On-flight calibration and instrument performance assessment of the BepiColombo/PHEBUS UV spectrometer based on Venus observations

Rozenn ROBIDEL

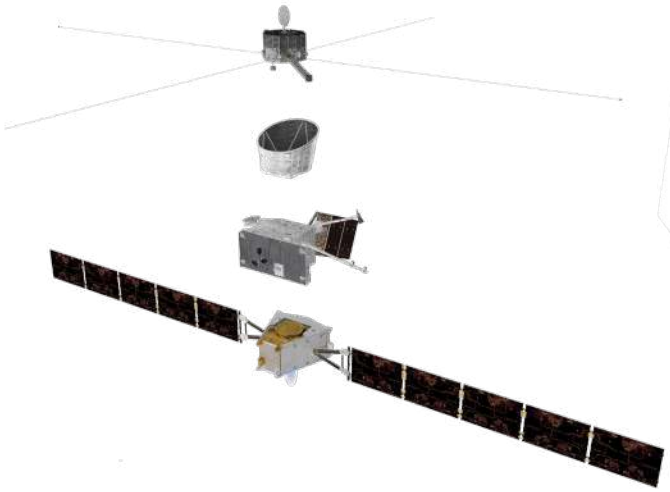
Mercury image, credit : NASA

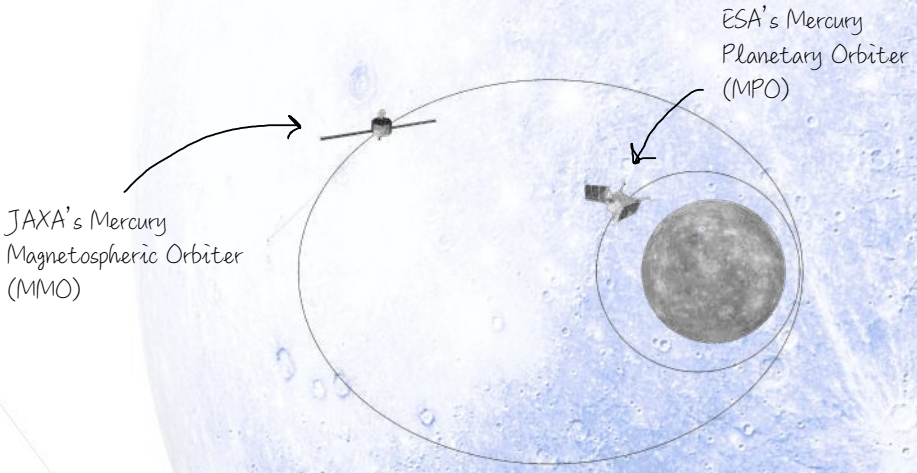
BepiColombo, the mission

PROBING OF HERMEAN EXOSPHERE BY ULTRAVIOLET SPECTROSCOPY

bepicolombo

- Europe's first mission to Mercury, launched on 20 October 2018 (arrival at Mercury: December 2025)
- Aims to study the planet's interior, exosphere, surface and magnetosphere to understand its origin



