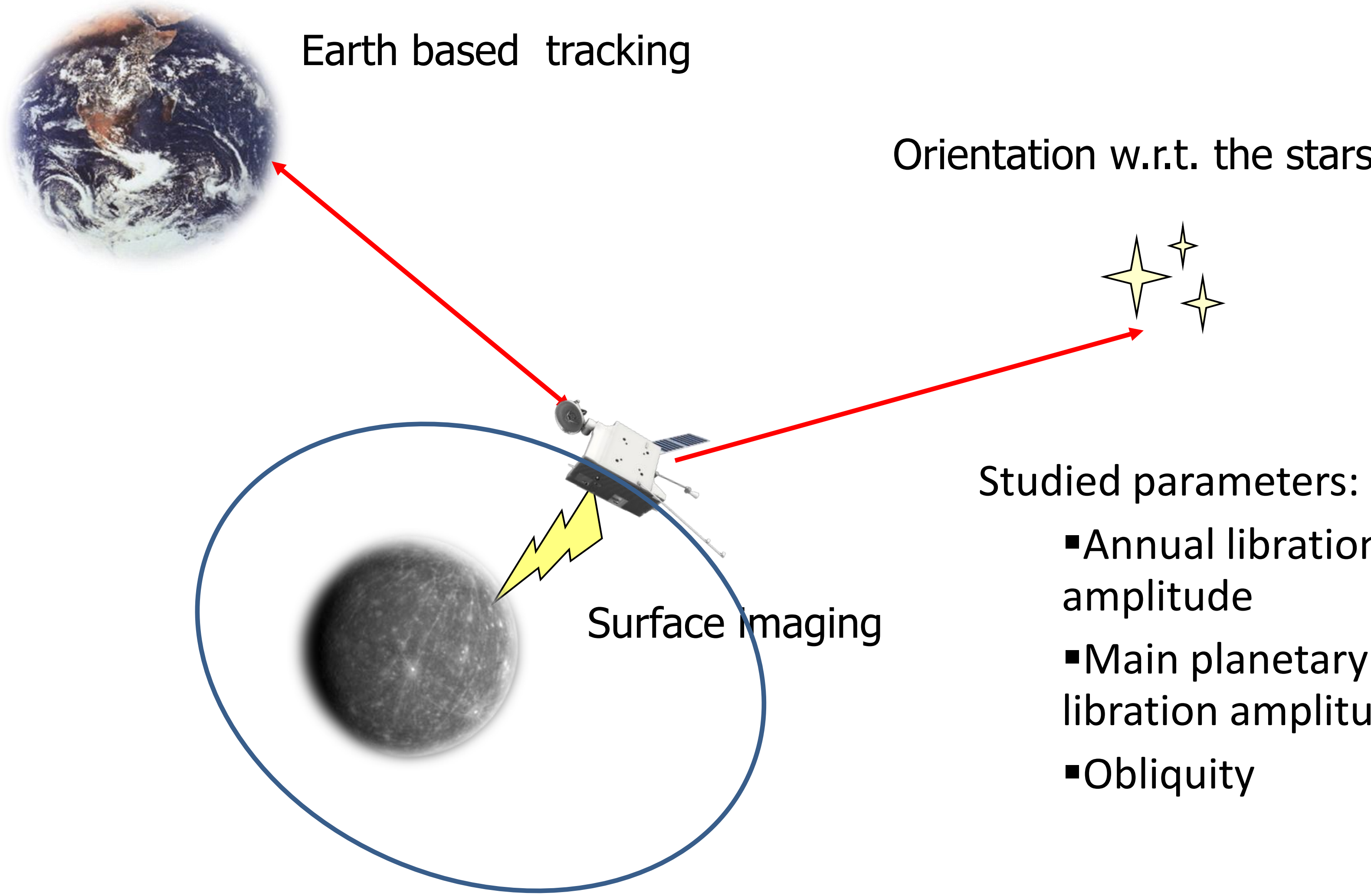
γ = 45±1as

R= 1950±40km



Source: The interior structure of Mercury and its core sulfur contents, Rivoldini *et al.* 2009, *Icarus 201, 12-30*

