CONTRIBUTION OF MICROMETEOROID IMPACTS TO THE EXOSPHERES OF THE GALILEAN MOONS

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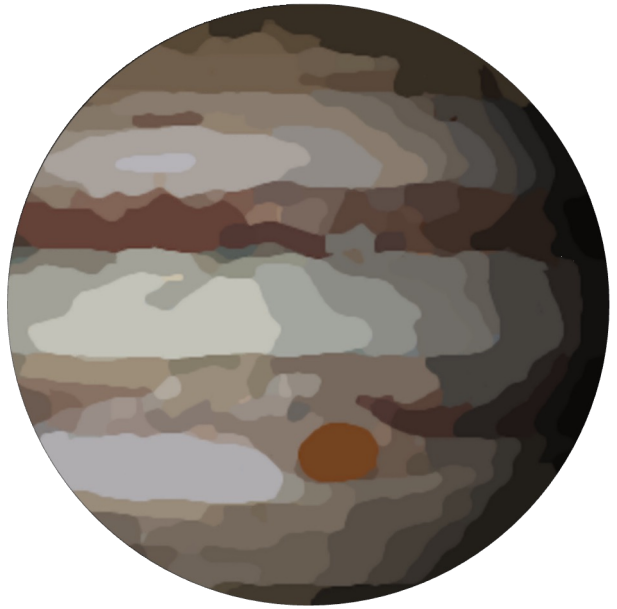
SCI Science Workshop
23-25 Jan 2024



