In-flight calibration and performance verification of the Metis and STC instruments

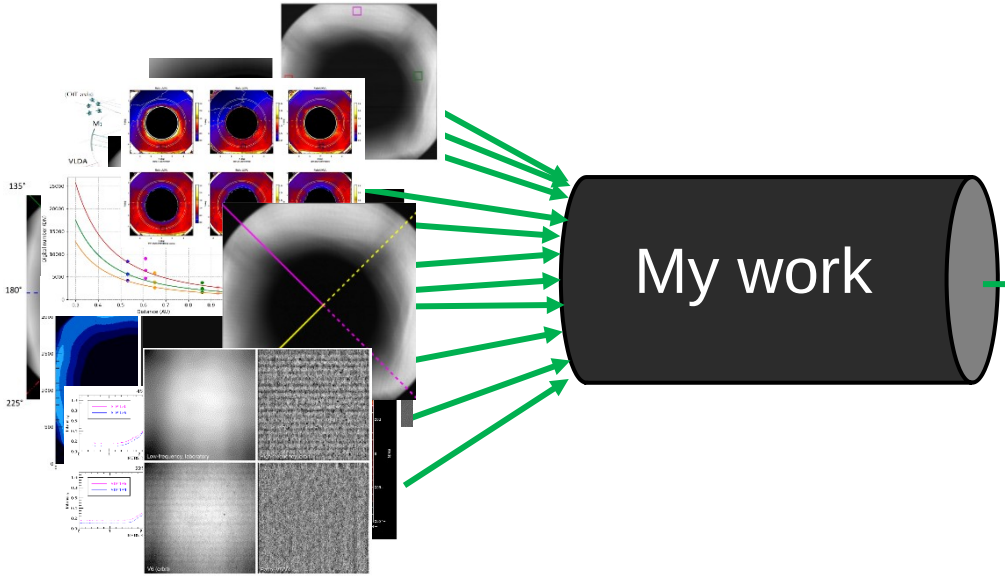
Chiara Casini - 36th Cycle

MEETING FOR THE ADMISSION TO THE SECOND YEAR

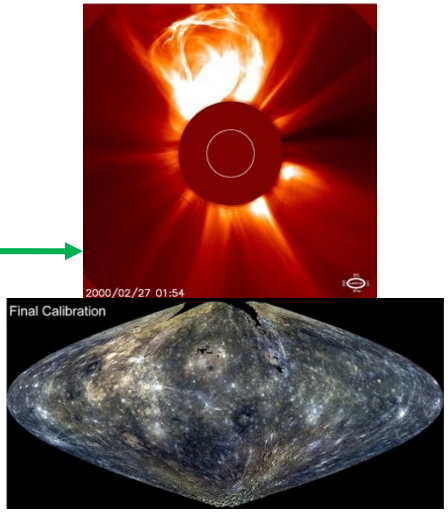
08/09/2021

Scientific Images Calibrations

SCIENCE???



SCIENCE???



YES

My PhD activity serves to acquire a deep and detailed knowledge of the Metis and STC instruments in one of the most critical and important phase of a space mission: it's essential to obtain scientific useful images.

https://www.researchgate.net/publication/321358296_Calibration_Projection_and_Final_Image_Products_of_MESSENGER's_Mercury_Dual_Imaging_System/figures

Metis of Solar Orbiter

Launch 09/02/2020 | **06/2020** | **11/2021** | **01/2026** | **2030**

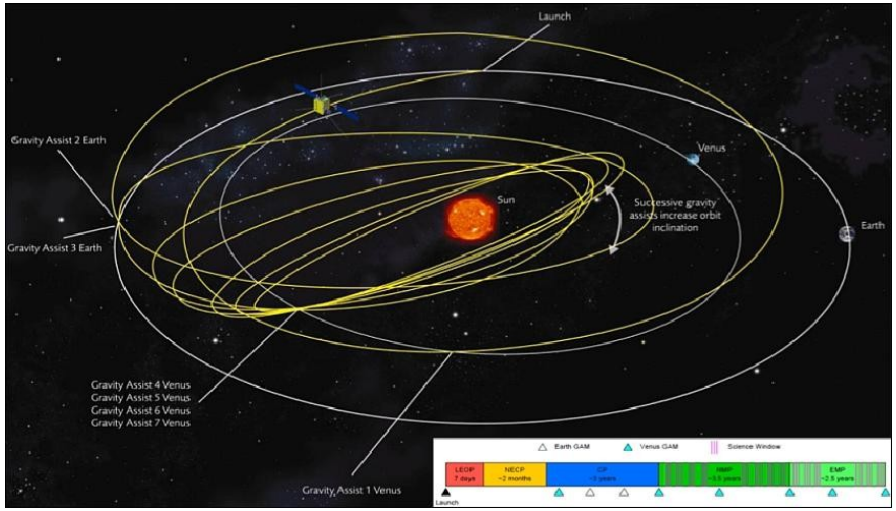
Mission phases

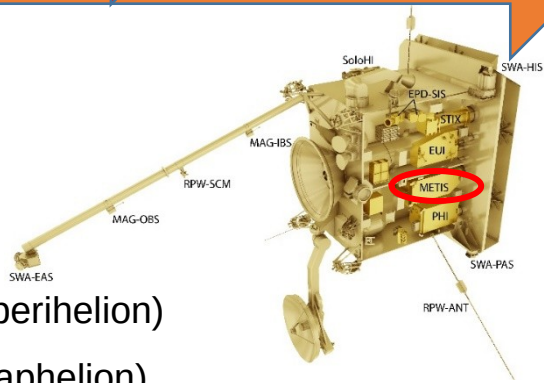
Commissioning

Cruise

Nominal

Extended mission time





ORBIT:

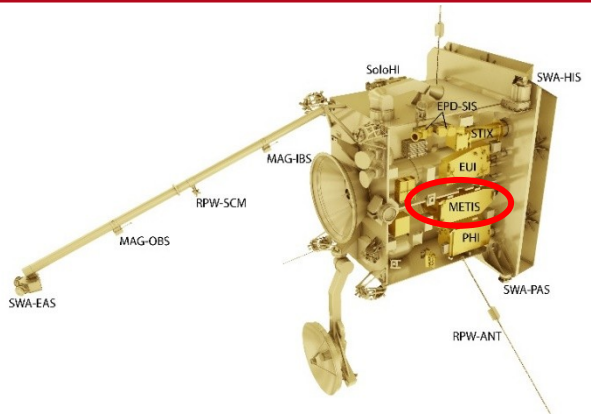
0.28 – 0.32 AU (perihelion)

0.74 -- 0.91 AU (aphelion)

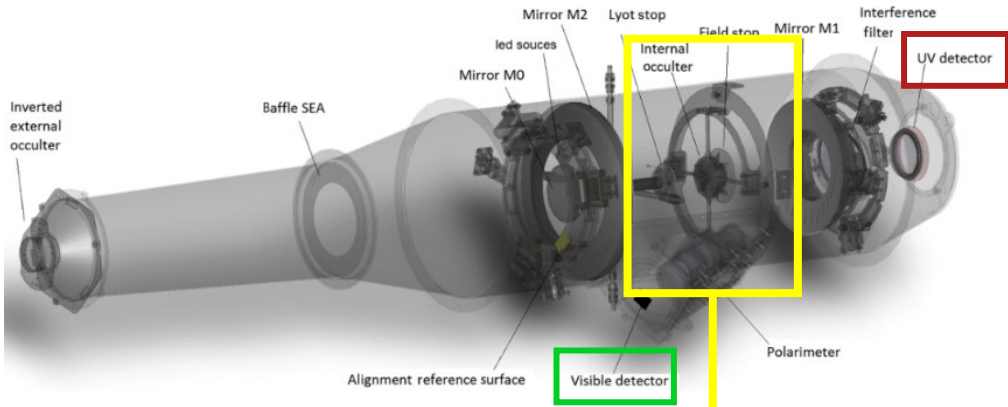
Out-of-ecliptic view:
Multiple gravity assists with Venus to increase inclination out of the ecliptic to :
>24°(nominal mission);
>34°(extended mission)

Antonucci, E. et al. Metis: the Solar Orbiter visible light and ultraviolet coronal imager

Metis of Solar Orbiter



1024 x 1024 pixels



2048 x 2048 pixels

Full Imaging of the corona (1.7 - 9 $R_{\odot}$):

- UV (121.6±10 nm)
- visible light (580-640nm) in total and polarized brightness

Spatial resolution and detector exposure time can change based on the science goal.

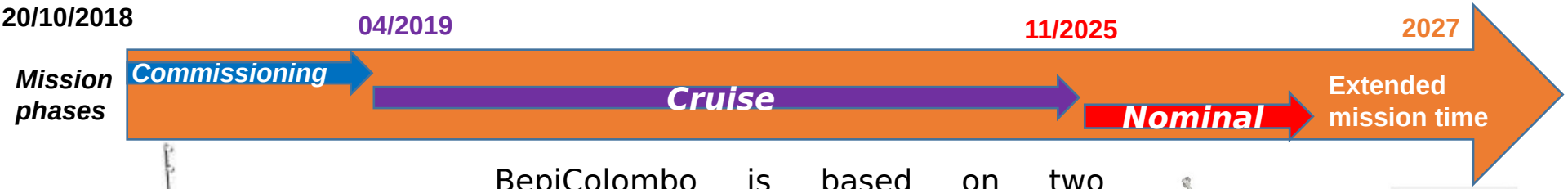
The Internal Occulter (IO) is extremely important to minimize the straylight.

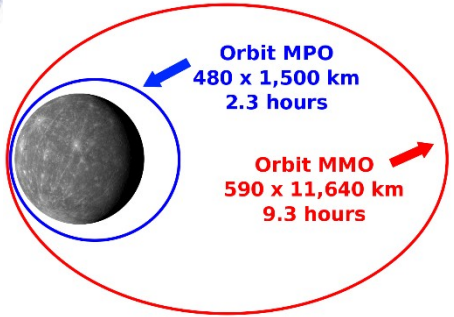
Antonucci, E. et al. Metis: the Solar Orbiter visible light and ultraviolet coronal imager

STC of BepiColombo

Launch BepiColombo

20/10/2018





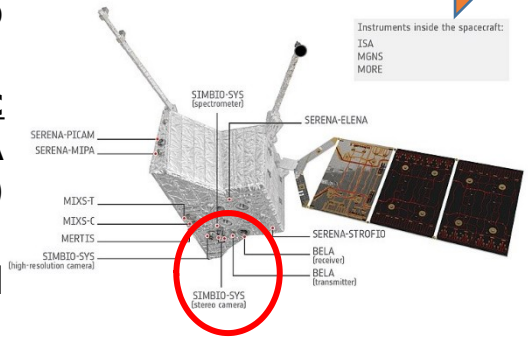
BepiColombo is based on two spacecraft:

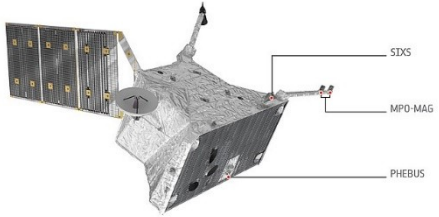
- **Mercury Magnetospheric Orbiter** (MMO) realized by the JAXA
- **Mercury Planetary Orbiter** (MPO) realized by the ESA.