The BepiColombo rotation experiment

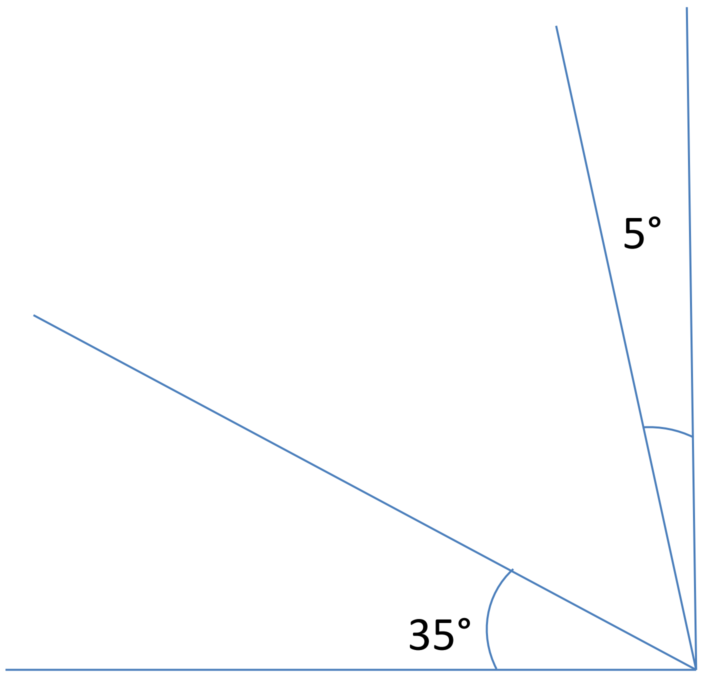


Studied parameters:

- Annual libration amplitude
- Main planetary induced libration amplitudes
- Obliquity

