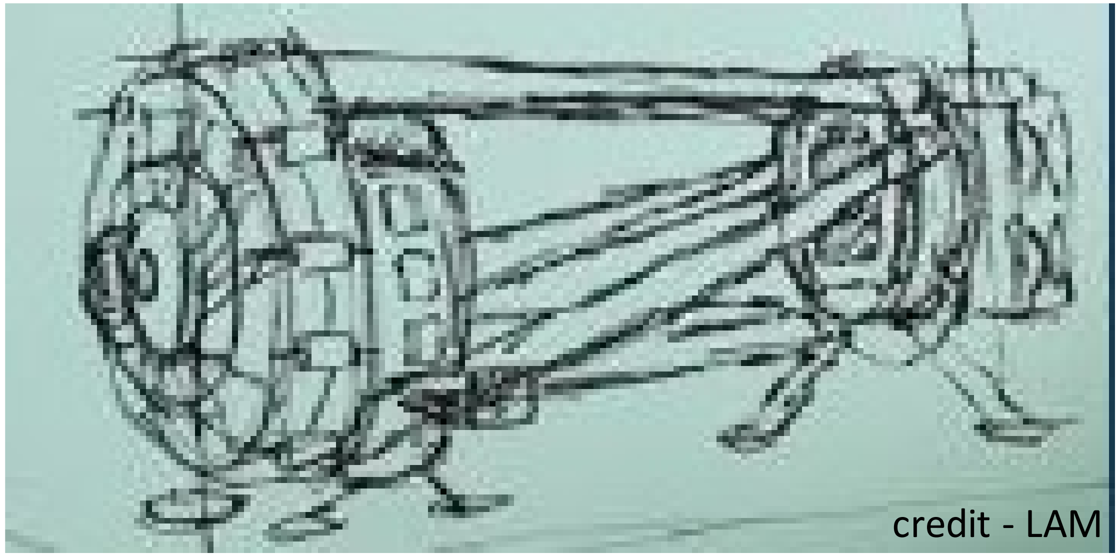
Puma2022

Sestri Levante 26-30 September 2022

*The **N**ear **I**nfrared **S**pectro**P**hotometer of the Euclid mission*

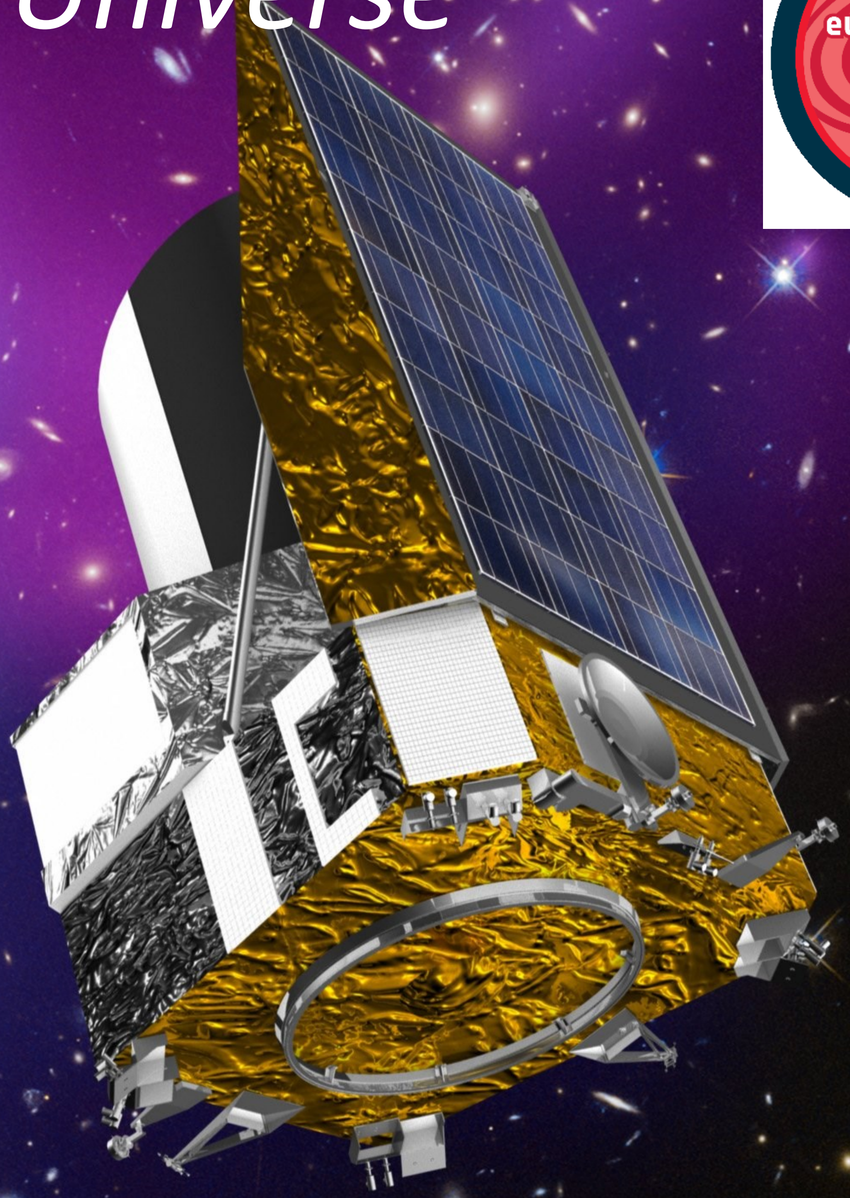


Chiara Sirignano – Università di Padova & INFN Padova

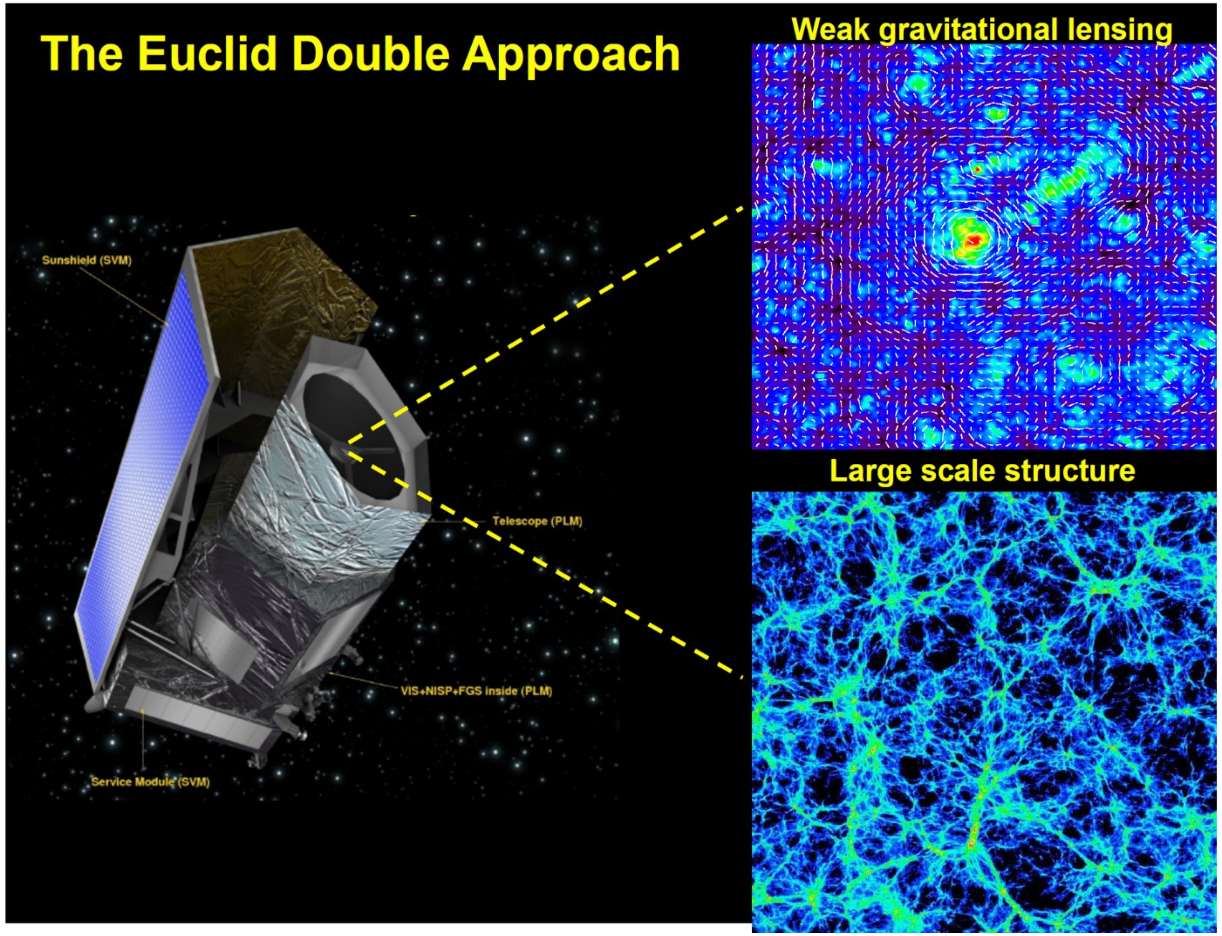
Euclid: exploring the Dark Universe

ESA scientific mission devoted to cosmology

- ***Euclid consortium***
  (more than 1500 scientific members, more than 200 institutions)
- ***ESA***
  (ESOC, ESAC)
- ***Industrial partners***
  (Thales Alenia Space , ADS ….)



