

Hyperscout-H: near-Earth commissioning phase

On behalf of the **HS-H Team**: Julia de León, Michael Küppers, Björn Grieger, Gábor Kovács, Nagy Balázs, George Prodan Marcel M. Popescu

Tuesday, November 19th 2024, ESA/ESAC

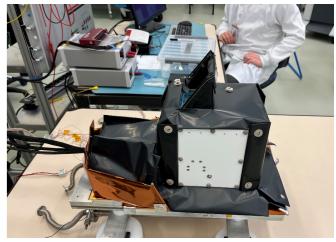
Hyperscout-H(HS-H): hyperspectral imager



- Miniaturized hyperspectral imager 2D pixel array, snapshot mode;
- 5x5 grid of Fabry-Pérot spectral bandpass filters integrated on the image sensor.

Parameter	Value		
Field of View	15.5° x 8.3° (paraxial) 15.9° x 9.9° (real)		
Focal length	41.25 mm		
Aperture diameter	10.3125 mm		
Pixel pitch	5.5 <i>µ</i> m		
Number detector pixels	2048 x 1088 (409 x 217 macro-pixels)		
Spectral range	665 – 975 nm		
Number of spectral bands	25		
Spectral resolution	8 – 27 nm		
Spatial resolution	26 cm @ 2 km (single pixel) = 1.3 m (macro pix)		





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λ_1	λ ₂	λ ₃	λ_4	λ_5
λ_6	λ_7	λ ₈	λ9	λ_{10}
λ_{11}	λ_{12}	λ_{13}	λ_{14}	λ_{15}
λ_{16}	λ_{17}	λ_{18}	λ_{19}	λ_{20}
λ_{21}	λ_{22}	λ_{23}	λ_{24}	λ_{25}

 $\lambda_1 {<} \lambda_2 {<} \ldots {<} \lambda_{24} {<} \lambda_{25}$

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Planned activities and observations log



✓ 147 downloaded images;

- Telemetry packages were decoded.
 Images where partially calibrated.
- ✓ All planned activities for the commissioning phase were executed.
- ✓ Ongoig data analyis
- ✓ The images were shared within the instrument team.

 ✓ The images will be available using the MOGI – BME server (Gábor Kovács)

Í	Nr. <u>Çrt</u>	Objective	Geometrical conditions/Observing constraints	Observing sequence	Total number of images	Exposure times (attempt)	Observations performed		
	1	Alignment	Different <u>pointings</u> in order to: - view different star fields, thus removing star catalog errors - use attitudes with different Sun directions. Suggested coordinates (RA[h,m], DEC[deg]): 04h21m +17.27deg; 07h30m -25.34deg; 08h29m -50.00deg; 10h25m -60.90deg;	5 exposure per pointing	22 / 20	3 sec, 3 sec, 4 sec, 5 sec, 5 sec	Done, according to specifications. Observations perform during Oct. 26 – Oct 27.		
			Notice: At least 2 <u>pointings</u> from the list above must be used with slight offset between the four pointings						
	4	Bias	Lowest exposure allowed by camera, no bright object in the FoX	5 x 0.0001 sec.	8/5	0.0001sec	Done. Eight images available.		
	5	Dark	No bright objects in the FoX	1 x 0.1s exposure; 1 x 1s exposure; 3 x 5s exposure	5/5	1 x 0.1s exposure; 1 x 1s exposure; 3 x 5s exposures;	Done, according to specifications.		
	6	Star fields (distortion measurement and radiometric calibration)	RA: 07h 21m; DEC:-25d 34m RA: 04h 25m; DEC:+15d 10m Implemented as 2x2 raster	5 long exposures for each field. Repeat with +- 3° off-pointing in X and Y	40/40	1 x 0.5s exposure; 1 x 1s exposure; 1 x 3s exposures; 2 x 5s exposures;	Done, according to specifications. Observations performed during 09-10 November		
	8	Standard star (radiometric <u>calib</u>)	Vega in the <u>FoV</u> , can be implemented as 2x2 raster RA: 18h 37m DEC: 38d 47m	3 exposures. Repeat with +- 3° off- pointing in X and Y	27 / 27	0.5 sec	Done, according to specifications.		
	9	Standard star (saturation test)	Vega in the FoV RA: 18h 37m DEC: 38d 47m	expose 6 times, at 25%, 50%, 75%, 100%, 125%, 150% saturation level of the less sensitive filter	5/6	0.1 sec, 0.3sec, 0.5 sec, 1sec, 2,sec, 3sec	Done, missing the 3 sec exposure.		
10		Extended target	Both Earth and Moon in Foy, Moon must be resolved. Distance must be less than 5e6 km to have the Moon in 1 macro-pixel.	4 images, 3x3 raster	40 / 36	0.005 sec, 0.01 sec, 0.02 sec, 0.05 sec	Done, missing 8 images of 5 ms. 11 x 0.0005 1 x 0.005 10 x 0.01 9 x 0.02 9 x 0.05		