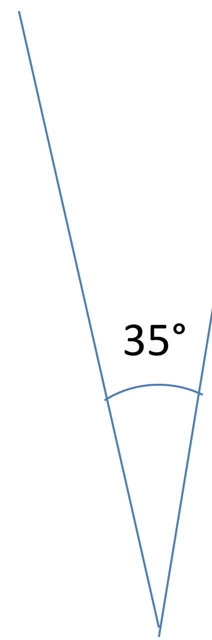
Illumination constraints

Sun must not be too close to zenith

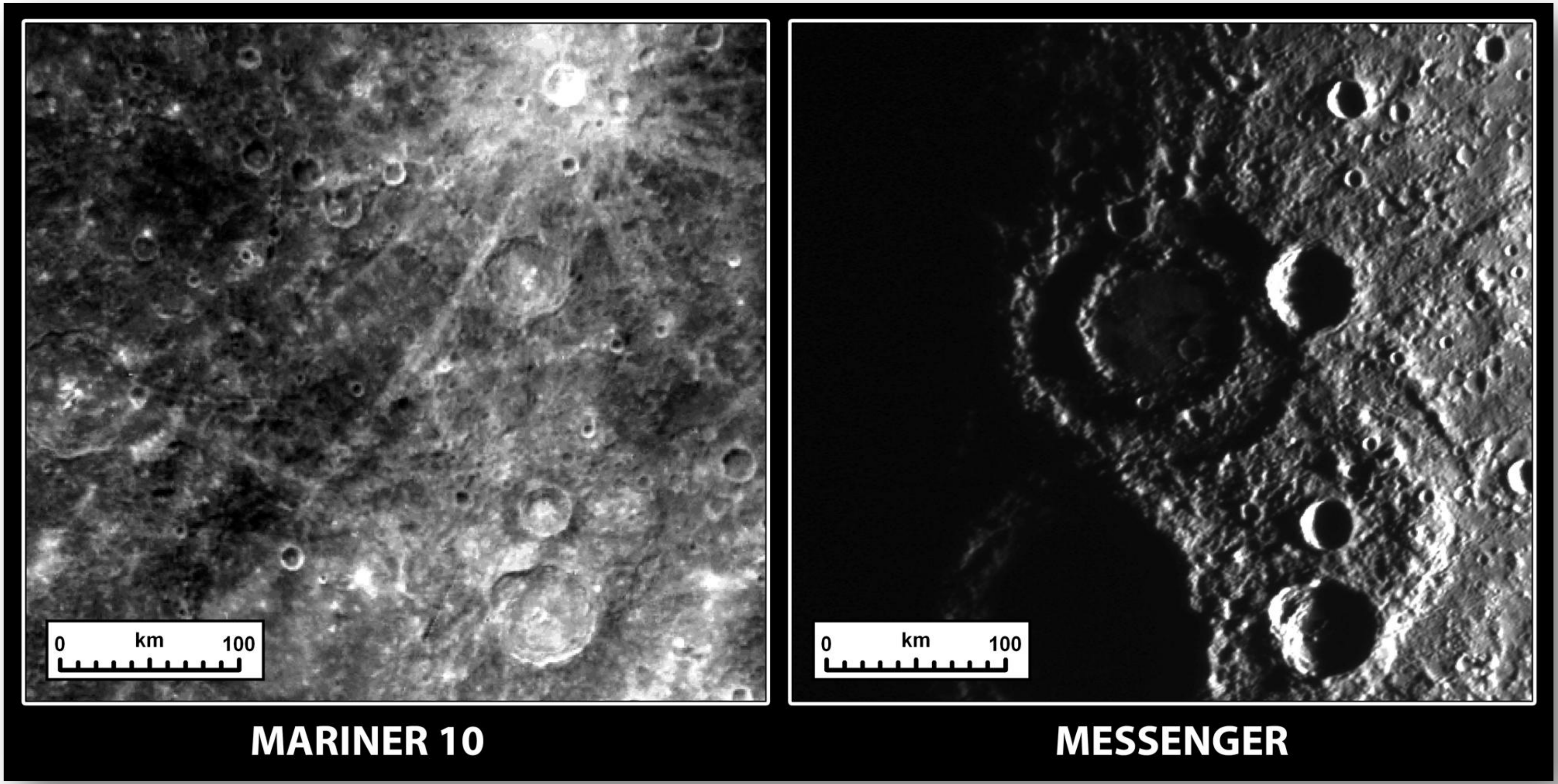


Sun must be above certain elevation

Maximum difference in illumination angle



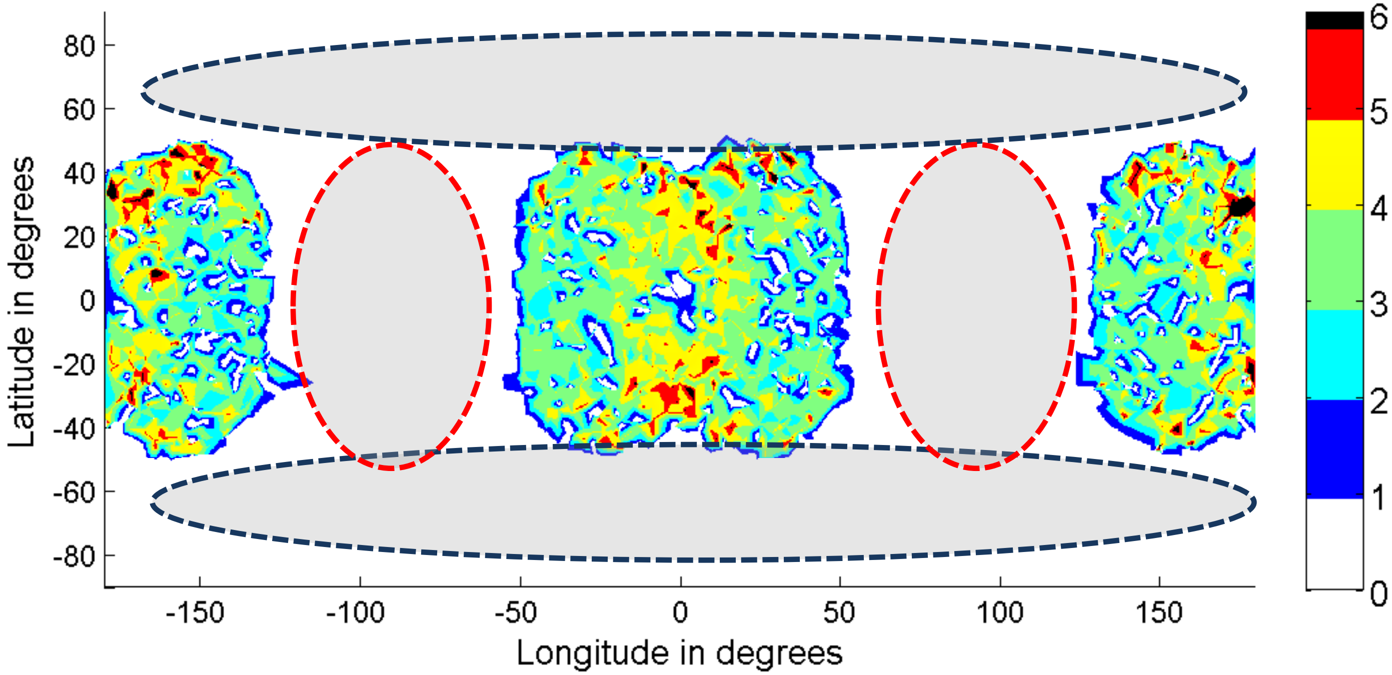
Illumination constraints