The Euclid mission will use two probes to study ***dark matter and dark energy 3D distribution.***
The aim is to trace the structure of the Universe, both visible (galaxies) and invisible (dark matter).



Wavelength Coverage: 550nm–2000nm

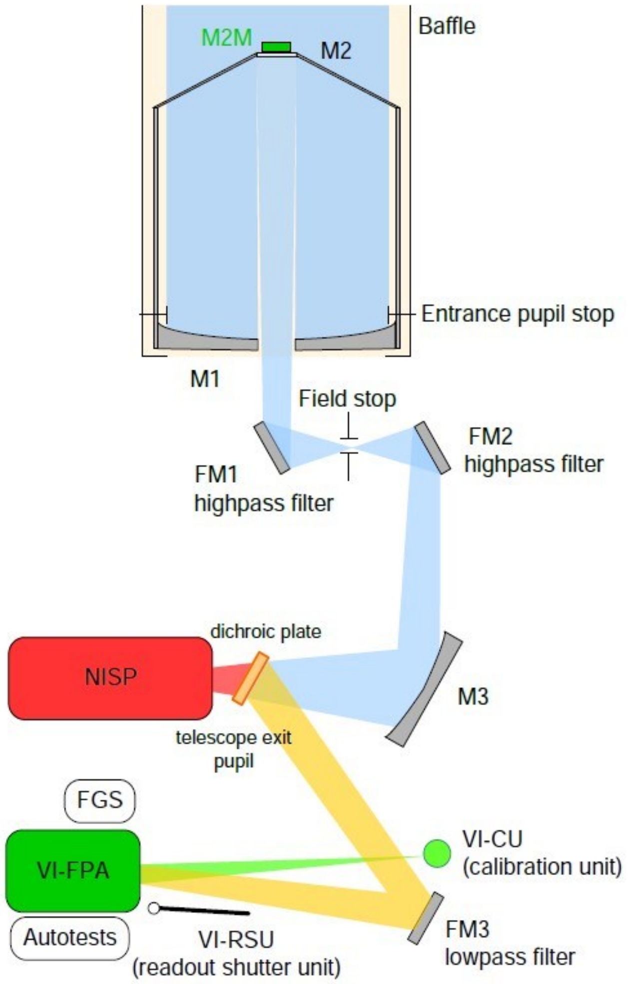
- **Weak Lensing**: (Optical + NIR photometry)

measurement of the distortion of the galaxy shapes due to the gravitational lensing caused by the dark matter distribution between distant galaxies and the observer. From the resulting galaxy shear can be deducted matter distribution. 2 billions of galaxies over 15,000 deg^2.