Calibration images: 100 µs dark (bias) frames



- The minimum exposure time of the instrument is 100 µs. These dark frames characterize the bias level (bias exposures).
- Eight bias exposures were acquired during two sessions, 3 + 5 images.
- The instrument works at low temperatures.
- Slight variations of the median level between the two sessions.

200

400

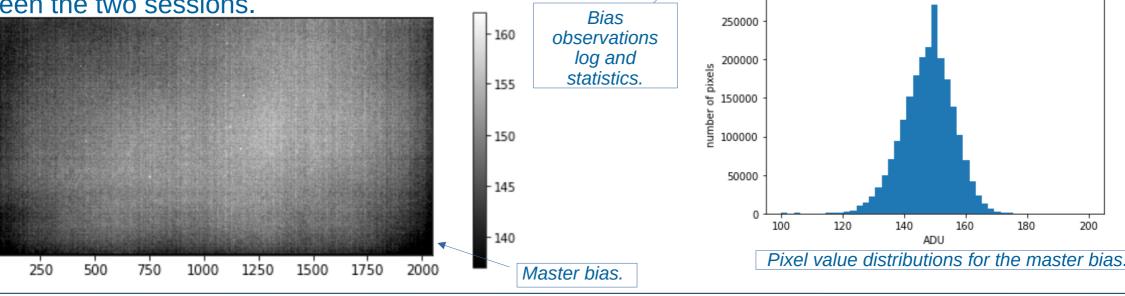
600

800

1000

0

File	TempC	TempEPA	Median	Mean	Std
File	۹ <mark>Ç</mark>	° <u>Ç</u>	ADU	ADU	ADU
HS-L0-FE-0179-01-01.fits	-21	-11.0	144	143.4	12.7
HS-L0-FE-017A-01-01.fits	-21	-11.4	148	147.3	12.7
HS-L0-FE-017B-01-01.fits	-21	-11.6	145	144.8	12.6
HS-L0-FE-0198-01-01.fits	-22	-13.5	149	148.2	12.8
HS-L0-FE-0199-01-01.fits	-21	-13.0	151	149.9	12.7
HS-L0-FE-019A-01-01.fits	-21	-12.7	149	148.4	12.7
HS-L0-FE-019B-01-01.fits	-21	-12.7	148	147.5	12.7
HS-L0-FE-019C-01-01.fits	-21	-12.5	150	149.8	12.7

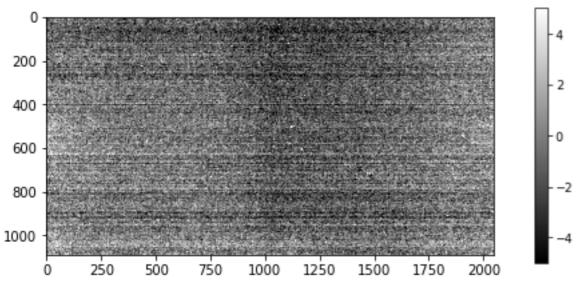


Calibration images: biases, in space vs laboratory

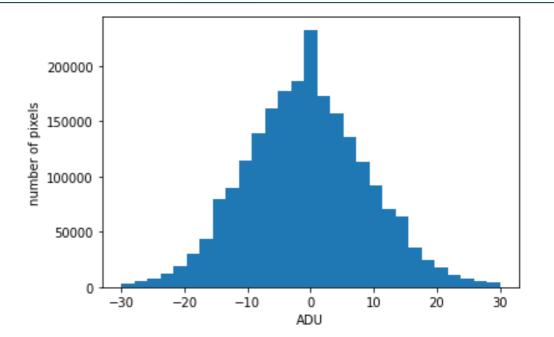


- The bias exposures obtained in the laboratory were taken around the ambient temperatures (internal sensor recorded between 11 and 19 °C). The exposure in space are at negative temperatures.

- The subtle pattern observed when analyzing the differences might be due to unintended illumination, as the instrument lacks a shutter.



The difference between the bias obtained in space at -21 °C and the obe obtained in laboratory at 11 °C (temperatures reported in the header of the fits files).



Histogram of the pixel values differences between the bias obtained in space and the one obtained in laboratory.