Source: NASA / Johns Hopkins University Applied Physics Laboratory / Carnegie Institution of Washington

Surface coverage

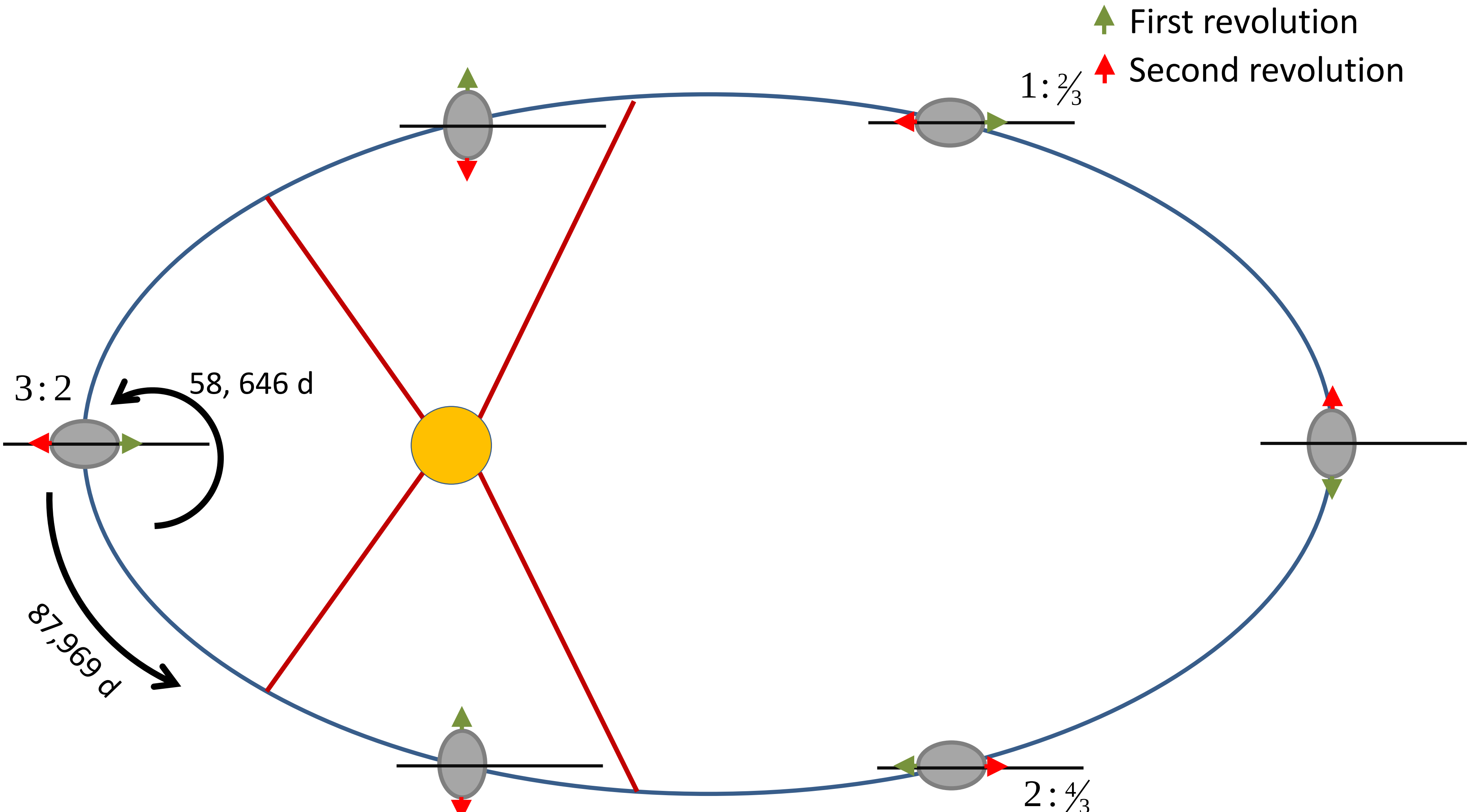
BepiColombo Orbite nominale	
Apoaltitude	1508 km
Perialtitude	400 km
Eccentricité	~0.16
Inclinaison	90°
Dérive du péricentre	-33,9°/a