MPO study: surface, exosphere and internal composition of the planet.

- ✓ Periherm and apoherm [480 km, 1500 km].
- ✓ Orbital period of 2.3 hours.

MPO accommodates 11 instruments including SIMBIO-SYS where STC is included.



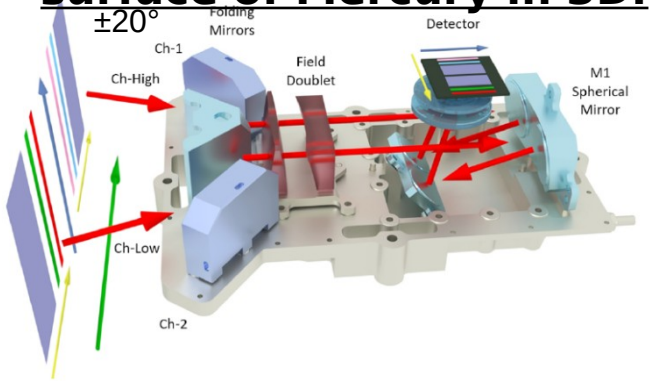


G. Cremonese et al. SIMBIO-SYS: Scientific Cameras and Spectrometer for the

SIMBIO-SYS is composed by:

- **HRIC** (High Resoultion Channel) the goal is the characterization of special surface targets with high resolution:
- **400-900 nm** spectral range
- **6m/px** Spatial resolution (at the best)
- **VIHI** (Visible Infrared Hyperspectral Imaging): the goal is to map the planet in order to provide the global mineralogical composition of the surface:
- **400-2000 nm** spectral range.
- **120 m/px – 480 m/px** spatial resolution
- **STC** (STereo Channel) is a double wide angle camera:
  - **410-930 nm** spectral range (2 panchromatics filters and 4 broad-band filters)
  - Total FoV **5.38° x 3.2°** (5.38° x 2.31° - 5.38° x 0.38°)
  - **58 m/px** Spatial resolution (at best)

STC main scientific objective is the global mapping of the entire surface of Mercury in 3D.

