METHODS OF ANALYSIS FOR STEREO OBSERVATION OF PLANETARY SURFACES AND LIBRATIONS

Scuola di Dottorato in Scienze Tecnologie e Misure Spaziali (STMS)
Curriculum: Misure Meccaniche per l'Ingegneria e lo Spazio (MMIS)
Cicle XXXIV

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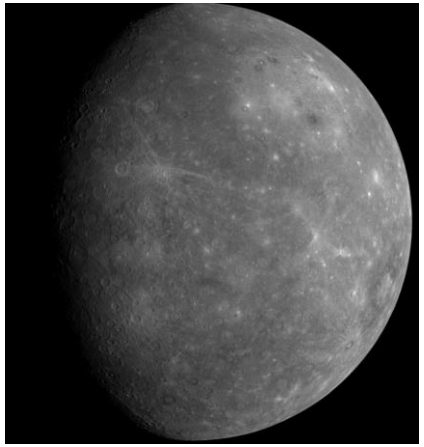
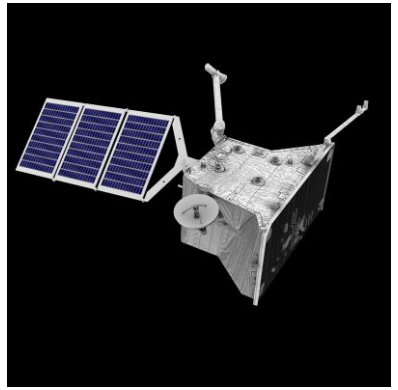
BepiColombo Mission

- **Collaboration between ESA and JAXA, launch 2018, arrival 2025**

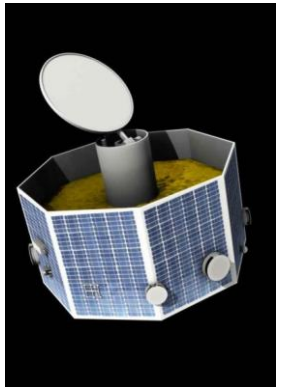
- **Scientific goal: exploration of Mercury**
  - Geology
  - Volcanism
  - Origin of the planet
  - Core of the planet
  - Magnetosphere

- **Two spacecraft:** Mercury Planetary Orbiter MPO (ESA)
  Mercury Magnetospheric Orbiter MMO (JAXA)





MPO

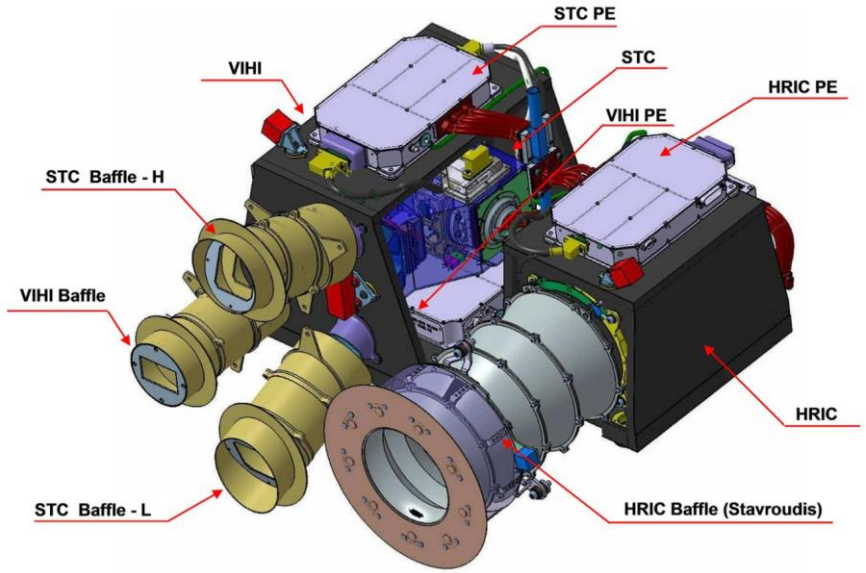


MMO

SIMBIO-SYS

Camera suite including three channels:

1. **High Resolution Imaging Camera (HRIC):** high resolution images (6.5 m/pixel) of more than 20% of the surface
2. **Stero Camera (STC):** mapping of the full surface in stereo mode with 60 m/pixel resolution
3. **Visual and Infrared Hyper-Spectral Imager (VIHI):** mapping the planet in visible and infra-red to provide a global mineralogical composition