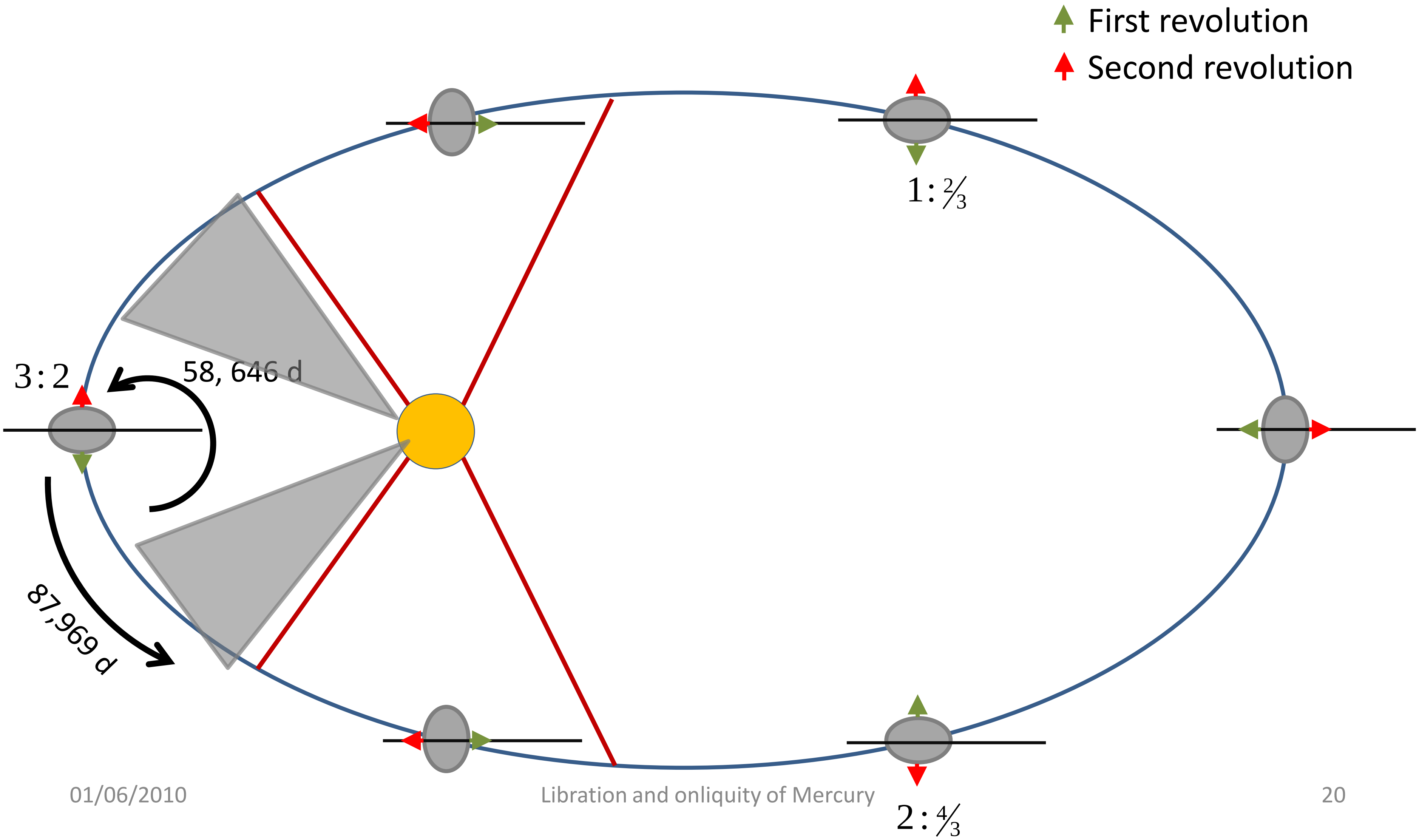
Illumination conditions heavily constrain the possible observations:

- To correctly observe surface patterns very low (less than 35°) or very high (more than 85°) local solar elevations are **not permitted**
- Image pairing constraint, **less than 35° illumination difference** between images

Longitude = 0° and 180 °



Longitude = 90° and 270 °



Couverture de la surface

BepiColombo Orbite nominale	
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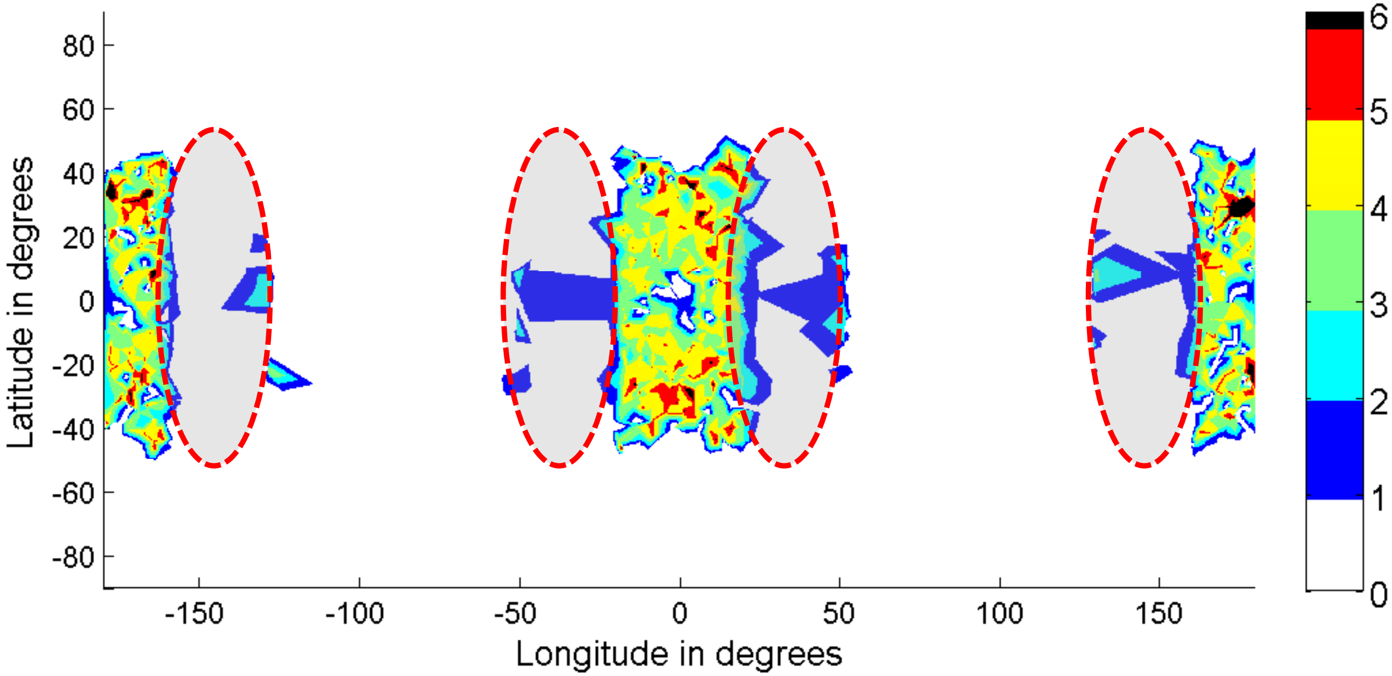
Inclinaison	90°
Dérive du péricentre	-33,9°/a