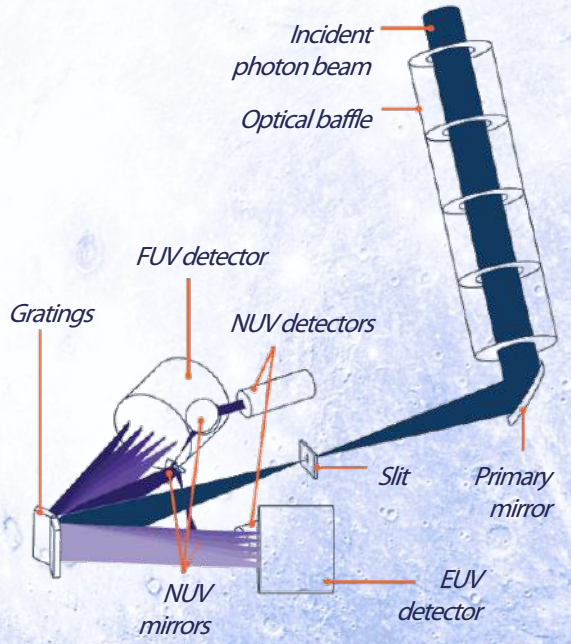


Mercury image, credit: NASA

PHEBUS, the instrument

PROBING OF HERMEAN EXOSPHERE BY ULTRAVIOLET SPECTROSCOPY

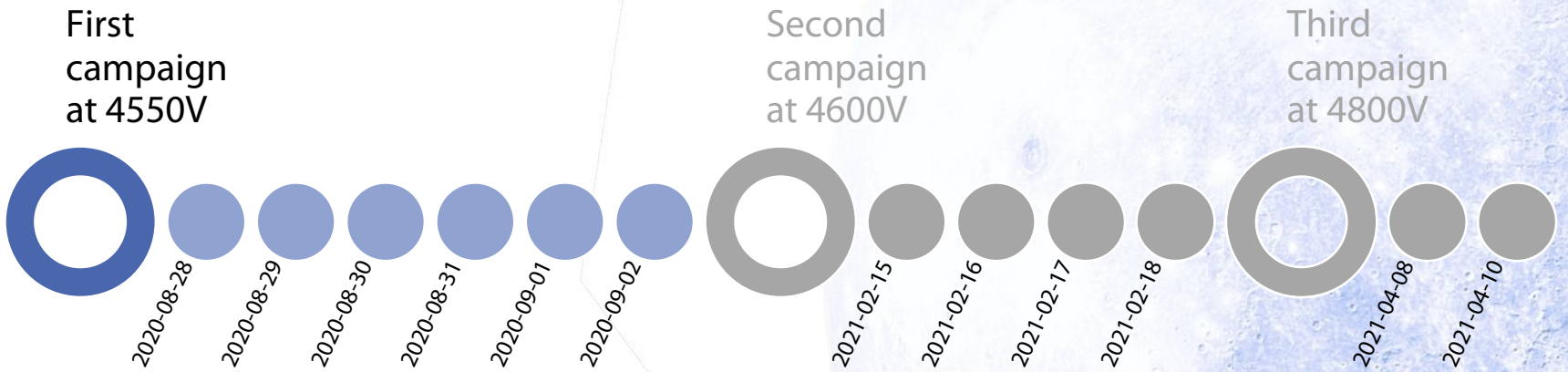
- **Characterize Mercury's exosphere composition and dynamics, and the interactions between the surface and the exosphere**
- **Two detectors**
  - EUV detector: [55 - 155 nm],
  - FUV detector: [145 -315 nm]
- **Two additional channels**
  - NUV-K (404 nm),
  - NUV-Ca (422 nm)



Mercury image, credit : NASA

Venus distant observations

- Distant observations of Venus with PHEBUS FUV detector, coordinated with several other observational facilities (in space and on the ground)



Mercury image, credit : NASA

Aug. 28 to Sept. 2, 2020

❑Venus FUV observation:

- 4550V
- Phase angle ≃ 60°
- Distance = from 0.27 AU to 0.23 AU
- Observation duration = 30min, 1 acquisition/10s, integration time = 8s

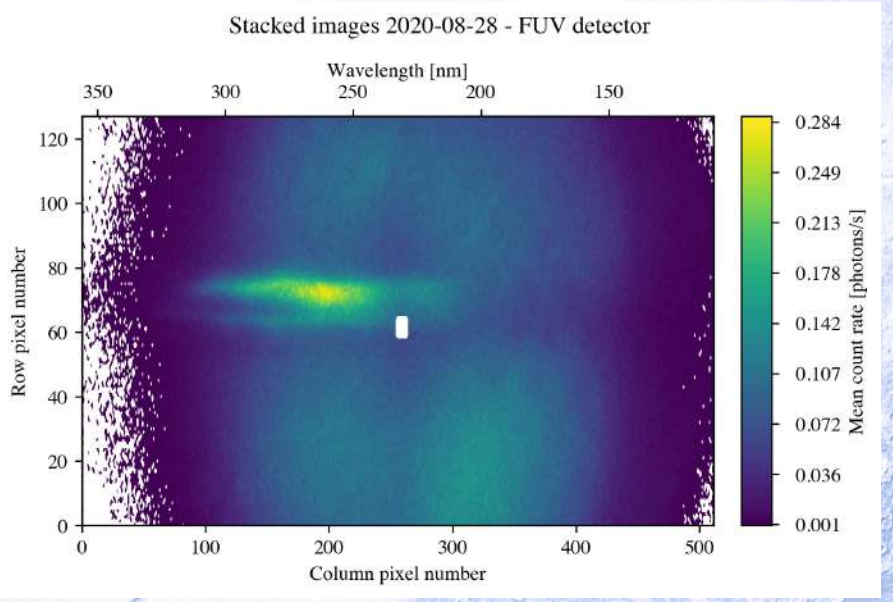
❑How to process the data?