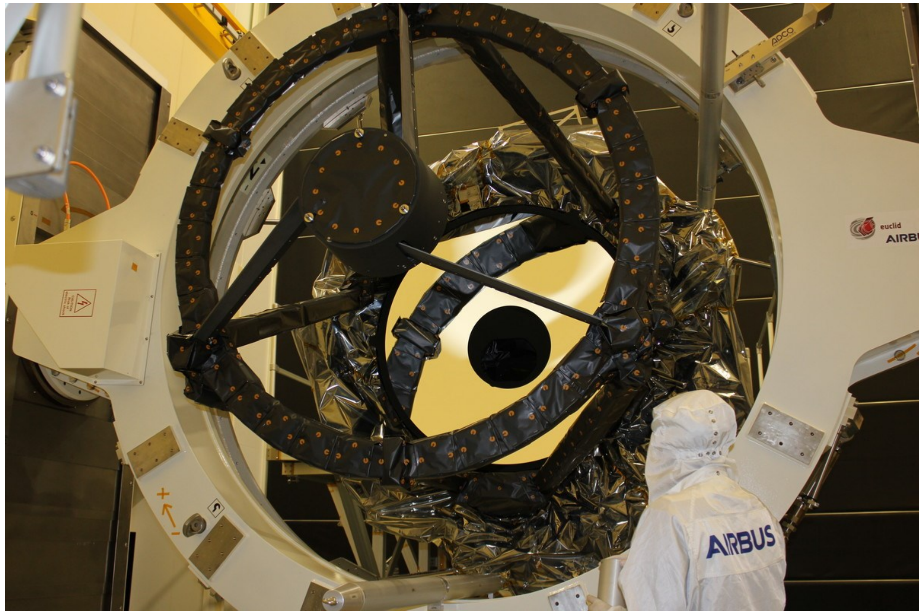
- **Galaxy Clustering**: (NIR Slitless Spectroscopy)

3D mapping of about 40 million galaxies over 15,000 deg^2 with slitless spectroscopy in space, redshift distribution of galaxies from their Hα emission line. ***Larger application of slitless spectroscopy ever.***

The telescope

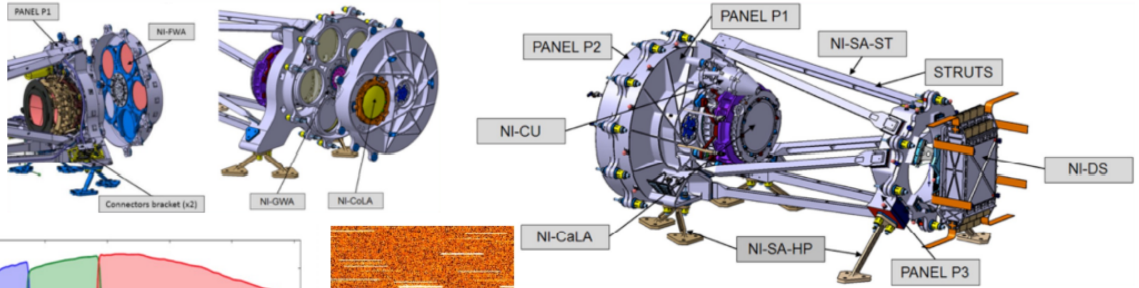


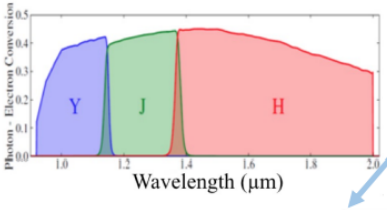
- Korsch telescope: three-mirror-anastigmat reflector telescope
- Primary Mirror: Concave ellipsoidal 1.2m diameter SiC
- Secondary Mirror: Hyperbolic
- Tertiary Mirror: Concave ellipsoidal

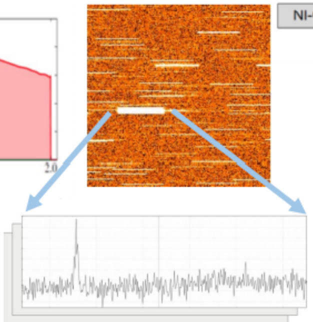


- Light is splitted to two instruments (VIS & NISP) through a dichroic filter
- Flat focal plane (0.5 deg^2) designed to avoid stray-light with accurate PSF

Two instruments: Optical + NIR



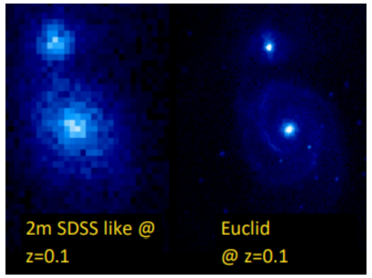




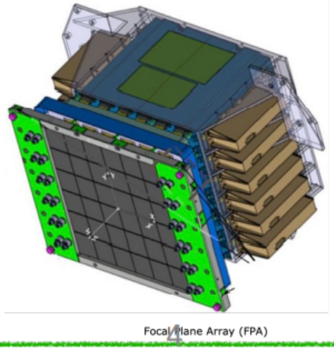
- 16 H2RG (HgCdTe) 2048 x 2048 pixels
- **67 Mpixel**, 18 µm pixel
- 0.3 arcsec pixel on sky, **0.55 deg² per field**
- Spectral resolution: **λ/Δλ > 380**
- 3 filter **Y, J, H**
- 4 grims: **1xB(920-1350 nm), 3xR(1250-1850)**