BACKGROUND

2014-2017
Aerospace engineering degree

2017-2018
Space systems engineering advanced master

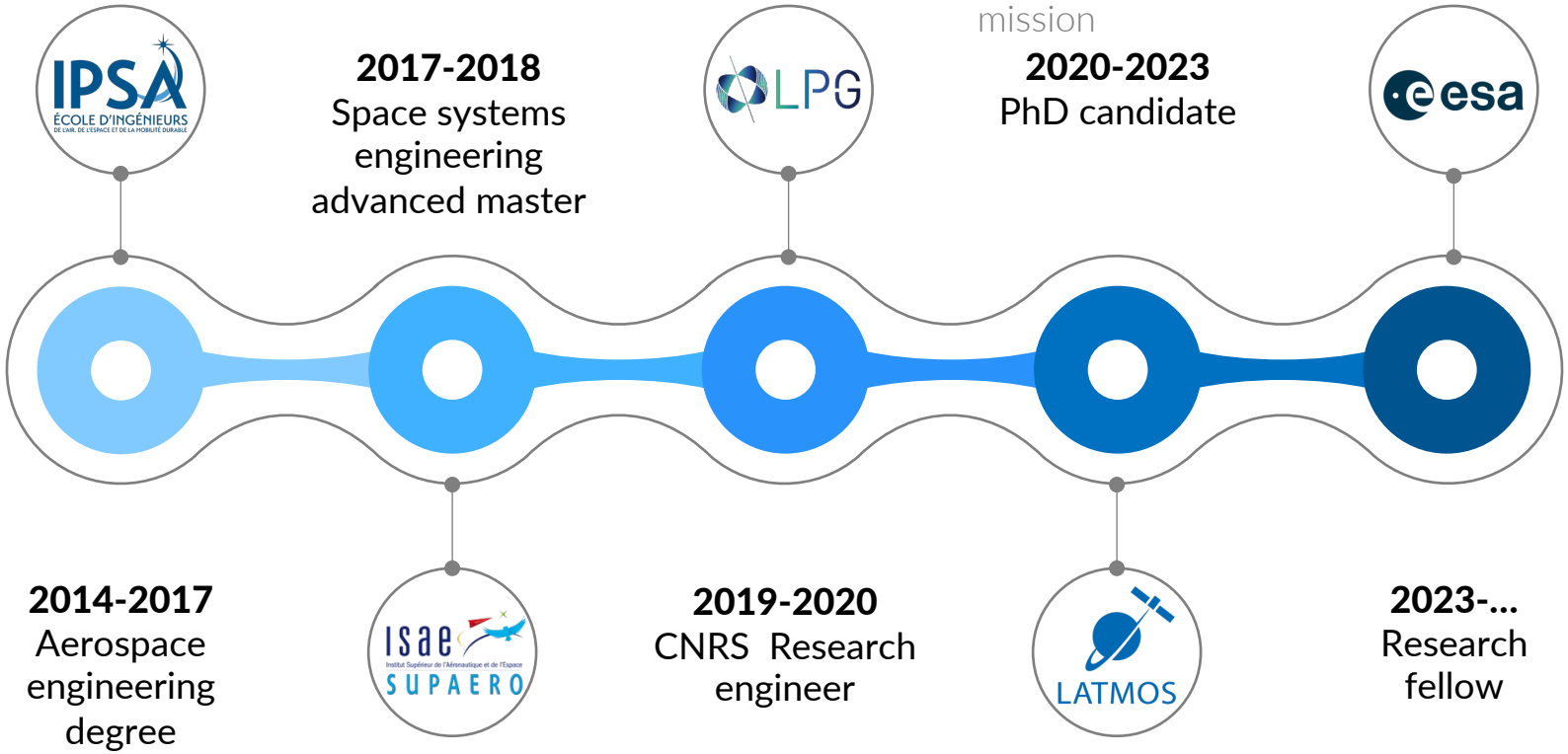
2019-2020
CNRS Research engineer

Study of the exosphere of Mercury with the PHEBUS spectrograph on the BepiColombo mission

2020-2023
PhD candidate

2023-...
Research fellow

Contribution of micrometeoroid impacts to the exosphere of the Galilean moons

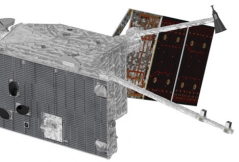


THE BEPICOLOMBO MISSION

Third mission to explore Mercury

JAXA-led spacecraft
Mercury Magnetospheric Orbiter
(**MMO**, or Mio)

Mio Sunshield and Interface Structure (**MOSIF**)



ESA-led spacecraft
Mercury Planetary Orbiter
(**MPO**, or Bepi)

Mercury Transfer Module
(**MTM**)