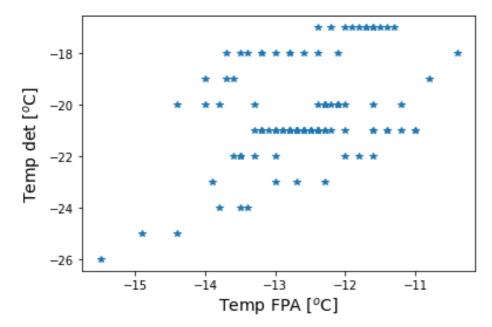
The average differences: -0.63 ADU
The median differences: -1.0 ADU
The standard deviation: 10.00 ADU

Calibration images: sensors temperature



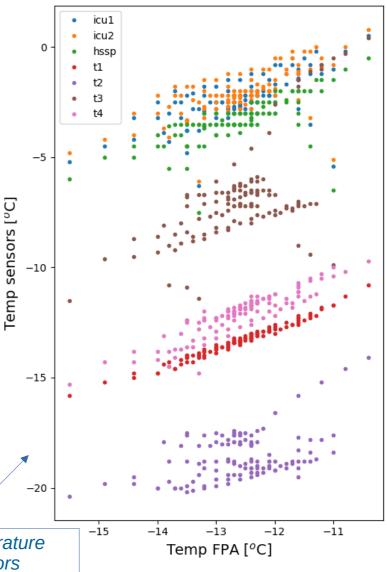


• Cosine (instrument producer): "The temperature sensor in the detector is not calibrated and it should not be trusted, FPA temperature should be used, therefore it is safe to operate the instrument in these conditions."



- The differences between the *detector sensor* and *FPA* (Focal Plane Array) sensor:
 - Mean (ΔT) = 7.8 °C
 - Median (ΔT) = 8.3 °C
 - Std (ΔT) = 1.7 °C

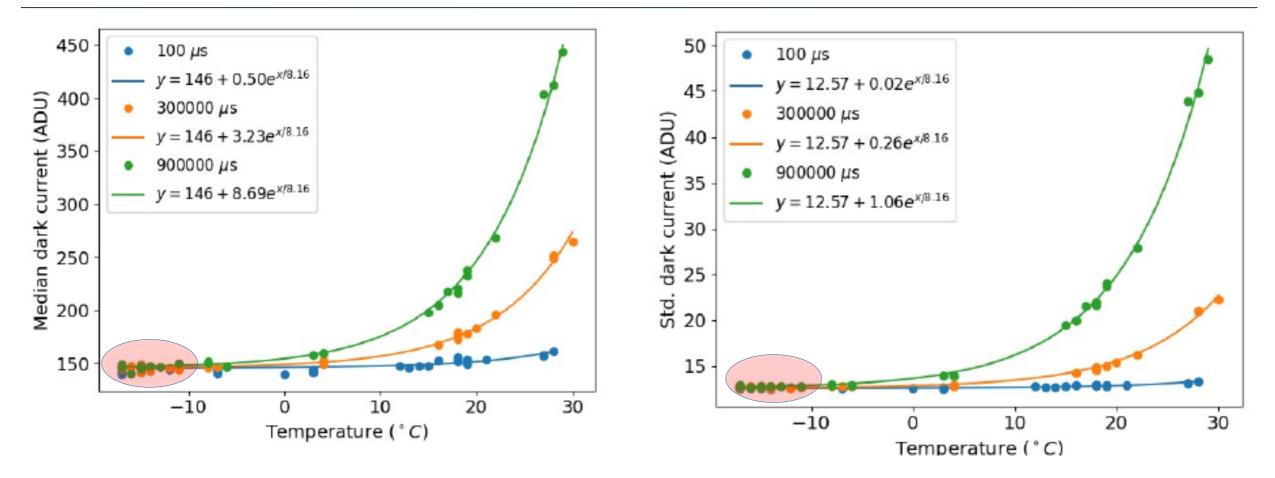
Comparison between the temperature reported by the different sensors



Comparison between the detector sensor (reported in the header of the images) and the FPA sensor.

Recall the laboratory characteristic curves



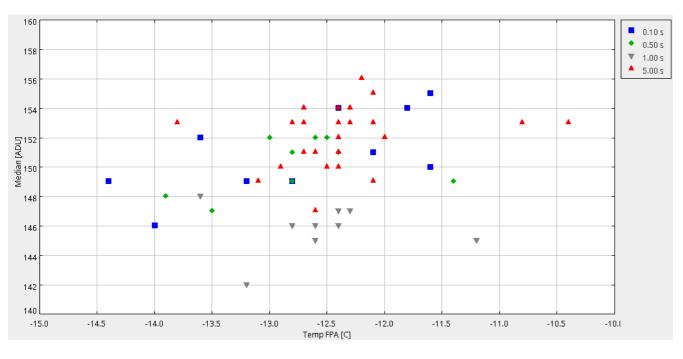


The variation in the median and standard deviation of pixel values of dark current as a function of temperature. Both plots are shown for three different exposure times, with the behavior approximated using an exponential function.