- Compute mean count rate
- Correct the dark current and the spike

Mercury image, credit : NASA

August 28, 2020

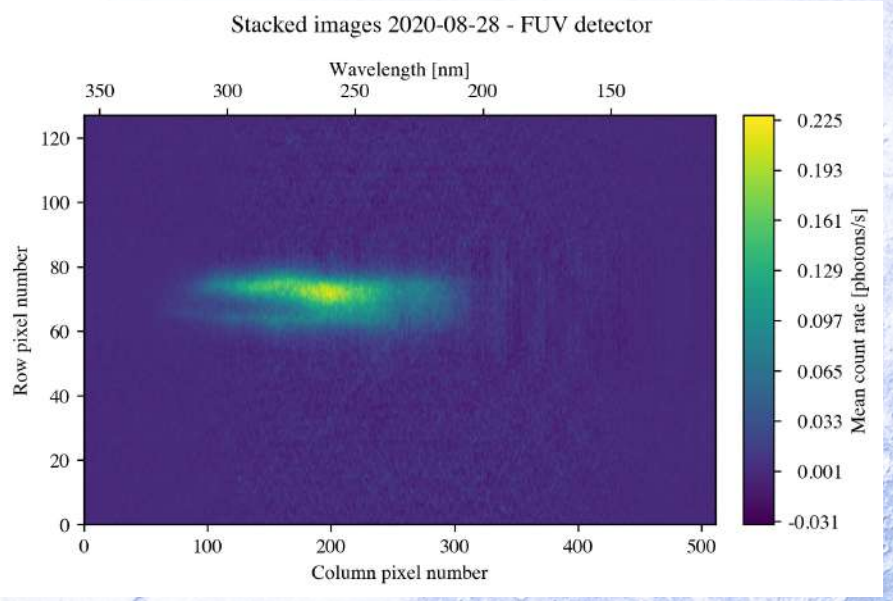
- 1 observation = 180 acquisitions
- 1 acquisition = 512 x 256 matrix mapping the number of photon counts registered onto each pixel of the FUV detector
  - 512: spectral dimension
  - 256: spatial dimension



Mercury image, credit : NASA

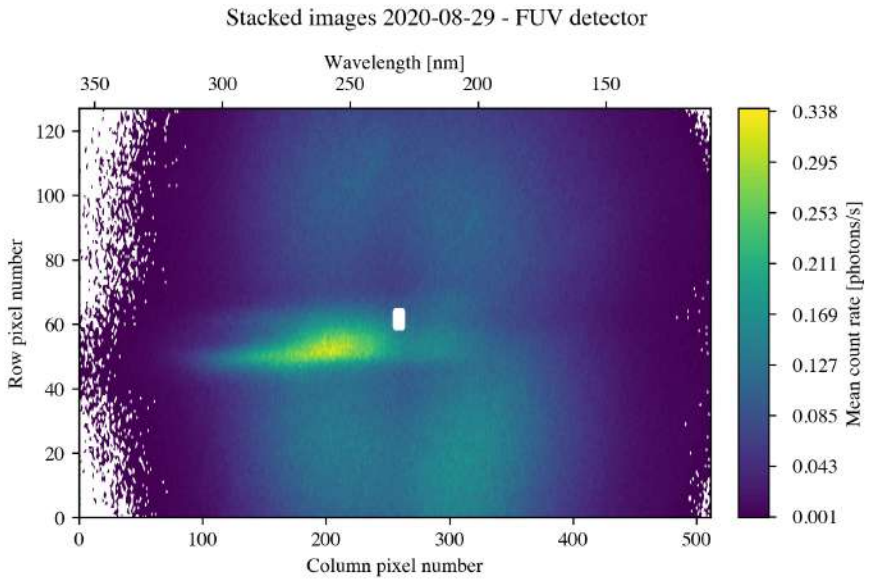
August 28, 2020

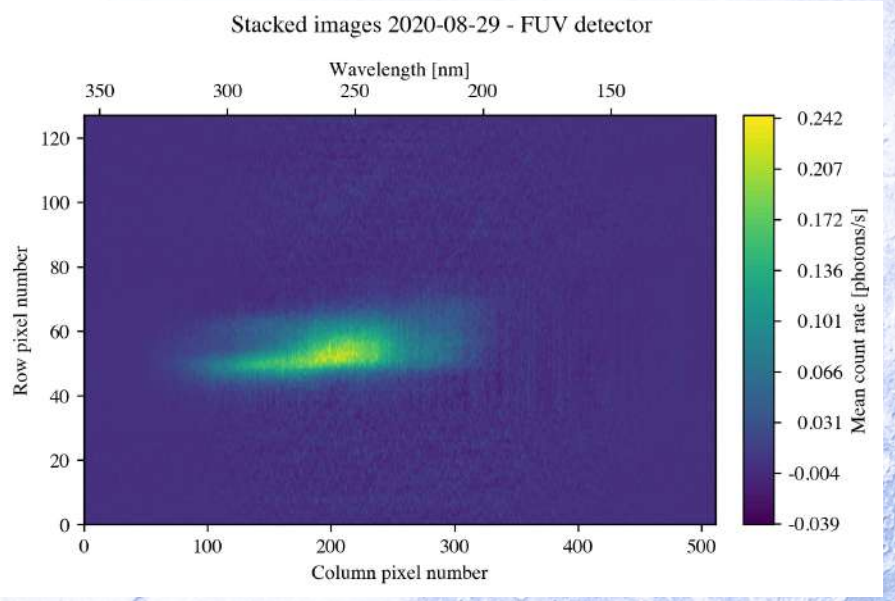
- Correct the dark current
- Correct the spike at the center of the detector using interpolation