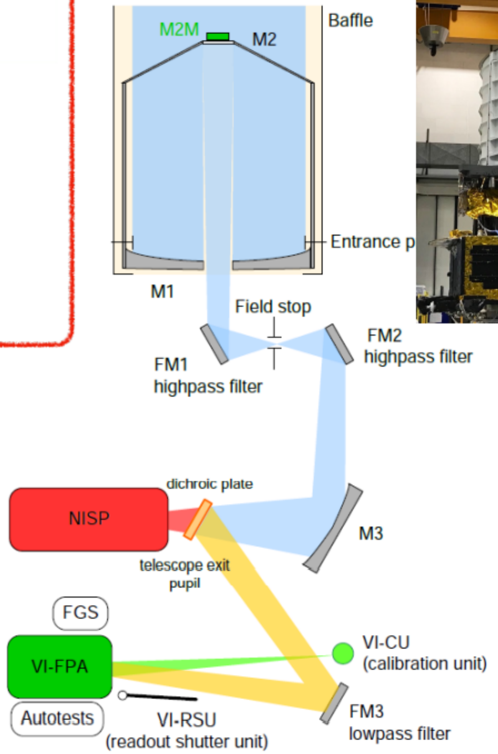
NISP

VIS

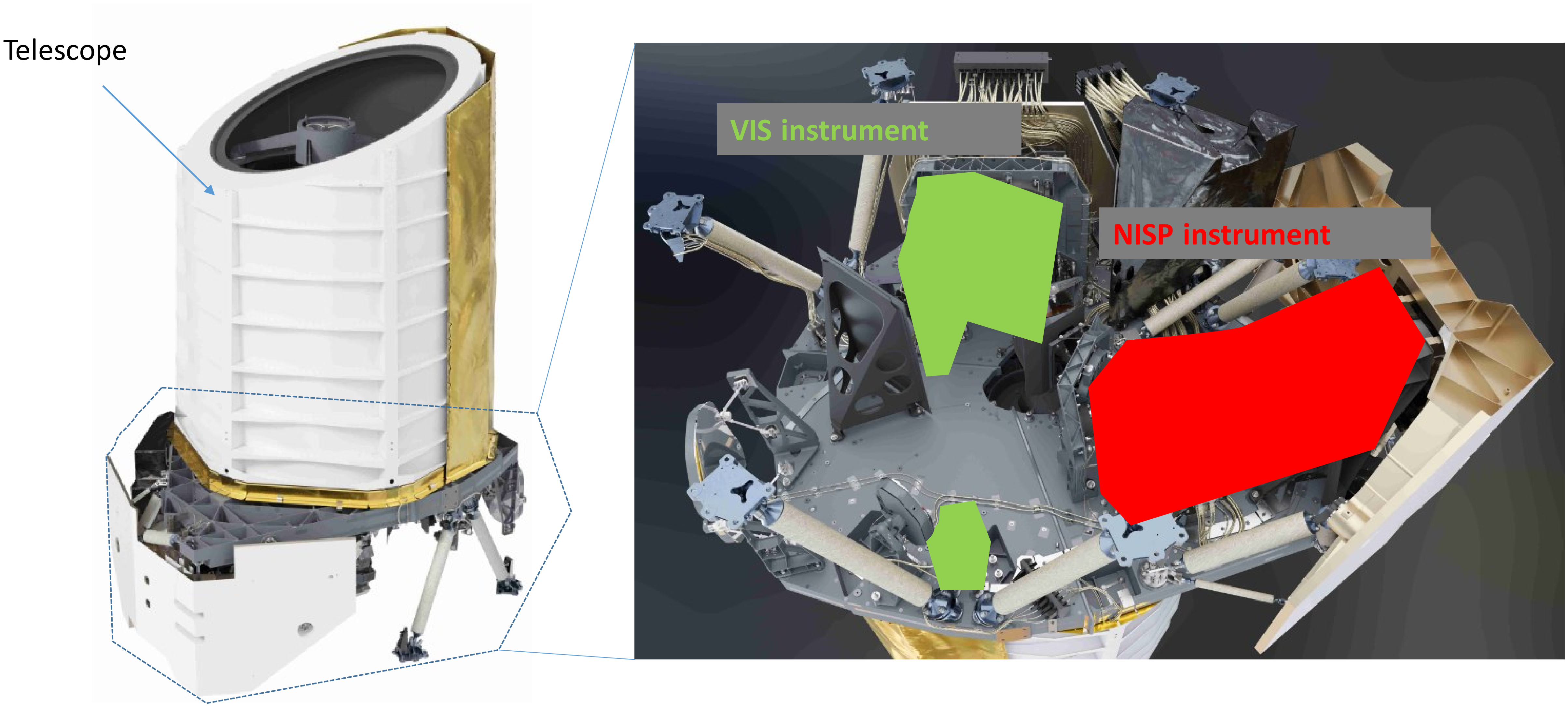


- 36 CCDs, **604 Mpixel**,
- 12 µm pixels
- 0.1 arcsec pixel on sky,
- **0.54 deg² per field**
- 1 filter Y (R+I+Y)
- Bandpass 550-900 nm





The Payload Module



VIS :
high quality imaging (resolution 0.1arcsec)