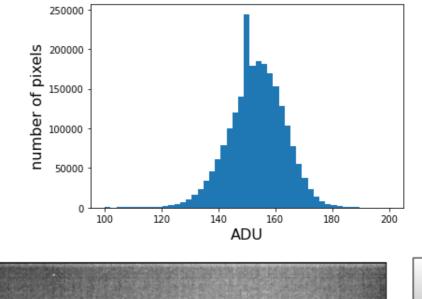
Calibration images: dark frames

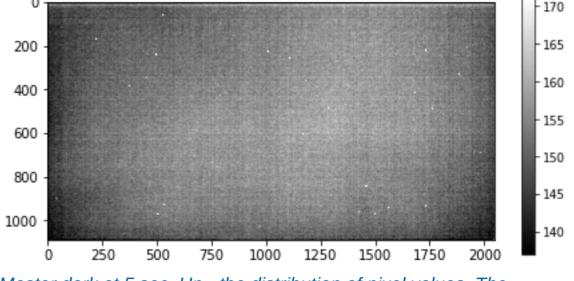


- Five dark frames were acquired with this purpose.
- The 62 star field images can also be used to monitor the dark current. Due to the detector's low sensitivity, only a few dozen stars may appear in the images. These stars can be masked after calculating the median of all the images.



Median level of darks at different exposure times and temepratures





Master dark at 5 sec. Up - the distribution of pixel values. The median image of all exposures at 5 sec.

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Calibration images: bad pixels map



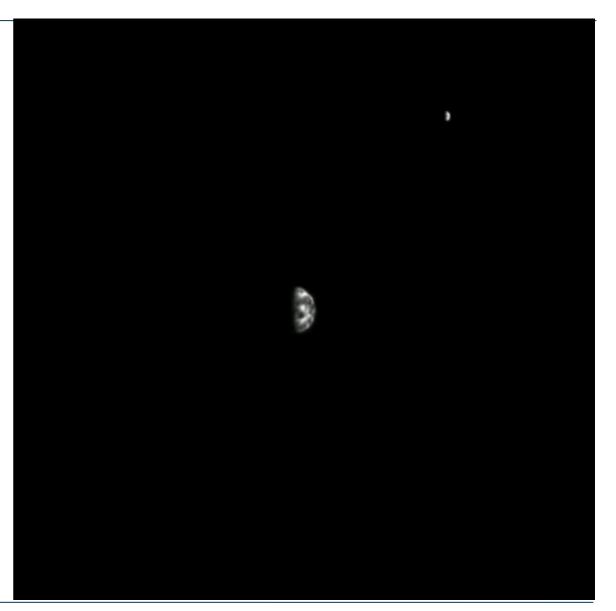
• 2274 (0.1 %) subpixels are outside +/-5 σ interval.

The bad/broken (white) pixels map. The white pixels were strongly enhanced in order to visualize them.

Earth - Moon system

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- A number of 40 exposures where acquired with the Earth Moon system;
- A 3 x 3 poster, 1° dithering offset each was used for observations
- (11 x 0.5 ms, 1 x 5ms, 10 x 10 ms, 9 x 20 ms, and 10 x 50 ms).
- The first exposure: 2024-10-10T14:12
- The last exposure: 2024-10-11T18:43
- The shortest exposures can be used for Earth, but for the longest, the Earth saturates.
- The Moon is most clearly visible in the longest exposures.
- Various false color images where generated for public outreach.



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Earth - Moon system



Spooky Earths

The false colour images are visualised using the TwilightShifted palette: a colour map ranging across bluish black through purplish white into reddish black to represent light intensity levels.