Mercury image, credit : NASA

August 29, 2020



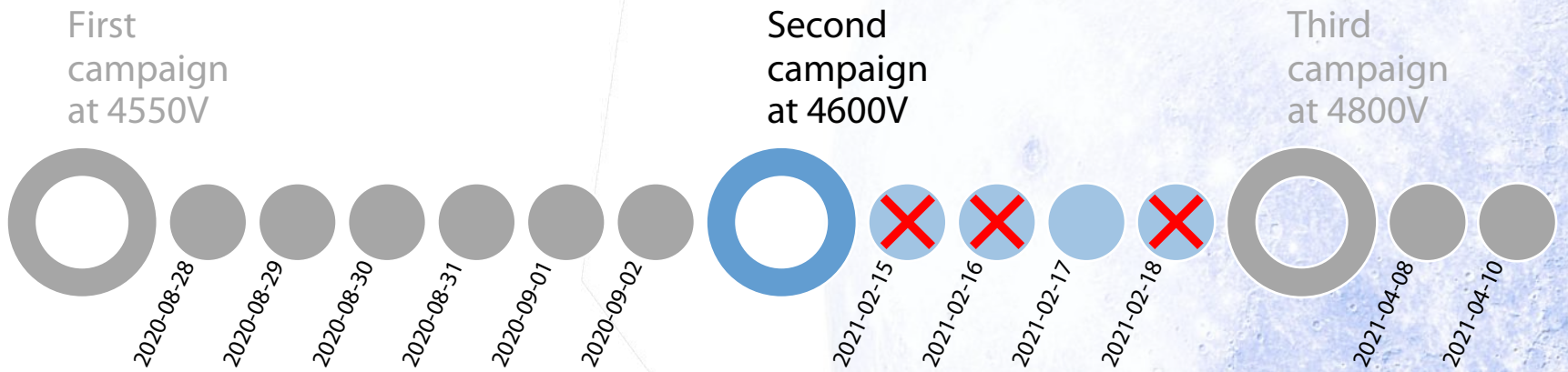


Mercury image, credit : NASA

Venus distant observations

PROBING OF HERMEAN EXOSPHERE BY ULTRAVIOLET SPECTROSCOPY

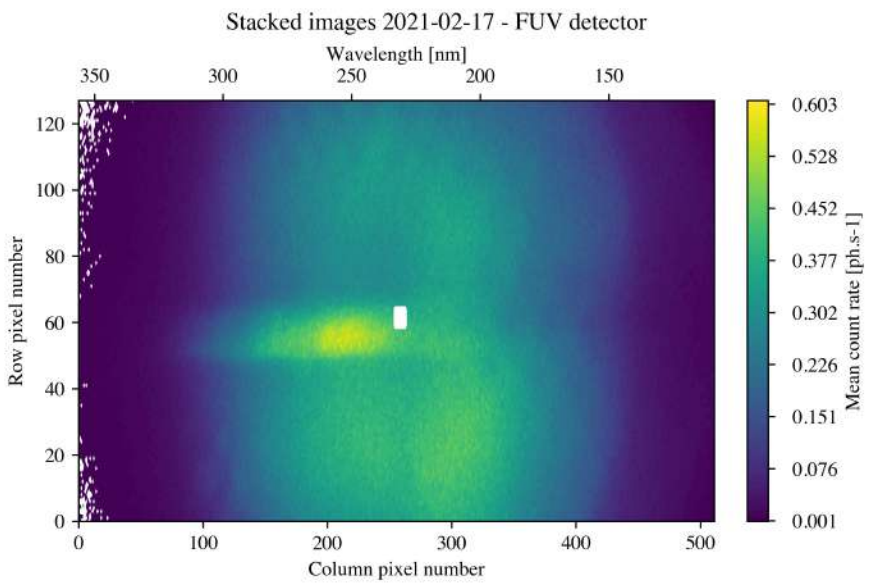
- Distant observations of Venus with PHEBUS FUV detector, coordinated with several other observational facilities (in space and on the ground)