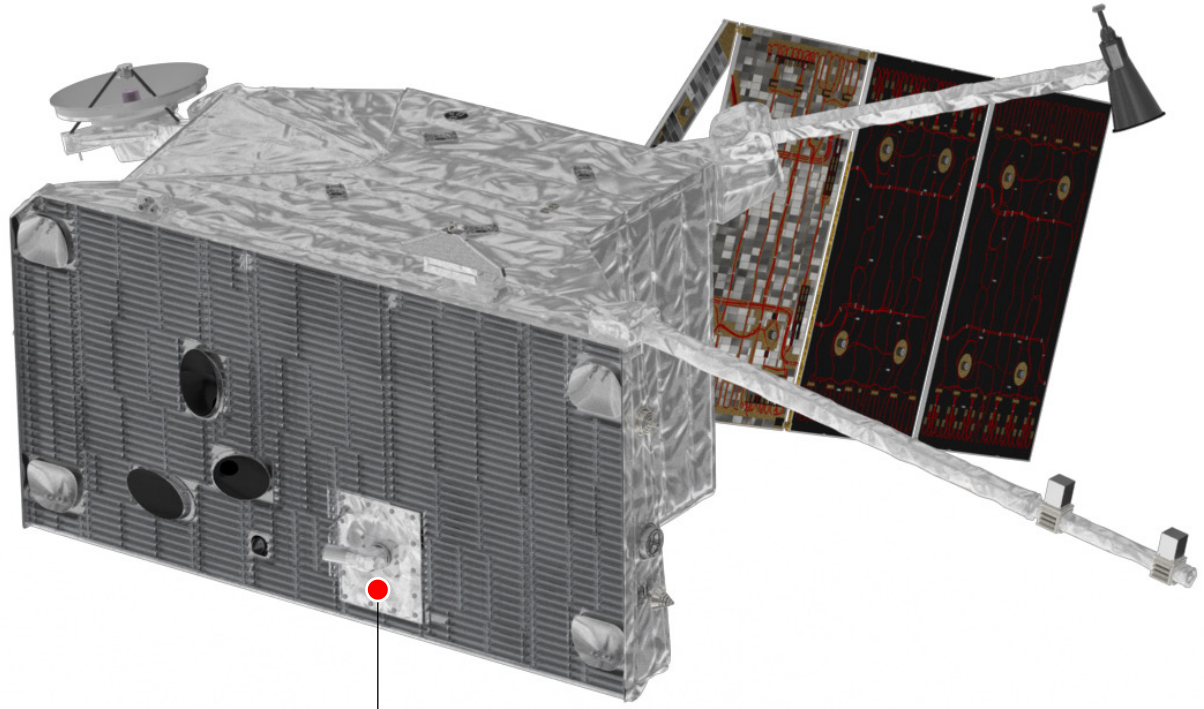
Credits: ESA/ATG medialab

THE PHEBUS SPECTROGRAPH

Stands for:
Probing of Hermean Exosphere By Ultraviolet Spectroscopy

Aims to:
Characterize Mercury's exosphere, its dynamics and composition but also its interactions with the surface and the solar wind