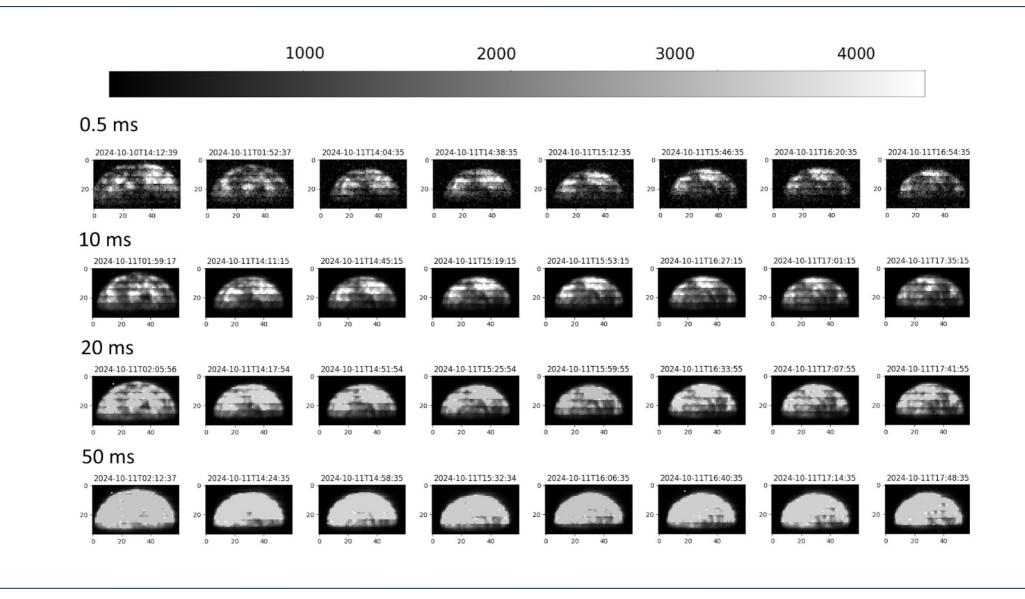


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Earth - Moon system: Earth images

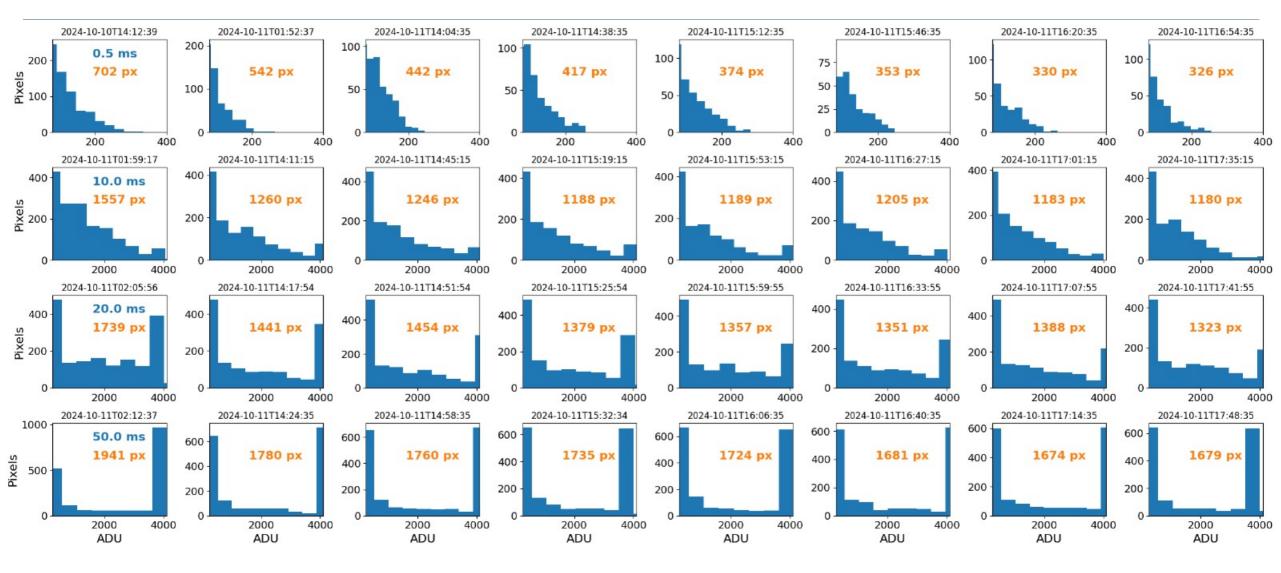




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Earth - Moon system: Earth images