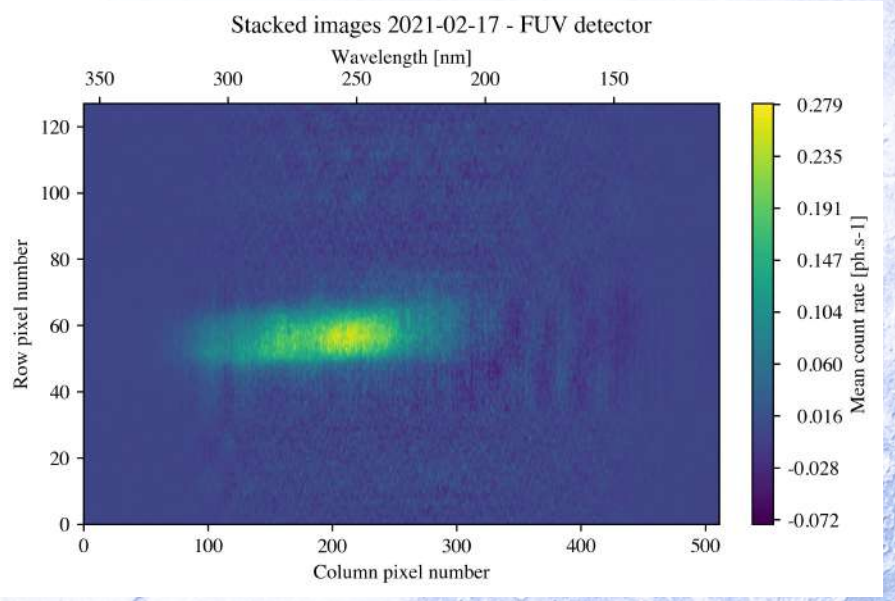


Mercury image, credit : NASA

February 17, 2021

2021-02-17 Venus FUV observation at 4600V (D8)
Phase angle = 52.3°
Distance = 0.34AU