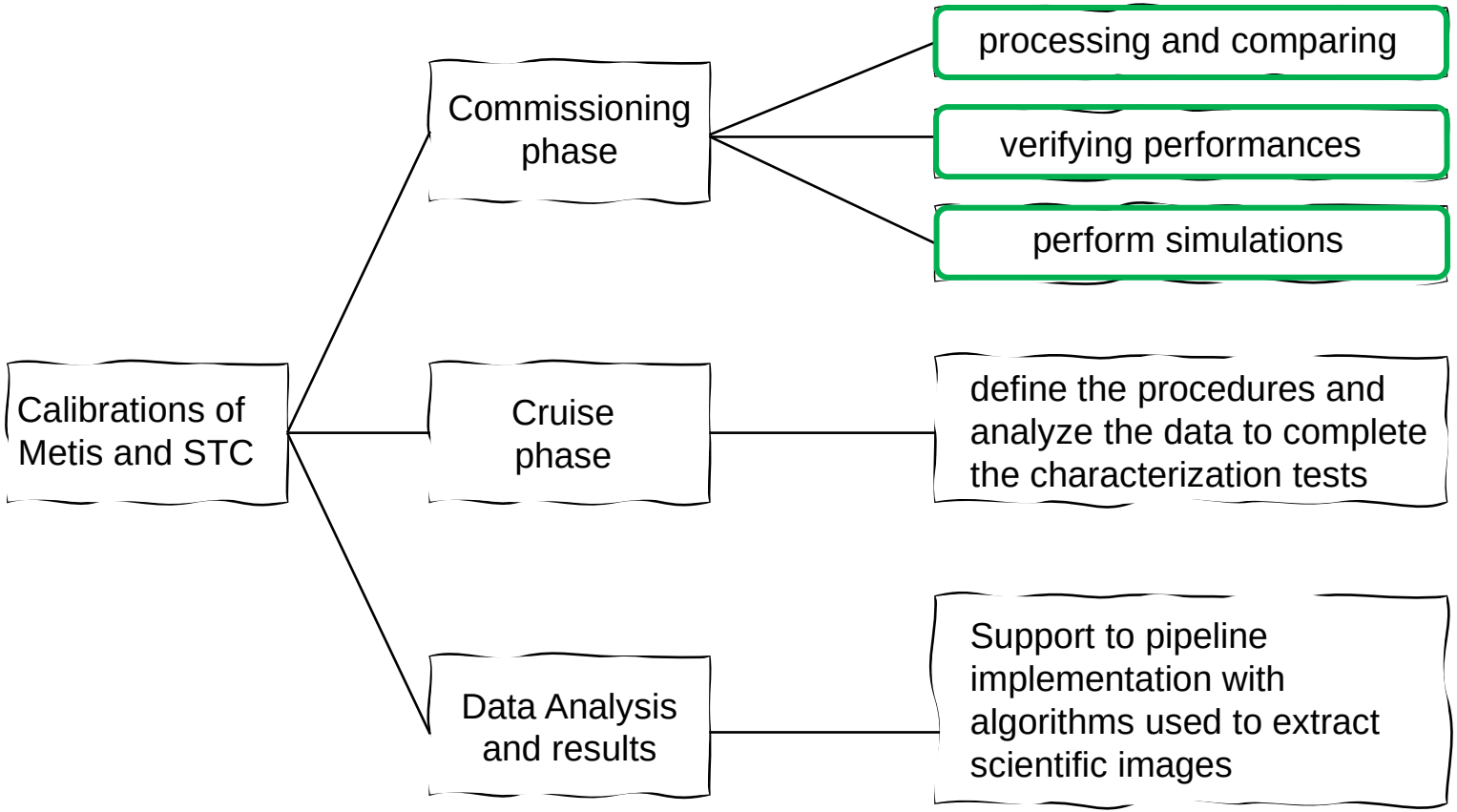


The STC camera is able to reach the goal thanks to the two sub-channels: High (H) and Low (L).

- a front unit, which consists of two independent fore-optics modules, one for each subchannel;
- a common telescope unit (off-axis modified Schmidt)

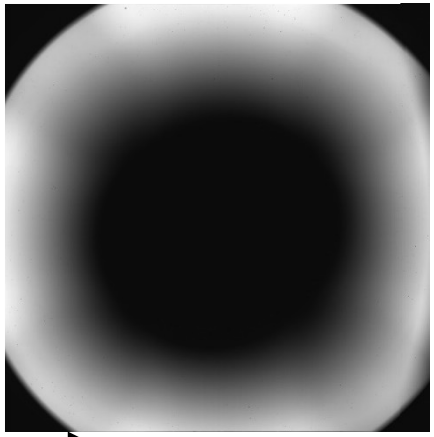
G. Cremonese et al. SIMBIO-SYS: Scientific Cameras and Spectrometer for the

Map of the project

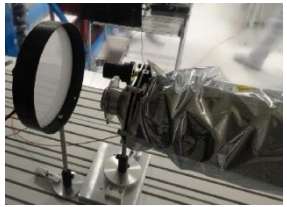


PROCESSED AND COMPARED

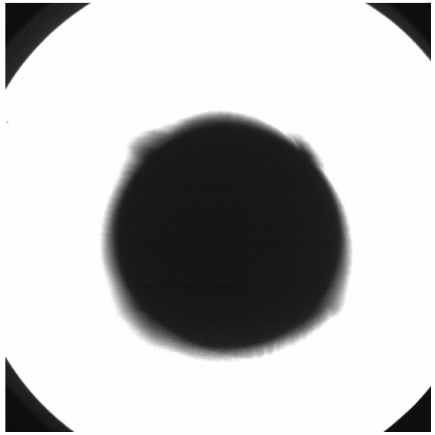
On ground



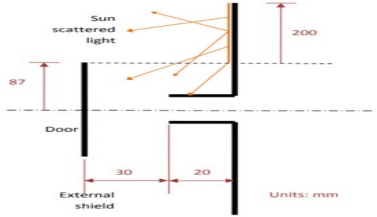
t_{exp}=100s



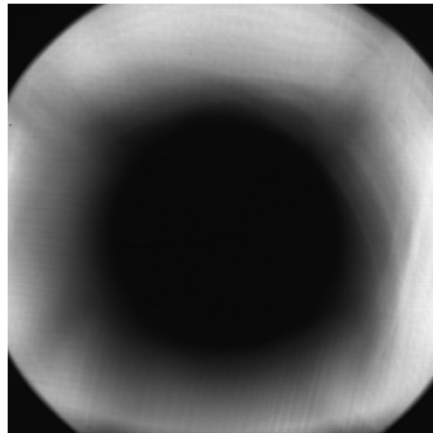
IT6-B2 (in flight)



t_{exp}=20s



STP-136 (in flight)

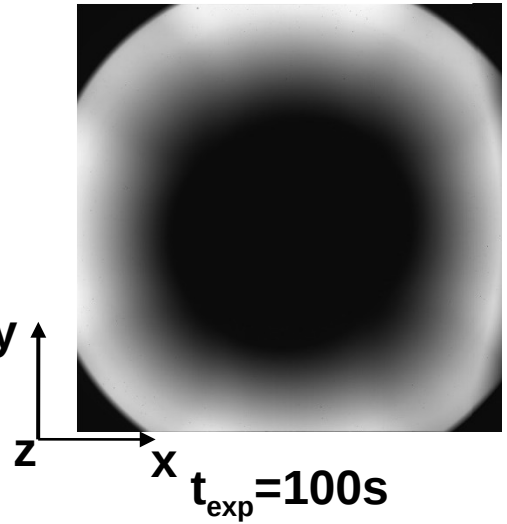


t_{exp}=1s

The light of the sun is reflected by the shield and, a portion is reflected towards the door. This reflected light behaves as a flat field panel.