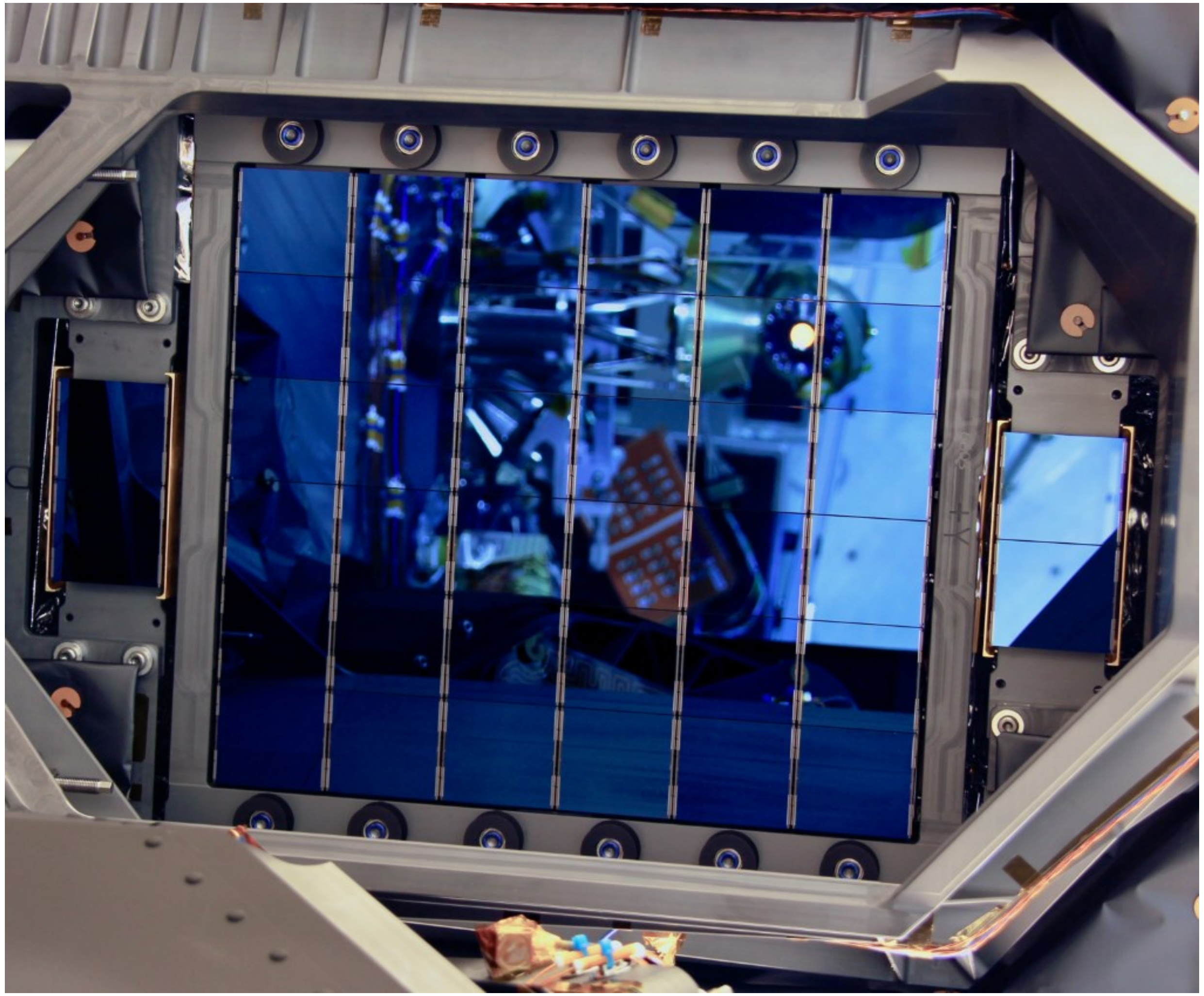
NISP:
NIR photometry of all VIS galaxies (resolution 0.1arcsec)
NIR low resolution (0.3arcsec) spectra ($\lambda/\Delta\lambda$~ 250)

NIR photometry + VIS data -> 1.5Bil redshifts
$\sigma(z)/(1+z) < 0.05$

NIR spectrometry (Hα) -> 35Mil redshifts
$\sigma(z)/(1+z) < 0.001$

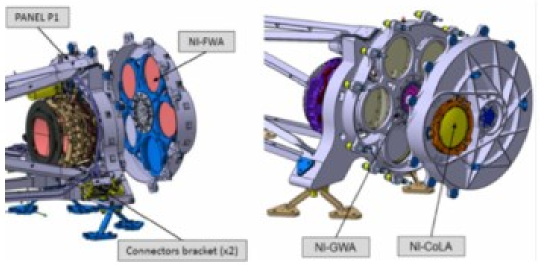
PLM baseplate – Courtesy of ADS-TASI-ESA

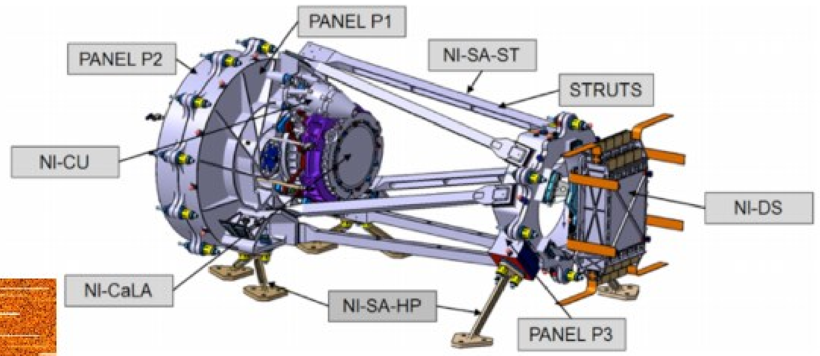
***VIS**ible Imager*

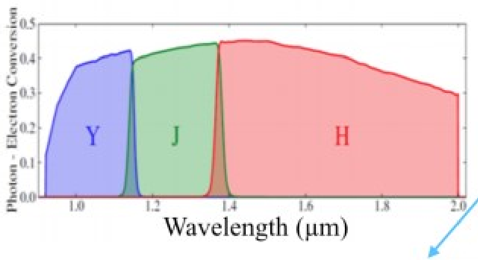


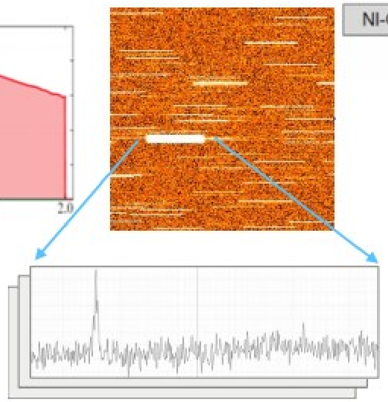
- Focal plane instrument, no optics;
- limiting magnitude: m_{AB}=24.5 extended sources at 10σ
- spectral range λ: 550–900nm
- focal plane: 6x6 CCDs (e2v, 12x12μm^2 pixels, 4096x4096 pixels)
- plate scale: 0.1 arcsec/pix
- FOV: FoV=0.787x0.709 deg^2
- focal length: f=24.5 m
- Data rate: ≤ 520 Gb/day