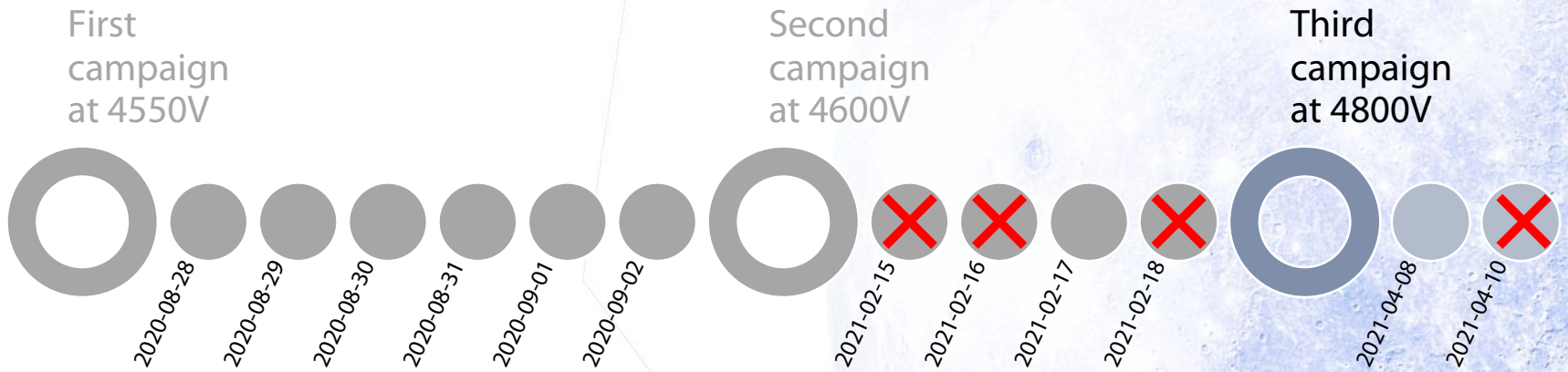




Mercury image, credit : NASA

Venus distant observations

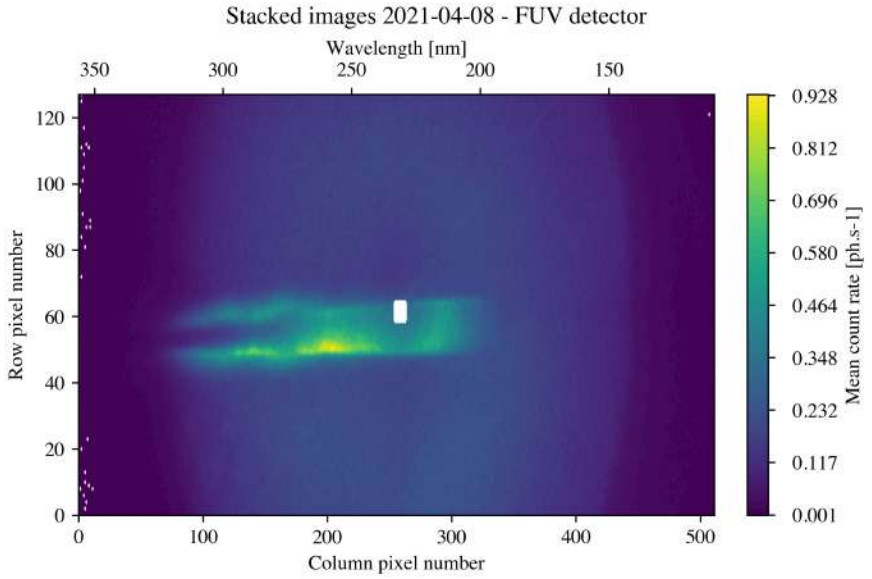
- Distant observations of Venus with PHEBUS FUV detector, coordinated with several other observational facilities (in space and on the ground)

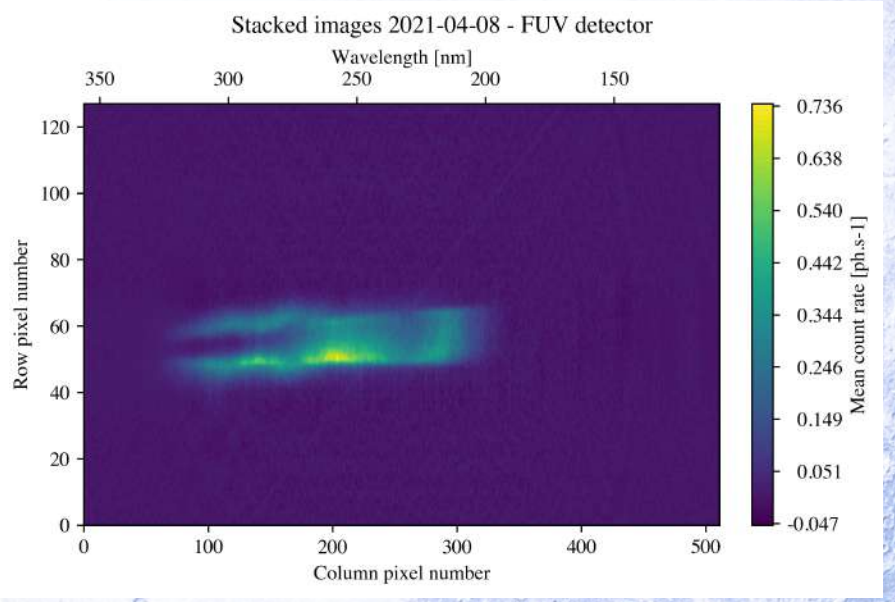


Mercury image, credit : NASA

April 8, 2021

2021-04-08 Venus FUV observation at 4800V (D14)
Phase angle = 52.7°
Distance = 0.34AU





Mercury image, credit : NASA

- Retrieve the spectrum of Venus by summing the mean count rate over the lines where Venus is located
- Compare the spectra with a model to determine the response of the instrument (convolution with a Gaussian function)

Mercury image, credit : NASA

Venus model

❑Venus spectrum model:

$$N(\lambda) = A_{eff}(\lambda)F(\lambda)$$

- N: number of detected photons per s per nm
- A_{eff}: effective area of PHEBUS FUV detector [cm2]
- F: stellar flux [ph/s/cm2/nm]

Mercury image, credit : NASA

Venus model

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- N: number of detected photons per s per nm
- **A_{eff}: effective area of PHEBUS FUV detector [cm2]**
- F: stellar flux [ph/s/cm2/nm]

❑Effective area A_{eff}

$$N_p(\lambda) = A_{eff}(\lambda, HV)\phi(\lambda)\Delta\lambda$$

- N_p: number of photoevents per second reported by FUV
- Φ: SPICAM reference photon flux interpolated on PHEBUS reference spectrum wavelengths grid
- Δλ: pixel size [nm]

Mercury image, credit : NASA

Venus model

❑Venus spectrum model:

$$N(\lambda) = A_{eff}(\lambda)F(\lambda)$$

- N: number of detected photons per s per nm
- A_{eff}: effective area of PHEBUS FUV detector [cm2]
- **F: stellar flux [ph/s/cm2/nm]**