PROCESSED AND COMPARED

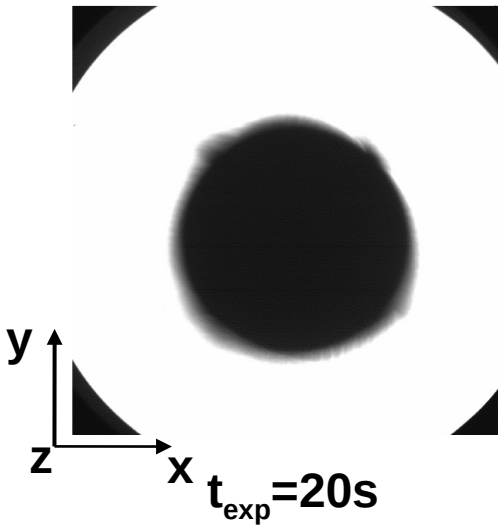
On ground



t_{exp}=100s

Internal (px) x=1008 y=1060

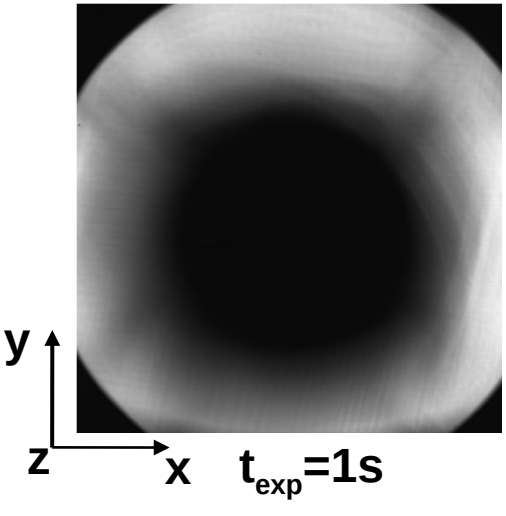
IT6-B2 (in flight)



t_{exp}=20s

Internal (px) x=971 y=1001

STP-136 (in flight)



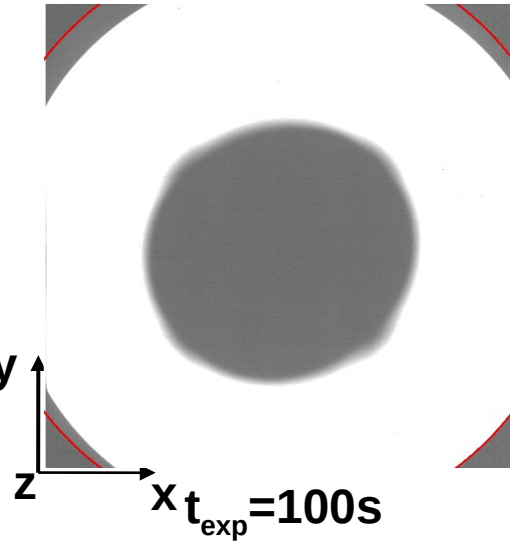
t_{exp}=1s

Internal (px) x=979 y=1008

The centre of the image is changed because we move the IO to minimize the straylight