Is composed of:
Two UV detectors and two visible channels



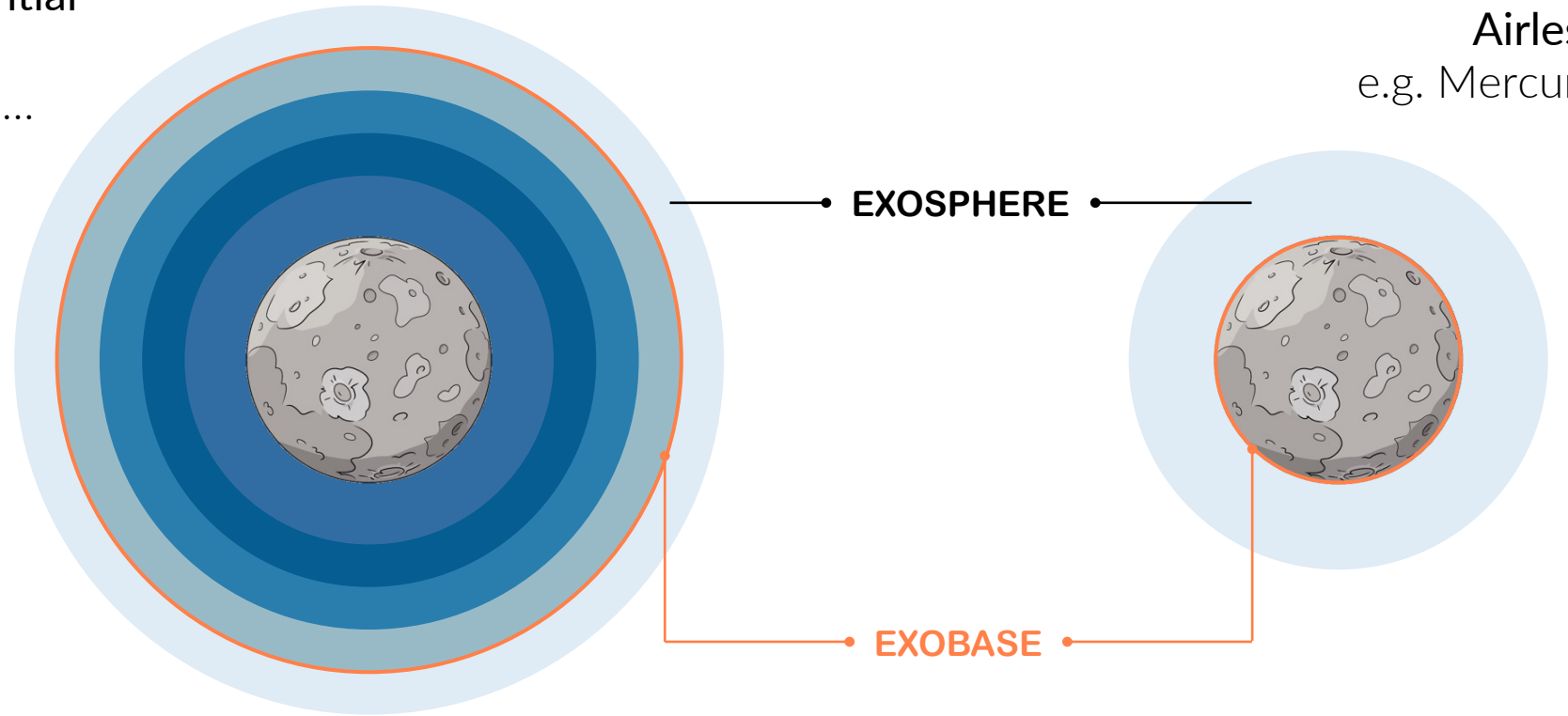
Credits: ESA/ATG medialab

THE EXOSPHERE OF MERCURY

Exosphere = thin collisionless atmosphere

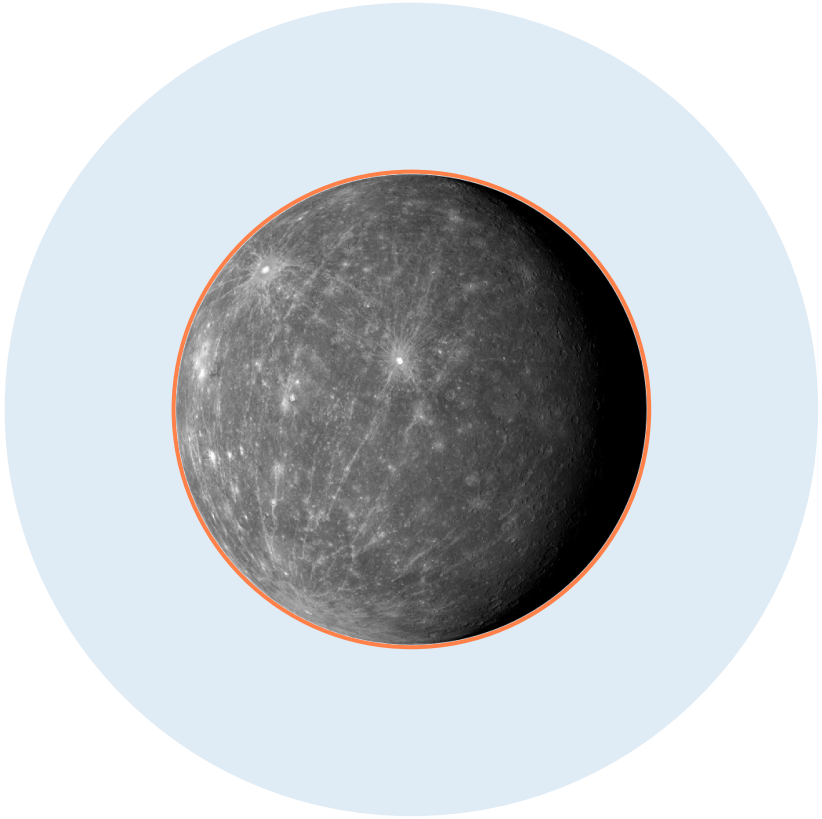
Bodies with substantial atmosphere
e.g. Earth, Venus …

Airless bodies
e.g. Mercury, the Moon …



THE EXOSPHERE OF MERCURY

Composition of Mercury's surface-bounded exosphere



- **He** Helium
- **H** Hydrogen
- **Na** Sodium
- **K** Potassium
- **Ca** Calcium
- **Mg** Magnesium
- **Al** Aluminum
- **Fe** Iron
- **Mn** Manganese