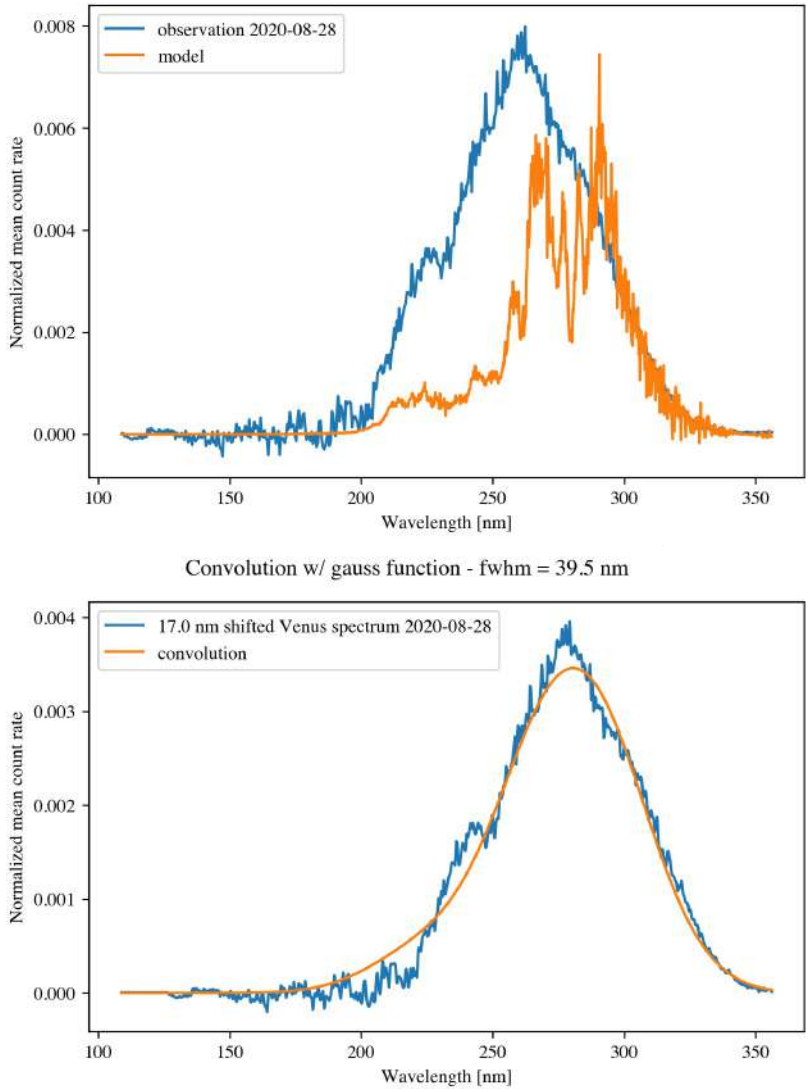
❑Stellar flux

$$F(\lambda) = F_{sun}(\lambda)A_L(\lambda)$$

- F: stellar flux
- F_{sun}: solar spectral flux [ph/s/nm/cm2] – Killen et al., 2009
- A_L: Venus Lambertian albedo – E. Marcq, personal communication of SPICAV-UV data

Mercury image, credit : NASA

Convolution and instrument's response



Date	Shift [nm]	FWHM [nm]
28/08/20	17	39,5
29/08/20	19,5	39,5
30/08/20	19	43
31/08/20	19	42
01/09/20	19	44
02/09/20	17	45
17/02/21	8	32,5
★08/04/21	11,5	46

Mercury image, credit : NASA

Conclusion

- Central spike ➔ difficult to use data around these lines to retrieve spectrum
- Dark current much stronger than what was observed on ground + unstable so difficult to remove
- Spectral shift between in-flight and on the ground wavelength assignment TBD
- Mispointing correction still on-going
- Decision was made not to use this detector for MSB1