*The **Near** **Infrared** **Spectro****Photometer***









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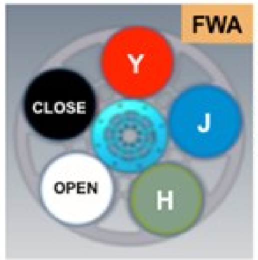
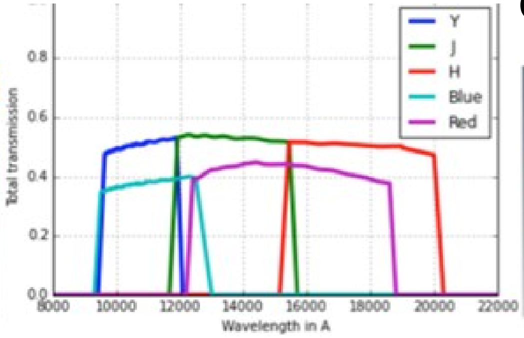
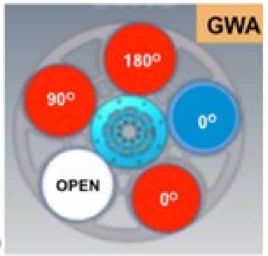
Filter Wheel

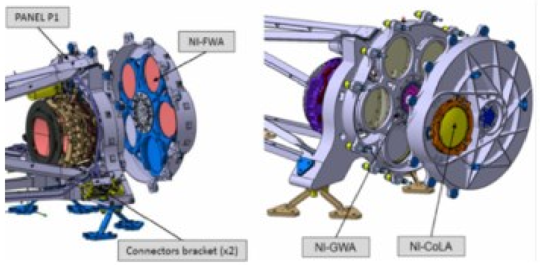


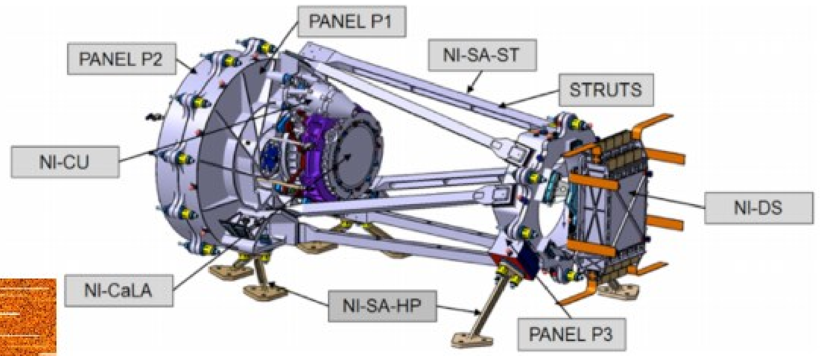


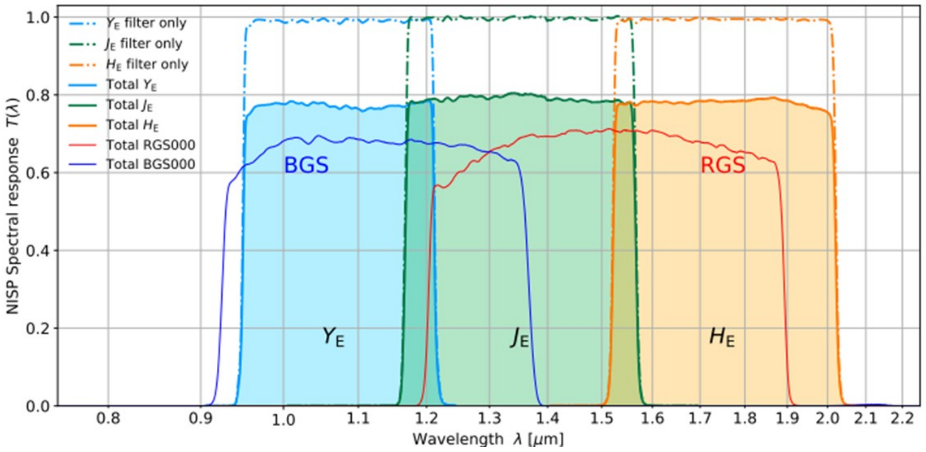
Grism Wheel



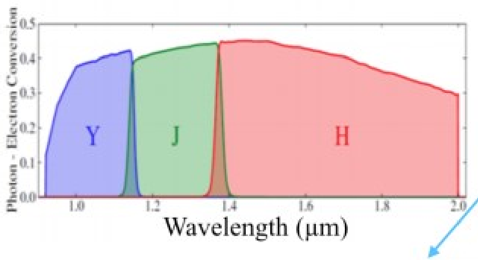
*The **Near** **Infrared** **SpectroPhotometer***

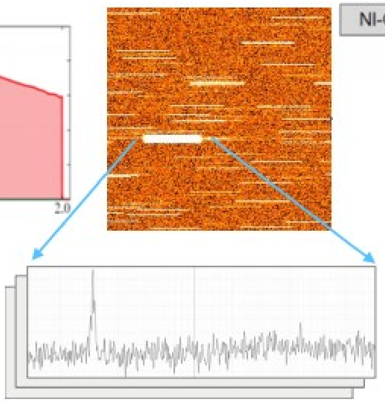






M.Schirmer et al., "Euclid preparation. xiii. the nisp photometic system," Astronomy Astrophysics 662, A92, 2022





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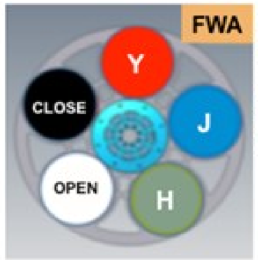
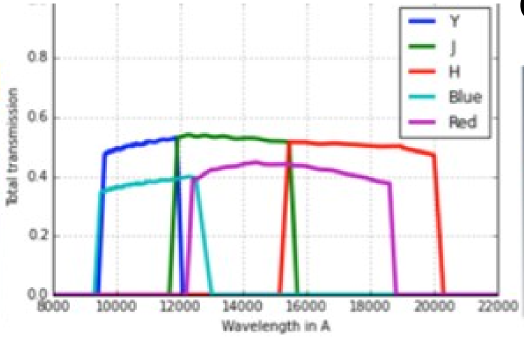
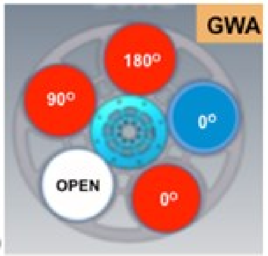
NISP