BEPICOLOMBO FLYBYS OF MERCURY

01
Time (UTC): 2021-10-01
Altitude: 200 km
TAA: 262.6°
Local time: 02:31:28

02
Time (UTC): 2022-06-23
Altitude: 200 km
TAA: 264.8°
Local time: 03:45:13

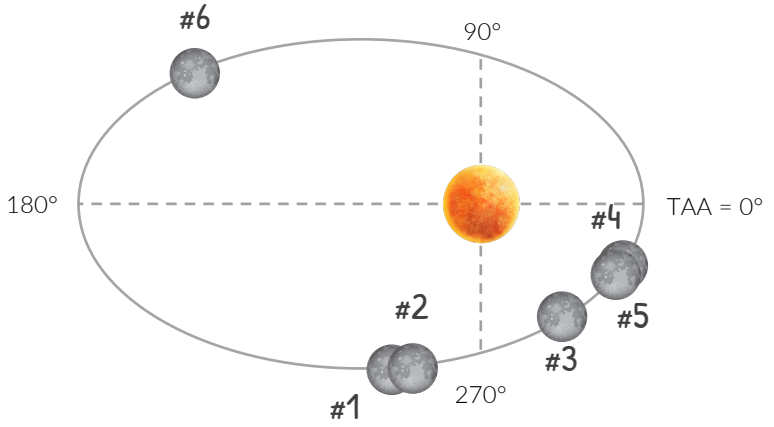
03
Time (UTC): 2023-06-19
Altitude: 235 km
TAA: 311.5°
Local time: 01:47:45

04
Time (UTC): 2024-09-05
Altitude: 200 km
TAA: 332.6°
Local time: 05:59:56

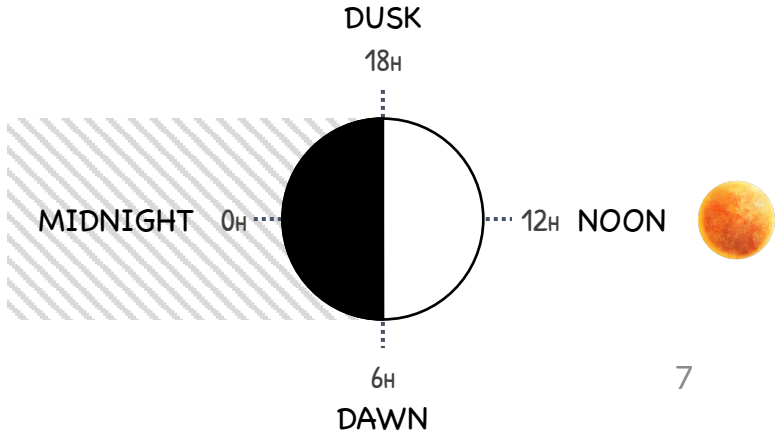
05
Time (UTC): 2024-12-01
Altitude: 40,000 km
TAA: 331.1°
Local time: 12:10:35

06
Time (UTC): 2025-01-09
Altitude: 385 km
TAA: 150.3°
Local time: 23:34:36

TRUE ANOMALY ANGLE (TAA)