Mercury image, credit : NASA

Mercury image, credit : NASA

Mercury Swing-By #1

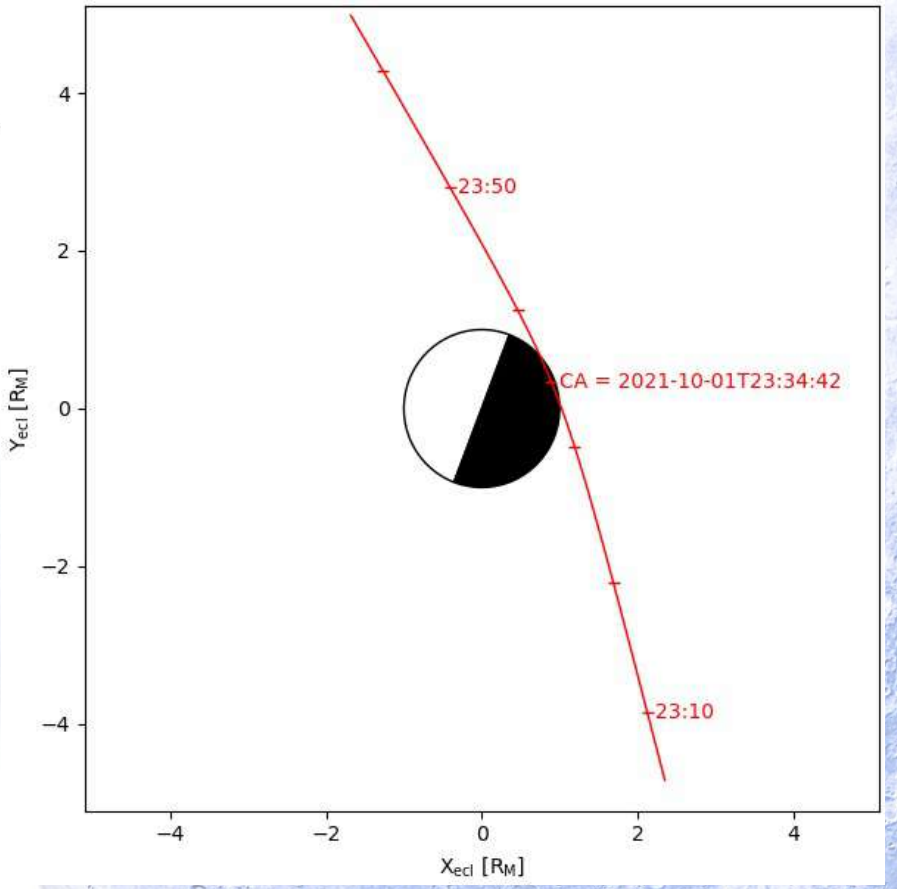
PROBING OF HERMEAN EXOSPHERE BY ULTRAVIOLET SPECTROSCOPY

- Objectives: observe the exosphere of Mercury (nightside and dayside)
- Constraints: do not observe the surface of Mercury but maximize the intensity of the species to observe (exospheric density profiles)
- Determine detector, scanner angle, duration, observation rate

Mercury image, credit : NASA

Mercury Swing-By #1

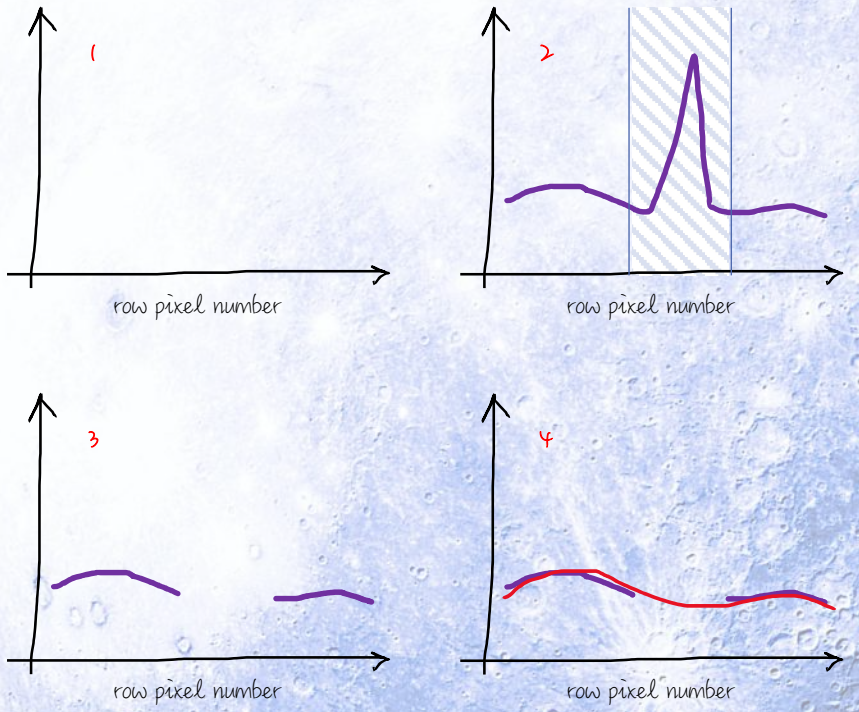
- Detectors: EUV + NUVs
- Scanner angle: 130°
- Observation duration: CA ± 30 min
- Observation rate: 10s
- Integration time: 8s
- Slit removed



Mercury image, credit : NASA

Dark correction

- **Model the dark current based on July 2020 observations:**
  - For each column, we only consider the edges of the image (3) i.e. lines on which Venus is not located to compute a polynomial fit of degree 5
  - We remove this fit and compute an additional correction
    - determine the shape of this trough by averaging on columns 350 to 400 and computing the ratio of the polynomial fit on the data. So, to get the right correction, instead of simply subtracting the polynomial of degree 5, we remove this polynomial multiplied by the ratio. We do it on all the columns.



Mercury image, credit : NASA