Grism Wheel

Filter Wheel







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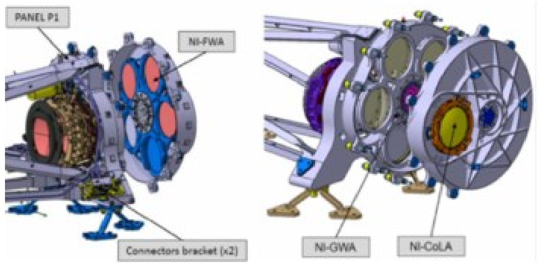

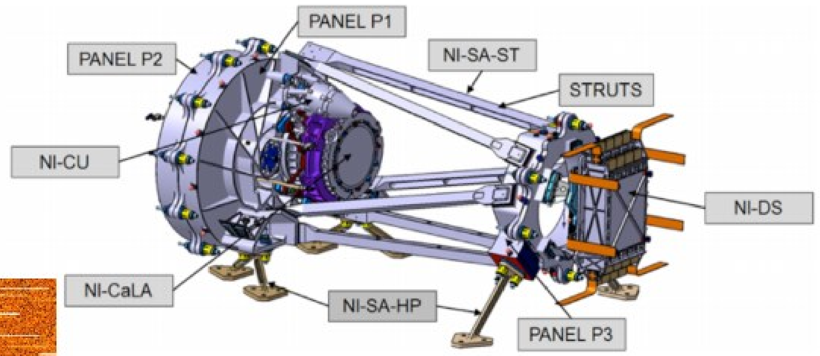

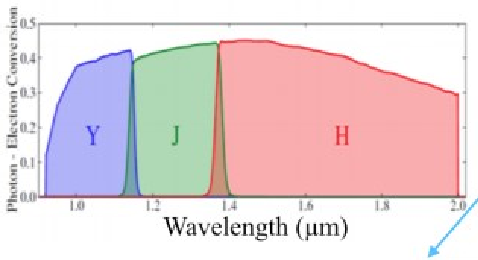

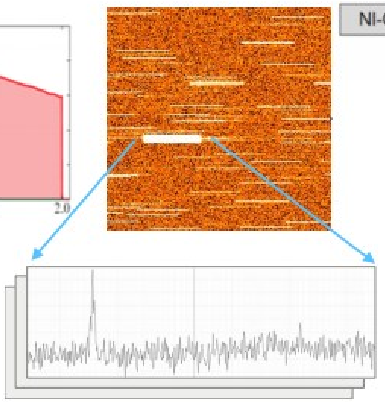

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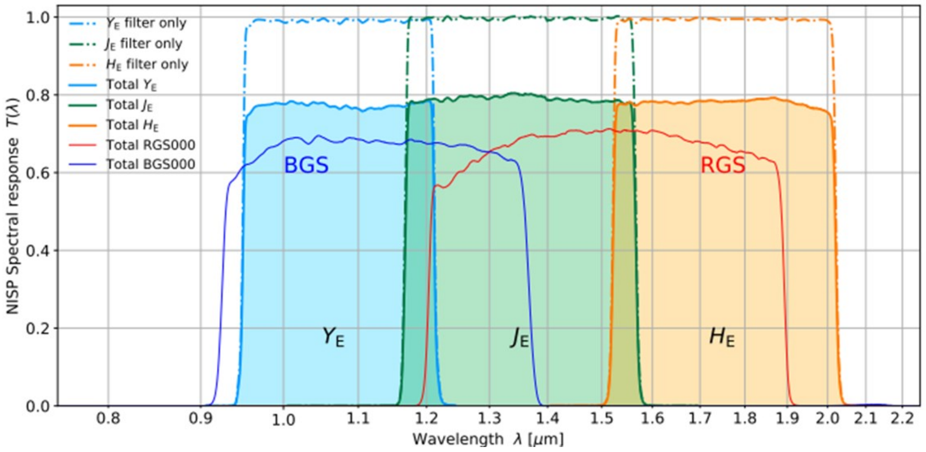

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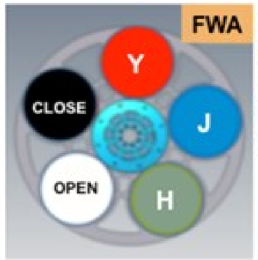