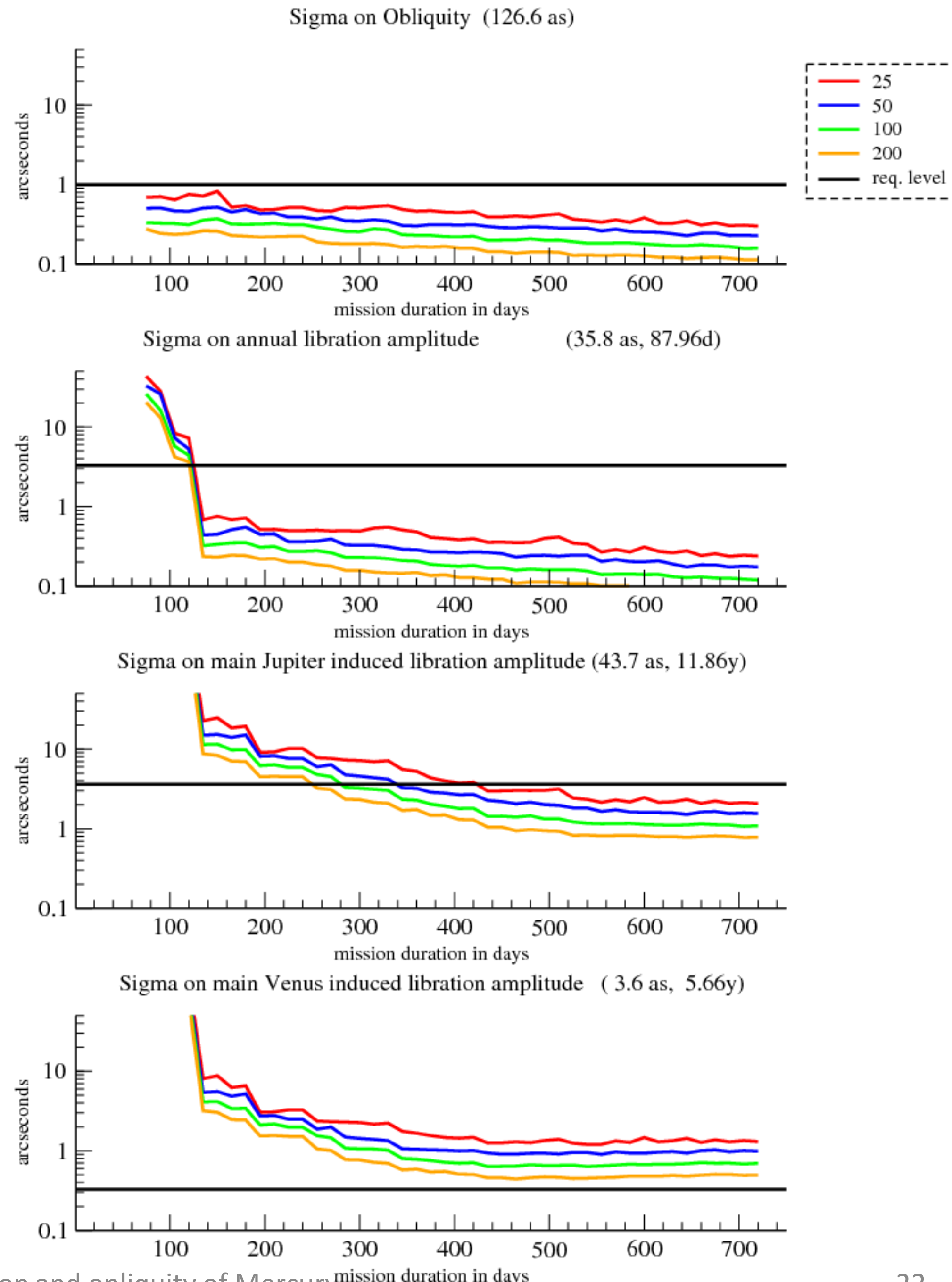


The blackout zones constrain the longitudinal distribution of possible image-pairs

Obliquity and libration determination

Formal errors as a function of the mission duration for different target numbers

1. Obliquity
2. Annual amplitude
3. « Jupiter » amplitude
4. « Vénus » amplitude



Obliquity and libration determination

Formal errors <u>as a function of the number of targets for different mission durations</u>