LOCAL SOLAR TIME



PHEBUS OBSERVATIONS DURING THE FIRST THREE FLYBYS OF MERCURY

01
Time (UTC): 2021-10-01
Altitude: 200 km
TAA: 262.6°
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Altitude: 200 km
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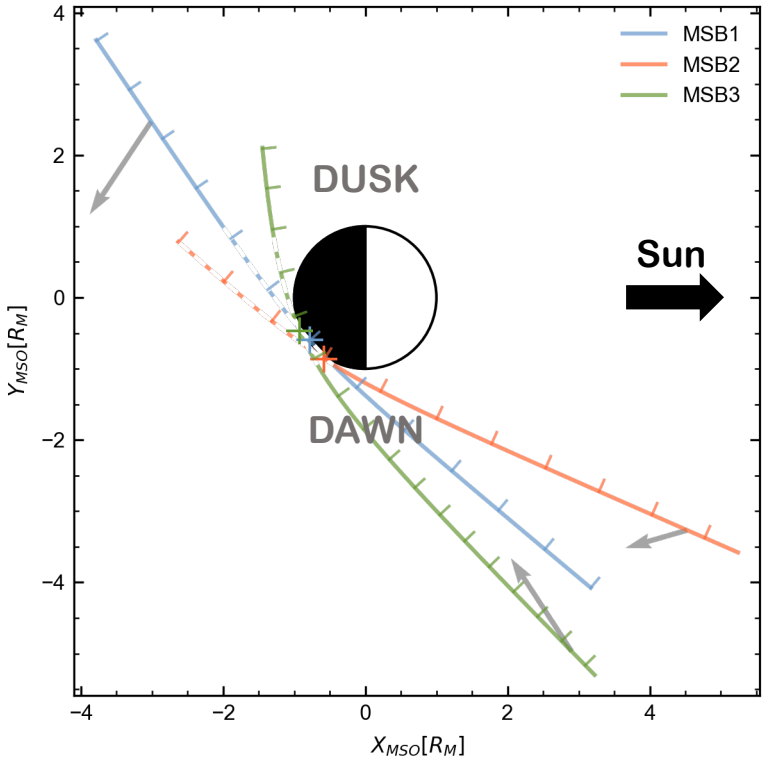
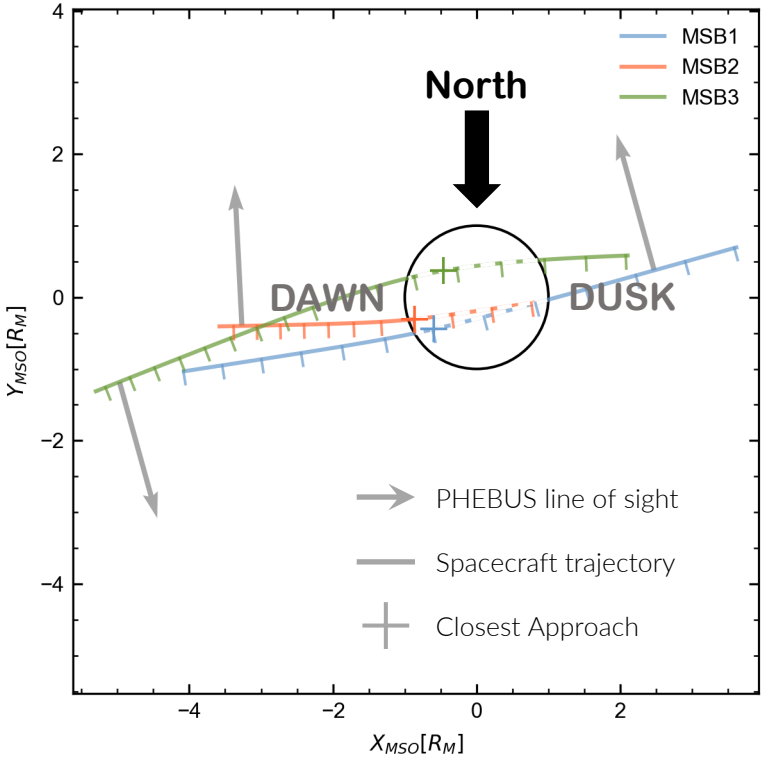




PHEBUS OBSERVATIONS WITH THE VISIBLE CHANNELS – MAIN RESULTS

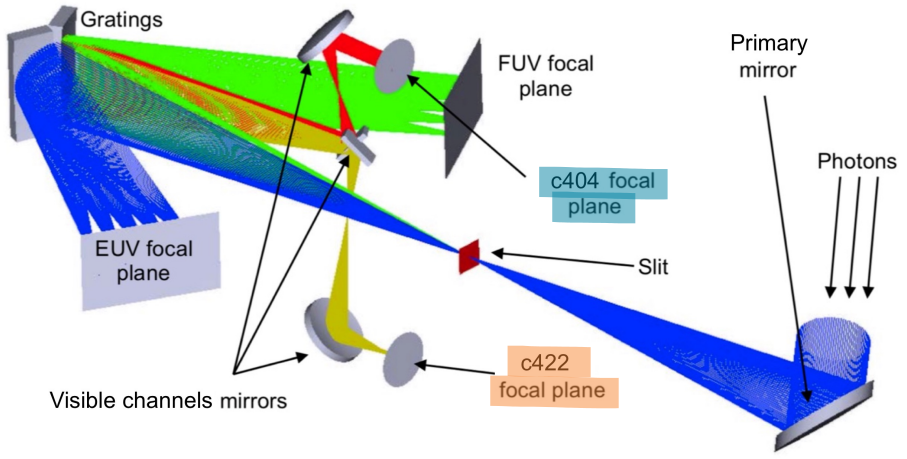
During the first three flybys, detection of:

Exospheric Ca with the c422 channel (centered at 422 nm, dedicated to the emission line of Ca at 422.8 nm)

- Enhanced near the **dawn** region
- **Extended** on the morning side (>10,000 km)
- Highly **energetic source** process

Additionnal species with the c404 channel (centered at 404 nm, dedicated to the emission line of K near 404 nm)

- Confined to the **predawn** region
- Potentially **Mn** (but does not correspond to MESSENGER TAA range of detection) or **K** (but MESSENGER never detected this emission line)



Robidel et al., 2023

PROCESSES ACTING AT AIRLESS PLANETARY BODIES

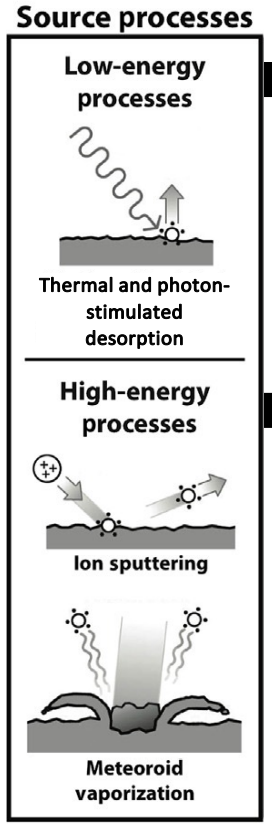
Primary **sources** that **generate exospheres** and **cause space weathering** on airless bodies:

Solar radiation

Charged particles

Micrometeoroids

PROCESSES ACTING AT AIRLESS PLANETARY BODIES



Volatile elements

Solar radiation

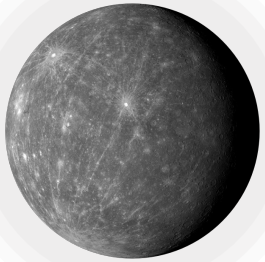
Refractory elements

Charged particles

Micrometeoroids

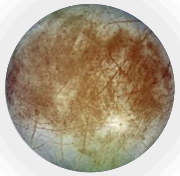
Source processes depend on:
- the elements (refractory vs. volatile)
- the environment (e.g. sputtering)