PROCESSED AND COMPARED

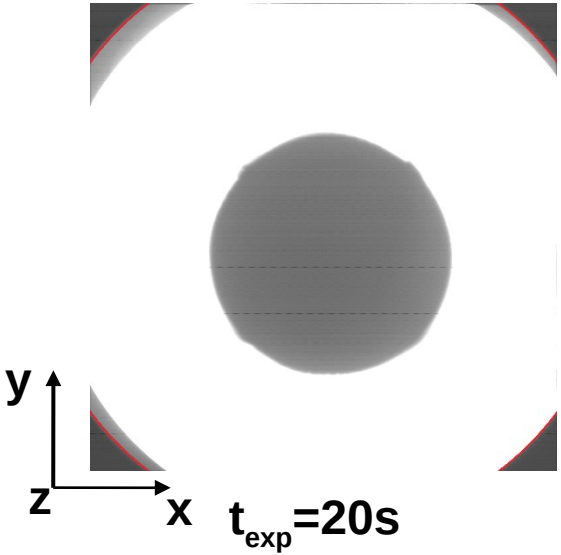
On ground



t_{exp}=100s

External (px) x=1024 y=1024

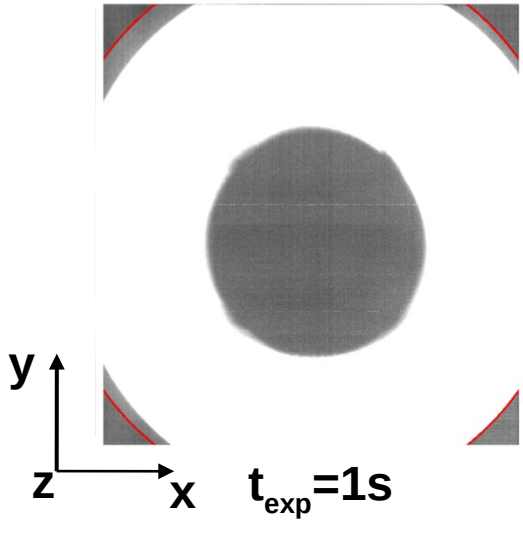
IT6-B2



t_{exp}=20s

External (px) x=1024 y=1024

STP-136



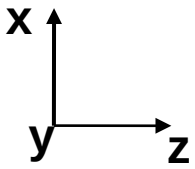
t_{exp}=1s

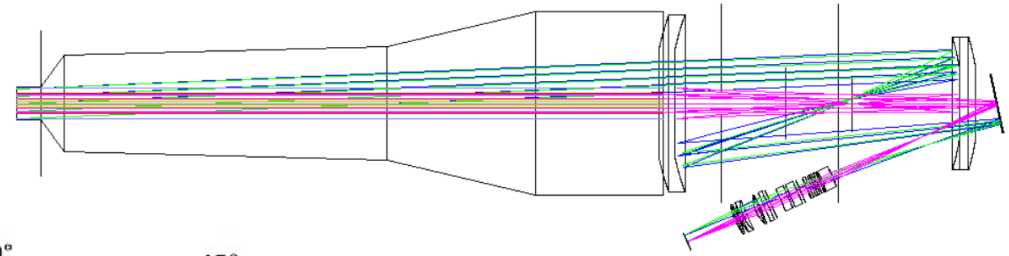
External (px) x=1024 y=1024

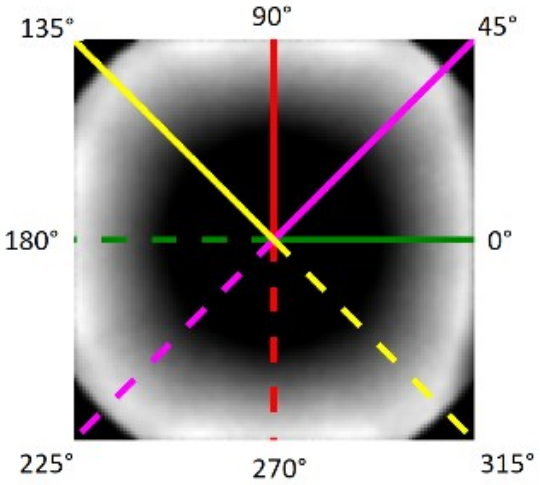
The external mask remain fixed during the launch

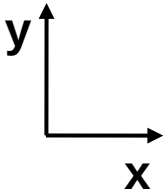
PERFORMED SIMULATIONS 1

Simulated Metis image with Zemax

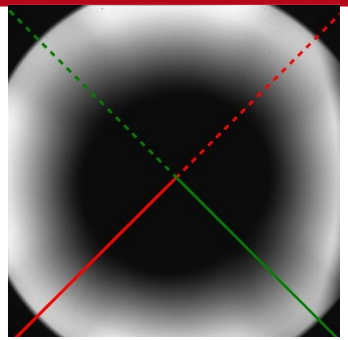








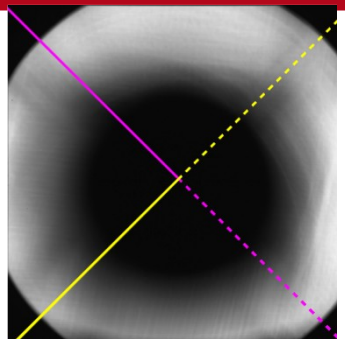
The coloured lines are the angles
that we take into account.



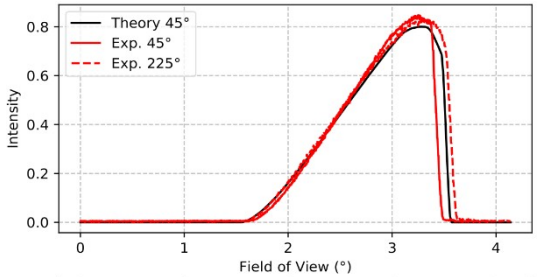
On ground
t_{exp}=100s

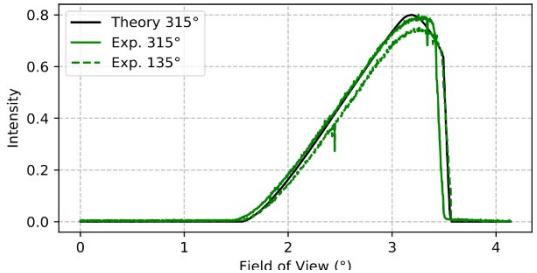
Vignetting:

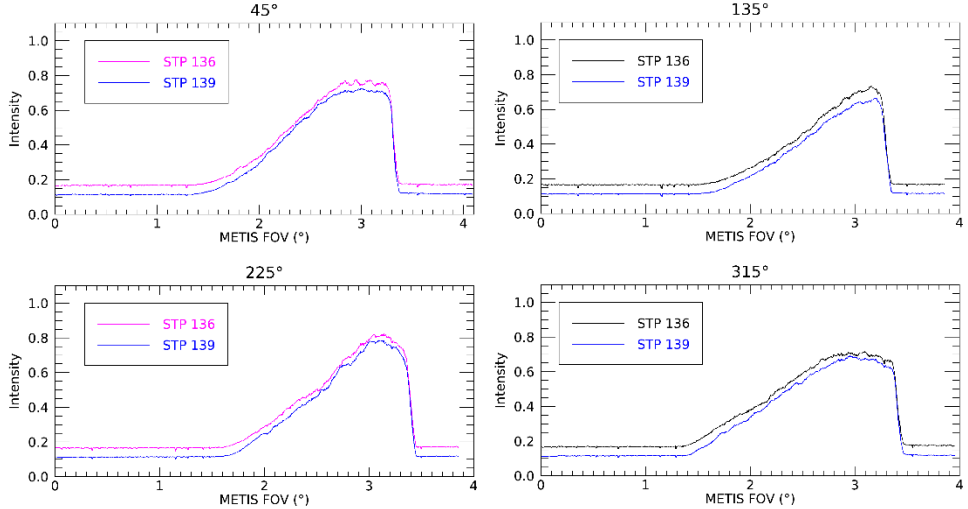
the darkening from the centre to the border