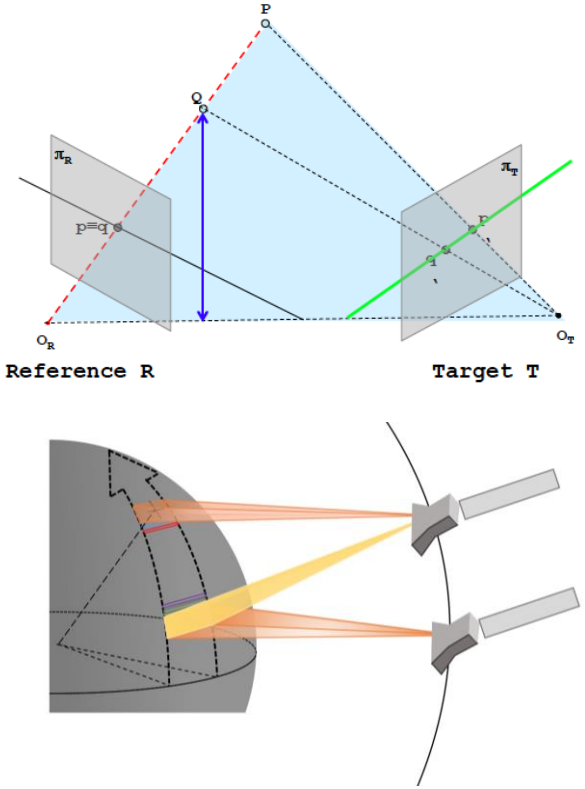
SIMBIO-SYS suite, PI: Gabriele Cremonese

Stereo Vision

Technique aimed at inferring depth from two or more cameras:

- **Un-distortion:** remove the lens distortions
- **Rectification:** obtain images row-aligned and rectified
- **Find correspondence:** find the same features in the left and right camera views, obtain a disparity map
- **Triangulation:** a depth map is calculated from the disparity map

Alternatively, it is possible to use the same camera from two different points



Concept of stereo acquisition with STC

TWO TASKS

Stereo images with HRIC

Find observation strategies to obtain stereo images

Creation of high resolution Digital Terrain Models

Integration of HRIC and STC acquisitions

Mission planning

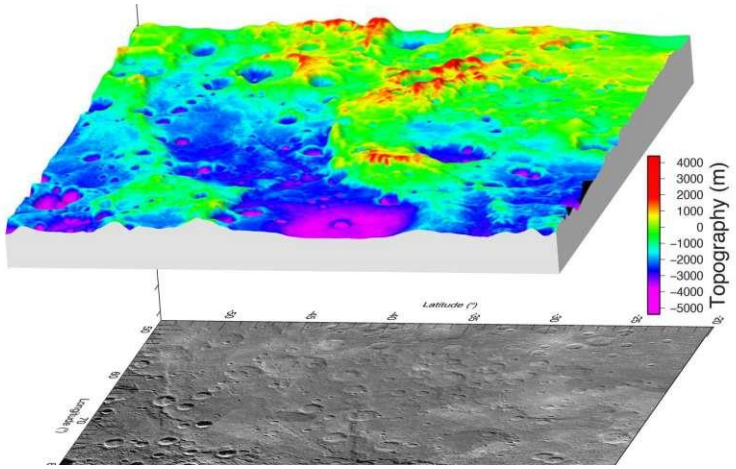
Identify observation strategy compatible with the mission's constraints

Investigation of the polar regions

Stereo images with HRIC

HRIC is nadir-pointing, but stereo images can be obtained rotating the spacecraft

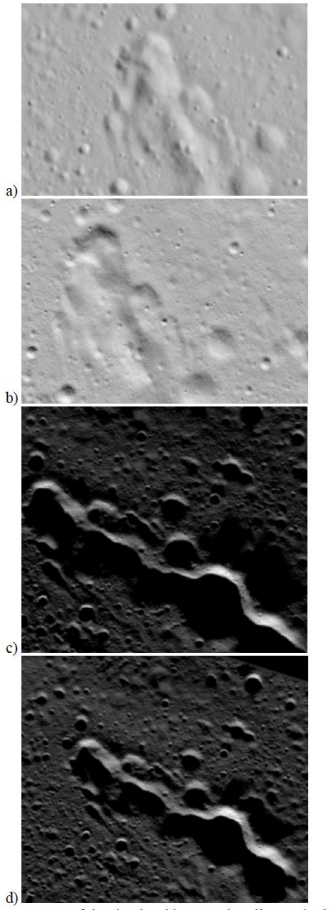
- Creation of DTM (Digital Terrain Model)
- Simulation of image acquisitions for this model (ray tracing)
- Evaluation of camera performances changing different parameters (illumination, altitude, light inclination, characteristics of the stereo pair…)