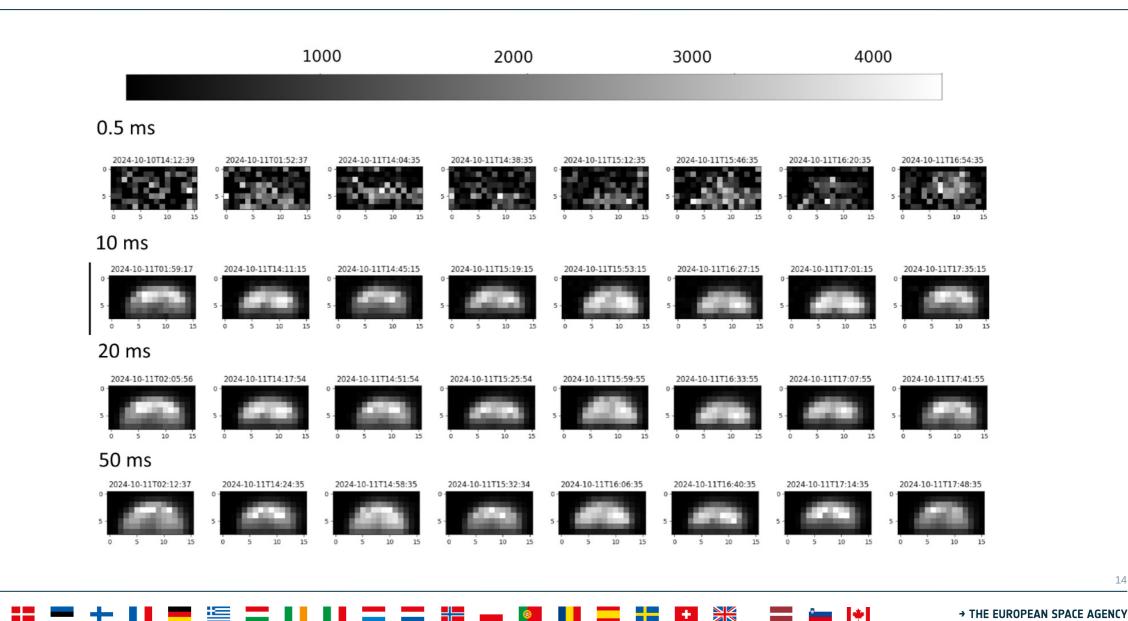
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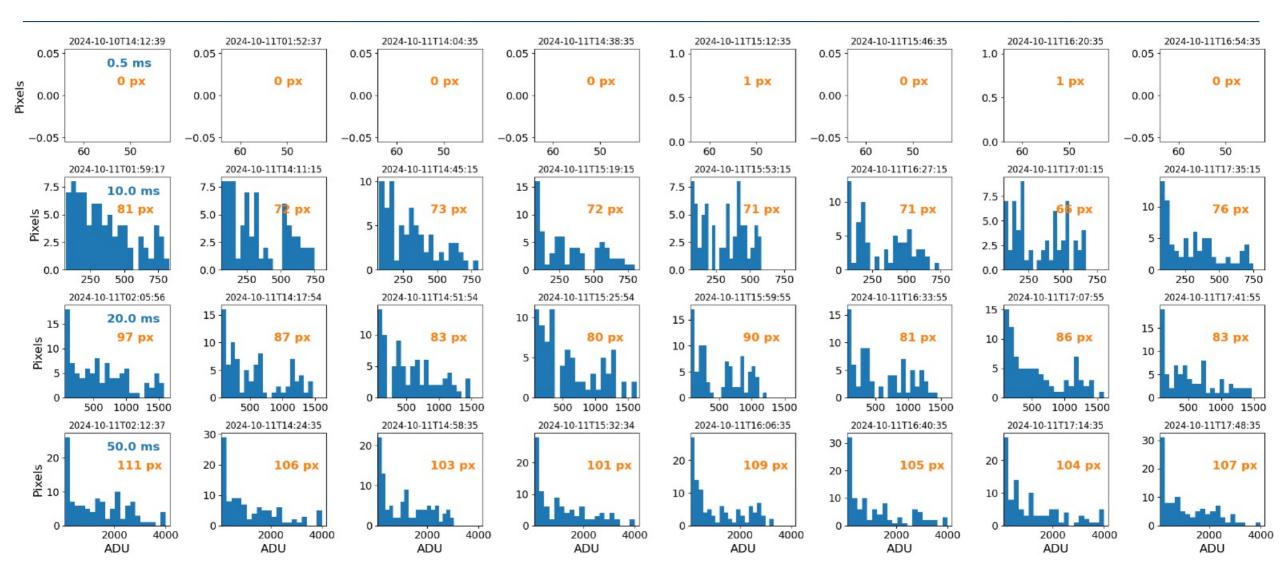
Earth - Moon system: Moon





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Earth - Moon system: Moon



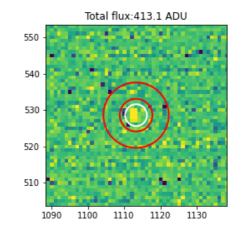


Calibrations using Vega

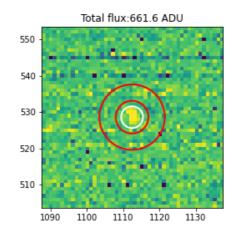


- Saturation test: 0.1, 0.3, 0.5, 1, 2 sec exposure;
- 27 images acquired in 3 x 3 pattern of pointings with 3° offset (dithering) after every three exposures.
- Radiometric calibration must consider that each channel has a specific gain and corresponds to a distinct segment of the spectrum.
- The position is a key factor for determining the number of ADU's and the radiometric calibration constant.