CALLISTO



MERCURY

GANYMEDE



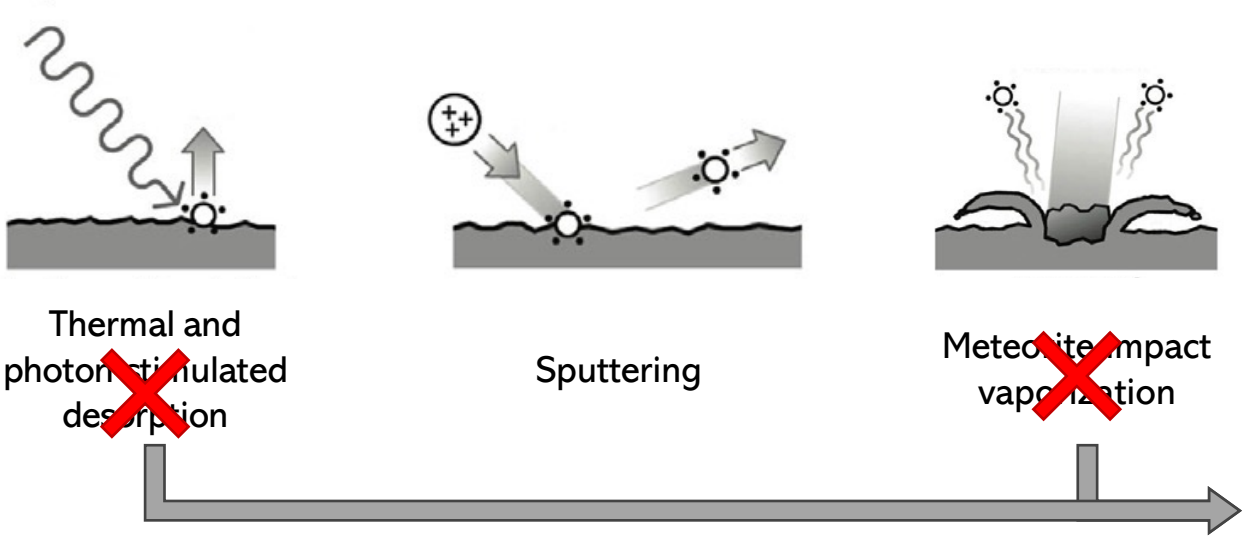
EUROPA

Solar wind ➤ Sputtering

Jovian plasma ➤ Sputtering

PROCESSES GENERATING GANYMEDE AND EUROPA'S EXOSPHERES

Dominated by **thermal processing** and **radiation bombardment**, with meteoroite bombardment playing a lesser role



Plainaki et al., 2010
Leblanc et al., 2017
Vorburger et al., 2024

BUT:
Meteoritic impacts participate in the space weathering of the surface materials

RESEARCH PROPOSAL

01

Meteoroid Impact Vaporization (MIV) currently not considered in Exospheric Global Model (EGM)

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02 Adapt the vaporization model used for Mercury to icy moons

Meteoritic source described with two mechanisms:

- Outgassing rate (clean source of exospheric material)
- Gardening rate (source of mixing of the regolith bringing fresh material to the surface)

RESEARCH PROPOSAL

01 Meteoroid Impact Vaporization (MIV) currently not considered in Exospheric Global Model (EGM)

02 Adapt the vaporization model used for Mercury to icy moons

03 Estimates based on models and measurements, extremely limited when it comes to icy surfaces

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01 Meteoroid Impact Vaporization (MIV) currently not considered in Exospheric Global Model (EGM)

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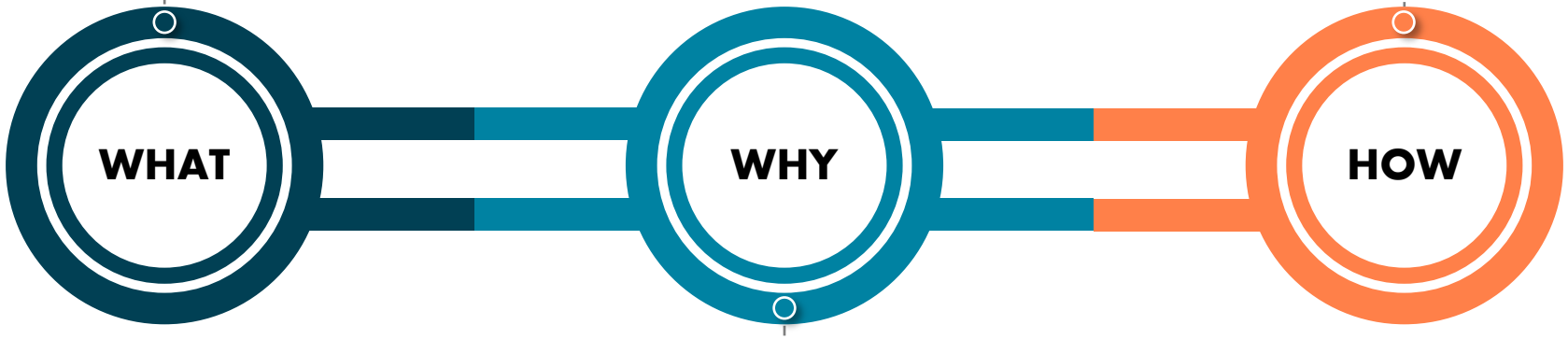
04 Micrometeoroid impact experiments on Jovian ices analogues in partnership with the University of Stuttgart (see poster N. Altobelli)

SUMMARY

Study of the contribution of dust hypervelocity impacts to the formation of the Galilean moons' exospheres

Theoretical + experimental models, adapting methods used for Mercury



Better constrain the exogenic alteration of the moons' surface
Characterize potential physical and chemical modification of the endogenic material