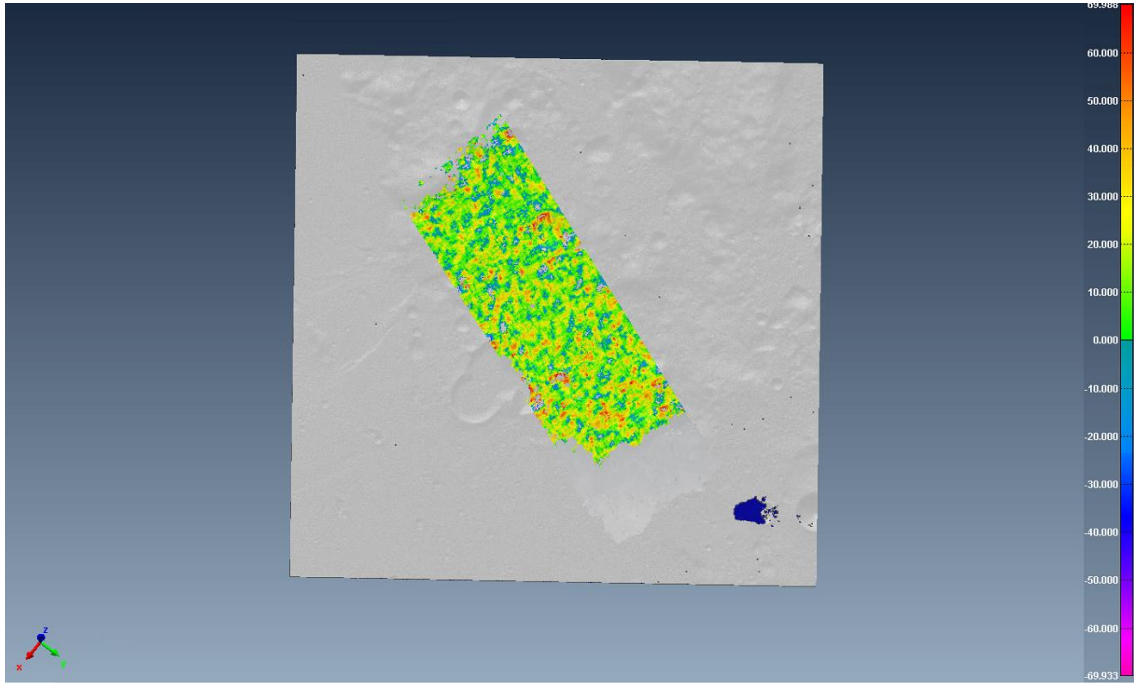
Planning the off-pointing angle for HRIC for stereo imaging

Reconstruction of high resolution DTMs using stereo technique

Results



Different synthetic images simulated with Surrender SW.
The images are taken at different latitudes under different illumination conditions.
High resolution DTMs of the Moon are used.



Comparison between the simulated DTM and the original DTM (ground truth)

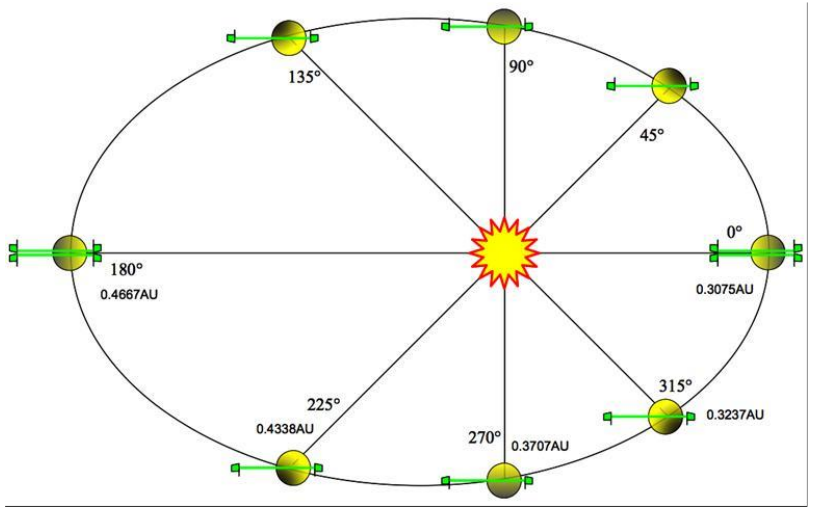
Mission planning

Different aspects to take into account:

- Orbits of the spacecraft
- Rotation of Mercury
- Revolution of Mercury
- Dayside/Nightside
- Temperature of the surface

Goal: find the optimal conditions for taking images (time, illumination, resolution, repeatability conditions…)

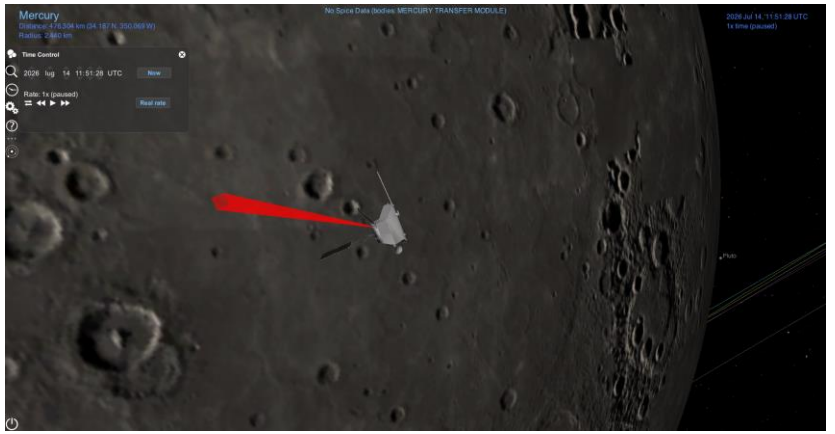
All these information can be stored and processed using the SPICE kernels



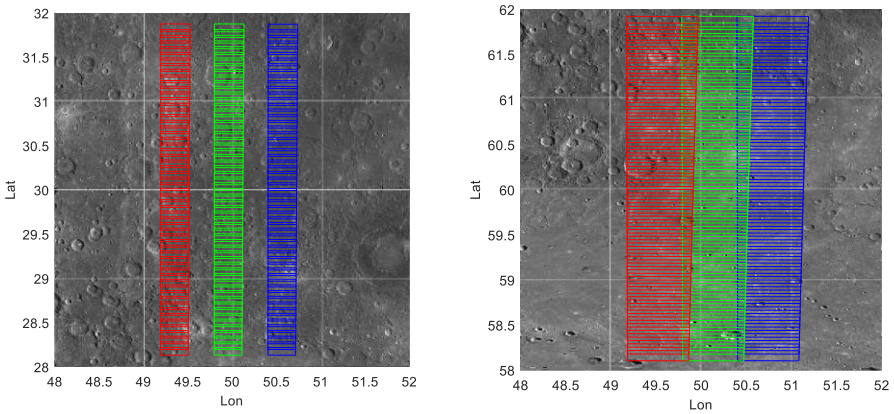
Orbit of MPO (green) around Mercury

Altitude < 600 km
Interval: 21/6/26 17:00 - 21/8/26 17:00
Coordinates: 30 < lat < 32; 8 < lon < 10
Sun inclination > 50°

```
resolution on ground [m/pixel] =            7.500
dimension of the image from this altitude [km] =           15.392
number of intervals useful for acquiring images:            7.000
orbit number:              1236
From : 2026 JUL 14 11:51:28.02 (TDB)
To   : 2026 JUL 14 11:51:57.39 (TDB)

vector: HRIC Boresight
  Planetocentric coordinates of the intercept (degrees):
     LAT =           30.175
     LON =            9.937
  Observer visible:  true
  Sun visible:       true

  Local Solar Time at boresight intercept (24 Hour Clock):
     09:30:53

vector: HRIC Boresight
  Planetocentric coordinates of the intercept (degrees):
     LAT =           31.884
     LON =            9.934
  Sun visible:       true

  Local Solar Time at boresight intercept (24 Hour Clock):
     09:30:52
```



Graphic visualization with Cosmographia4



Footprints of HRIC at different latitudes

Other tasks

- **Mosaicking:** write a code to mosaic different images of HRIC
  → different acquisitions of HRIC are mosaicked in a bigger image comparable to the size of the STC images
  → integration between HRIC and STC images to obtain DTM
- **Estimate of errors:** estimate the parameters and tolerances of the camera and the orbit for achieving the best image quality
  → Pointing errors
  → Thermal deformation
  → Calibration
- **Librations:** description of the phenomenon and its evaluation using high resolution DTM

Thank you for the attention

Questions?