STP 136 @ 0,53 AU
STP 139 @ 0,65 AU
t_{exn}=1s



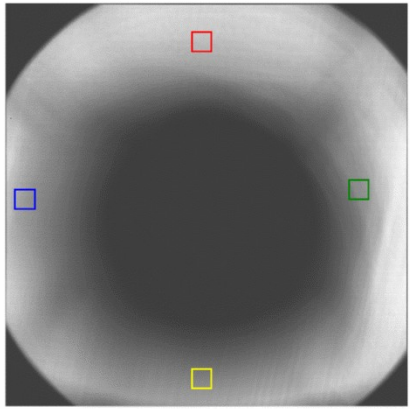




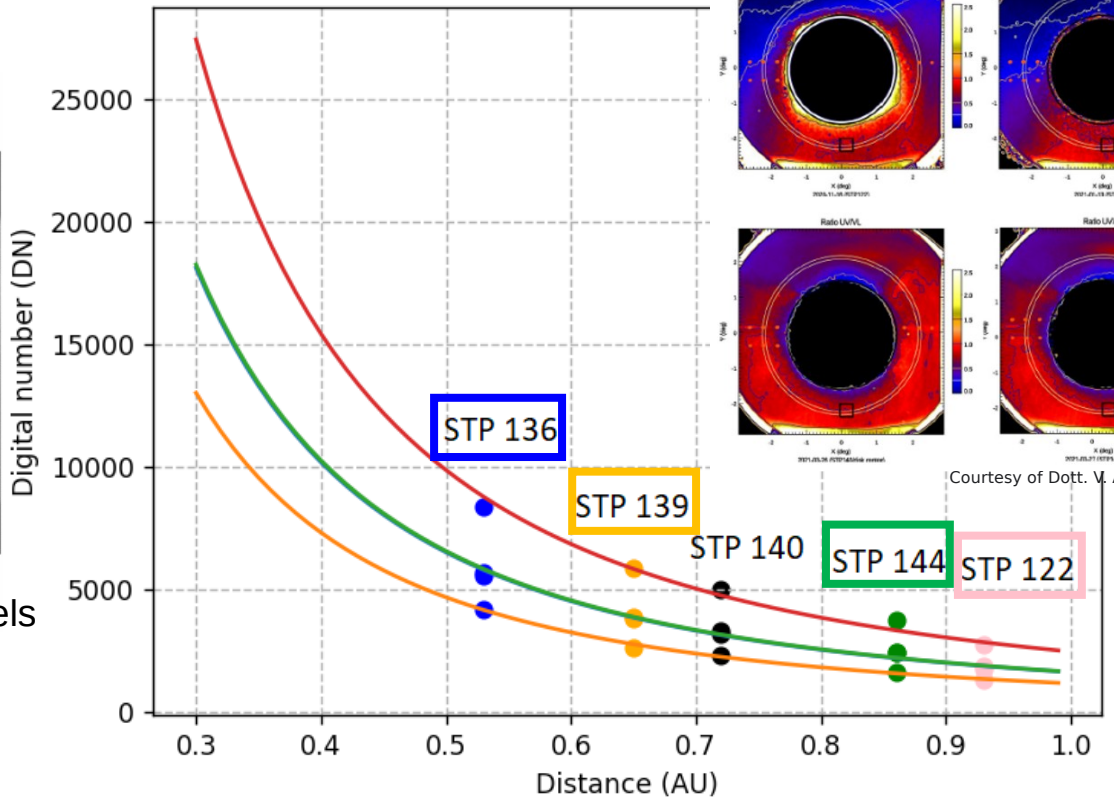
We can not use this image as flat field image

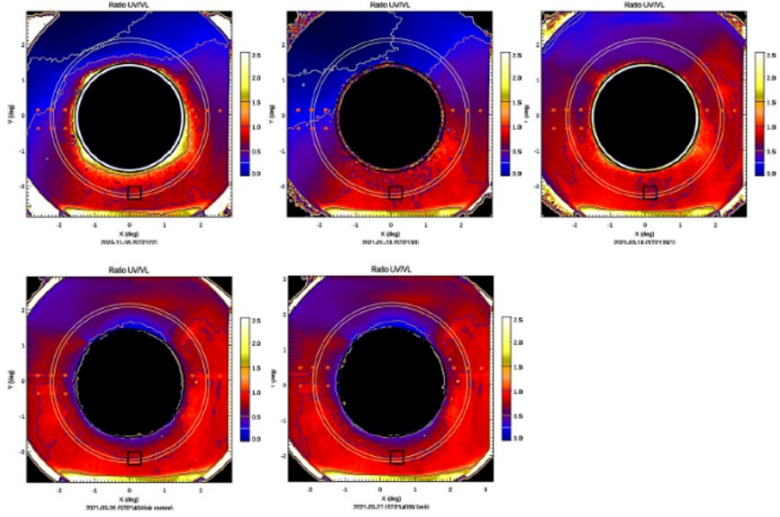
VERIFIED PERFORMANCES

5 images at 5 different Astronomical distances



Boxes of 100 x 100 pixels
in the visible channel
4 fitting curves.