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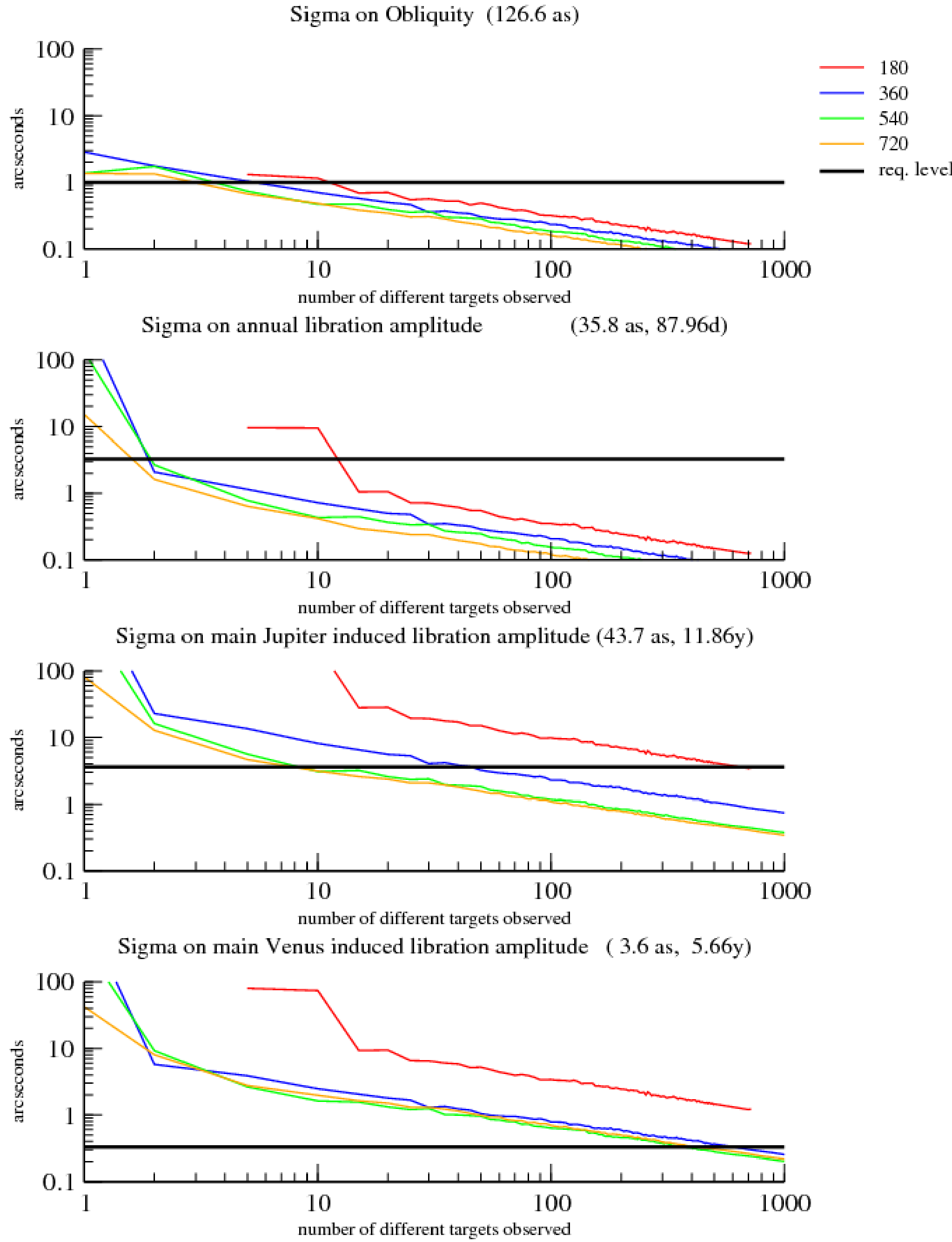

Conclusions

- After **360 days** we obtain a precision **< 1 arcsec** on the obliquity and annual amplitude that can constrain the liquid core radius to **< 30 km**
- The « Jupiter » induced amplitude **can be measured** with a *useful* precision for a **long** mission
- The « Venus » induced amplitude **cannot** be measured with sufficient precision

Acknowledgement

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BELGIAN SCIENCE POLICY

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