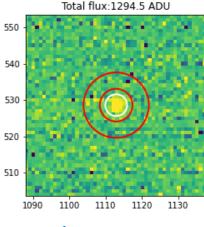
All channels were equalized by dividing them by their respective relative gains and the Vega spectrum.



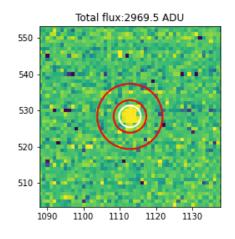
0.3 sec exposure



0.5 sec exposure



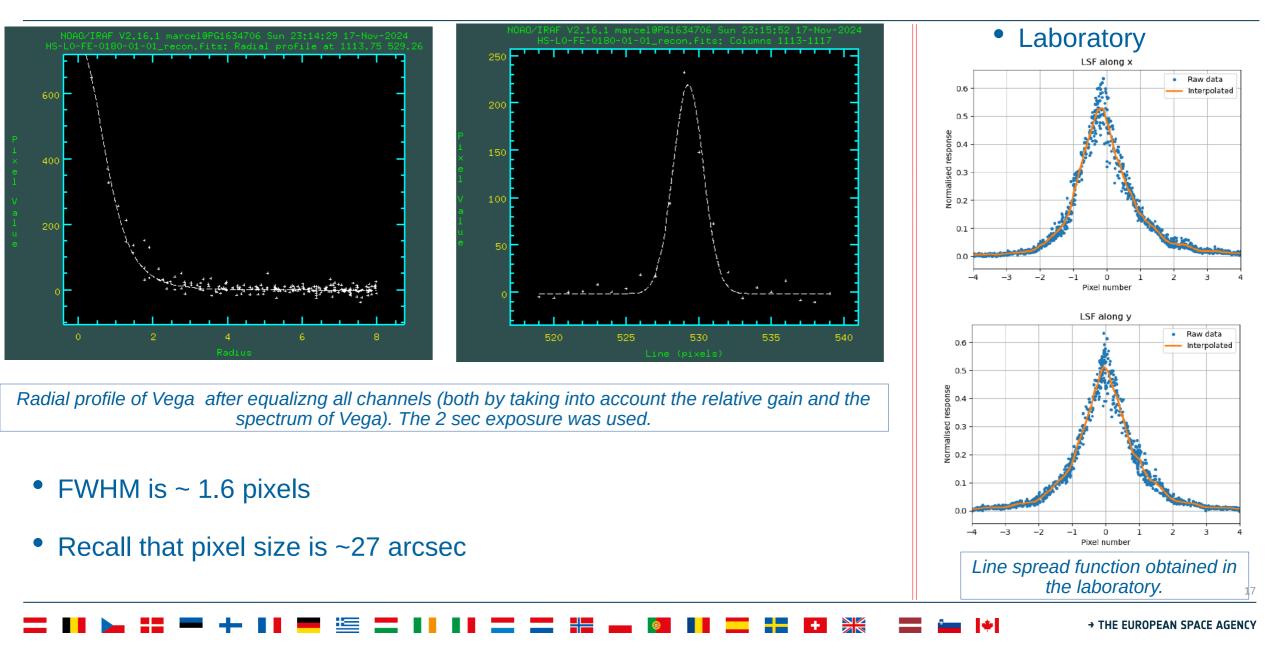
1 sec exposure



2 sec exposure

Calibrations using Vega

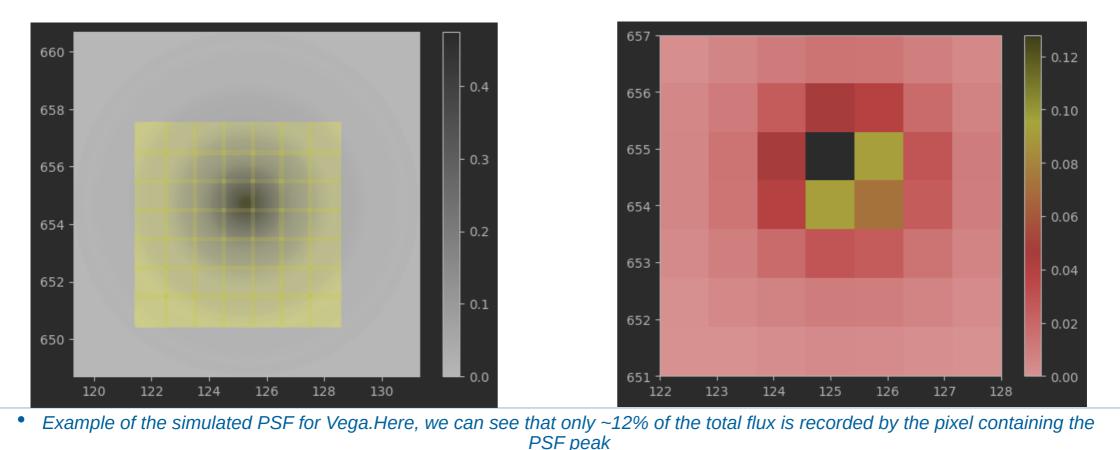




Calibrations using Vega: PSF simulations

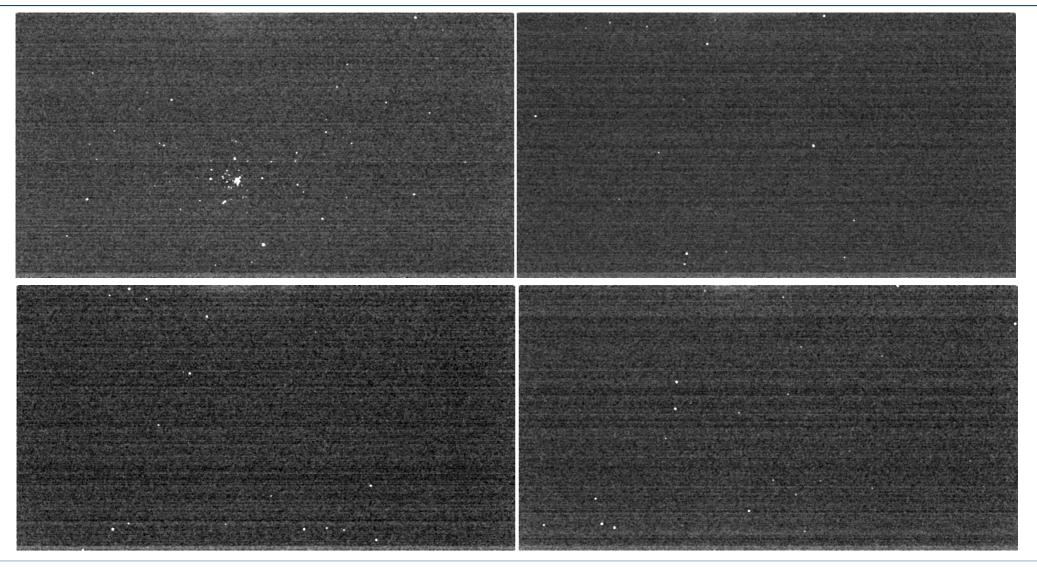


- The peak of the PSF distribution can be positioned anywhere within the area covered by a single pixel.
- The recorded flux within a pixel is proportional to the integral of the PSF distribution, with boundaries determined by the pixel's edges as a function of the distribution peak's position.



Star fields: ongoing work





The star fields observed by HS-H for alignment purposes A Gaussian blur filter was applied to distinguish to smooth the stars profile

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Conclusions



- \checkmark All planned activities for the commisioning phase were executed.
- ✓ A number of 147 images were acquired using the HS-H instrument. The targets include: the Earth – Moon system (40 images), Vega (32 images), bias and darks (13 images), star fields (62 images of four star fields).
- ✓ The instrument works in the cold temperature ranges, FPA sensor temperature (-15, -10) °C. The level of noise is the lowest possible for the instrument.
- ✓ Telemetry packages were downloaded and decoded succesfuly. Images where partially calibrated (dark and flat).
- ✓ The Earth-Moon exposures were used to create public outreach images. Demosaicking algorithms and interpolation techniques were tested on this dataset. Ongoing work on these exposures includes evaluating the saturation test for Earth, assessing the photometry of the Moon images, and conducting radiometric calibration.
- Radiometric calibration using the Vega exposures is ongoing. Work has been done to model its psf on the HS-H images, and to extract the spectrum.
- \checkmark The HS-H star fields images contain sources up to \sim 3 5 magnitudes.