Courtesy of Dott. V. Andretta UV/VL ratio: door back-illumination and

$\alpha \frac{1}{r^2}$ VERIFIED

PERFORMED SIMULATIONS 3

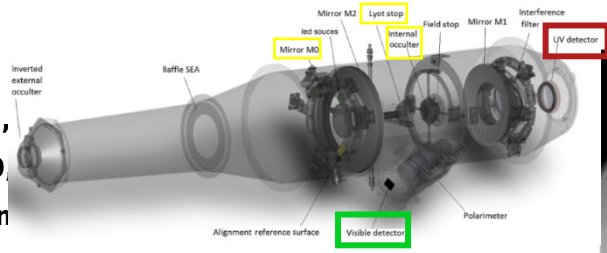
M0: 0,001- 0,01-0,1 mm

LS: 0,001- 0,01-0,1 mm

Spider IO: 0,001- 0,01-0,

Spider LS: 0,001- 0,01-0,

Spider IO + LS: + 0,1 mm

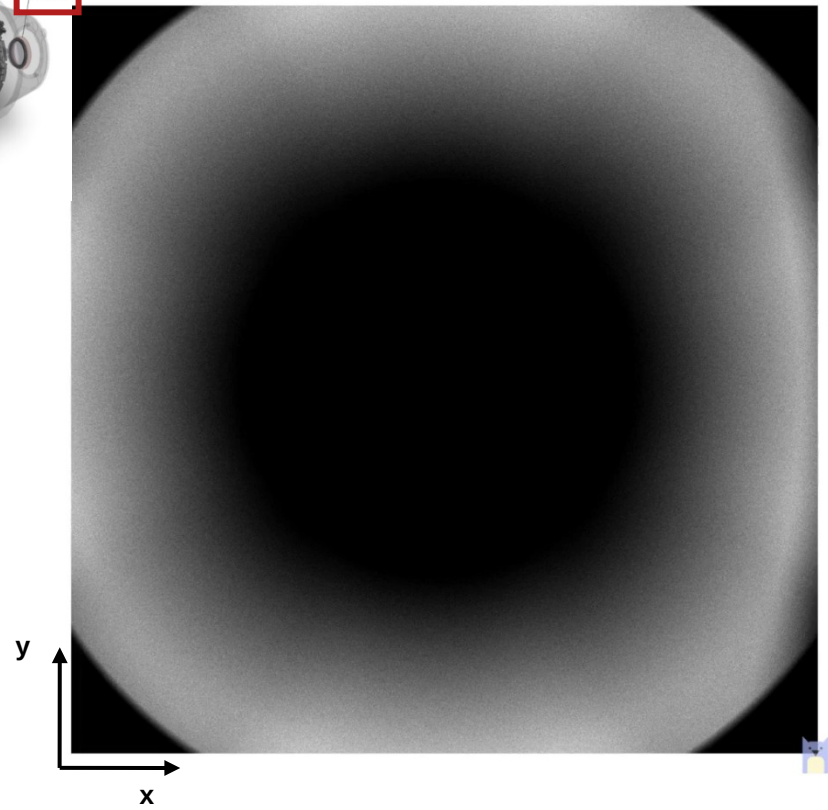


IO:

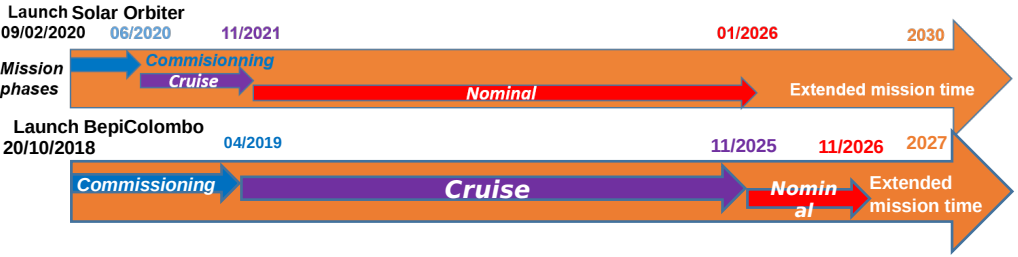
X(Mm)	Y(Mm)	X(pixel) ±1	Y(pixel) ±1
0	0	1023	1024
-0,06	0	1020	1024
-0.06	0.06	1020	1020
-0.06	0.12	1020	1017
-0.06	0.24	1020	1013
-0,12	0	1017	1024
-0,24	0	1013	1024

X: -0,06 mm ⟶ 4 px

Y: 0,06 mm ⟶ 4 px



Conclusions



WBS NUMBER	TASK TITLE	FIRST YEAR												SECOND YEAR												THIRD YEAR											
		T1			T2			T3			T4			T1			T2			T3			T4			T1			T2			T3			T4		
		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1	Commissioning phase																																				
1,1	Review of state of the art of the Metis and STC																																				
1.2	Calibration activities: comparison with on ground results																																				
1.3	Optical performances																																				
2	Cruise Phase																																				
2,1	Calibration sequence planning																																				
2.2	Performances validation																																				
2.3	Straylight																																				
3	Data Analysis and results																																				
3.1	Calibration input for the pipeline																																				
3.2	Support to pipeline implementation																																				
4	Phd Thesis Writing																																				
...	...																																				

Thanks for the attention

UNIVERSITÀ DEGLI STUDI DI PADOVA