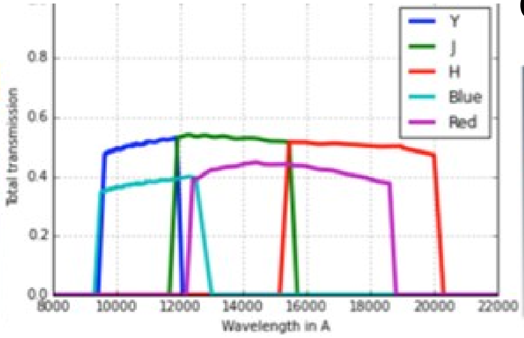

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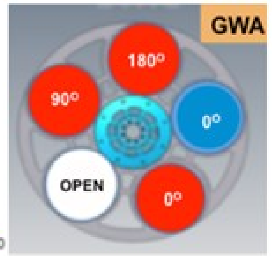
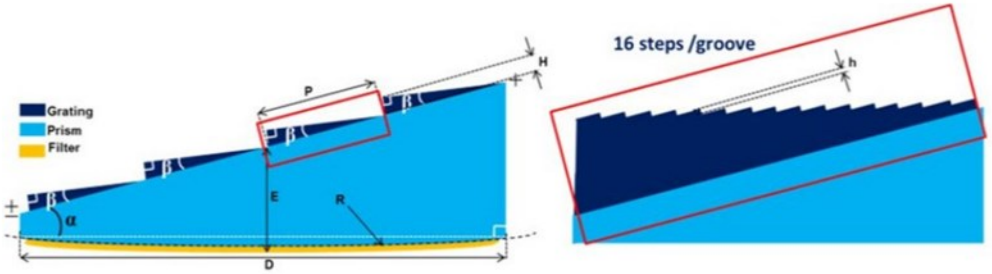
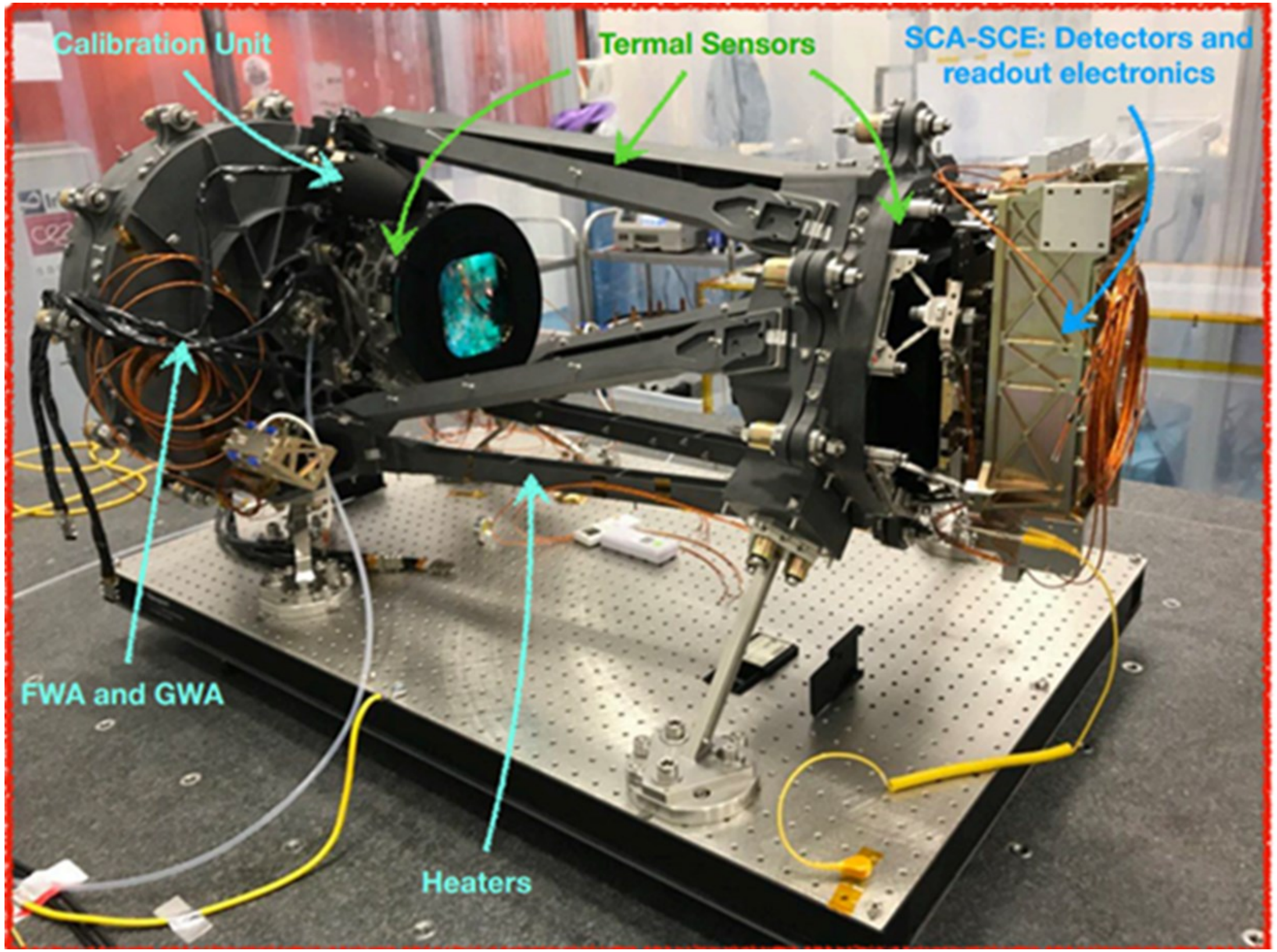




Grism Layout

- Box Size: 1.0 x 0.5 x 0.5 m^3
- Mass: 160 kg
- Power: 200 W



*The **N**ear **I**nfrared **S**pectro**P**hotometer of the Euclid mission*

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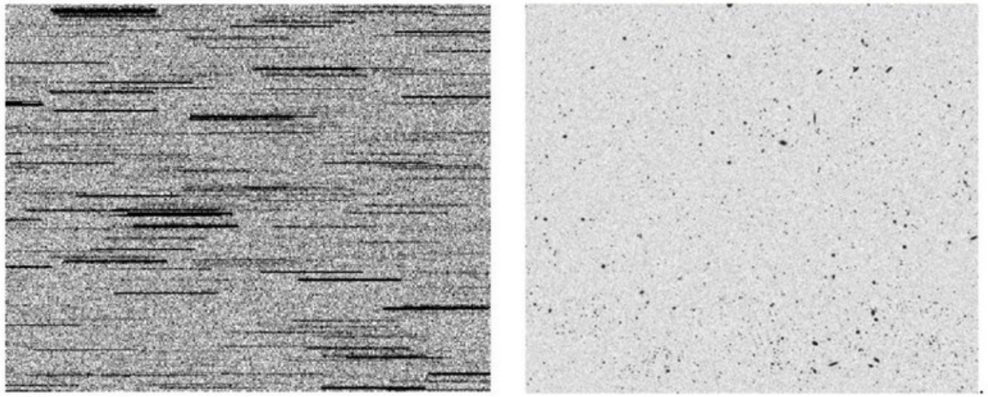
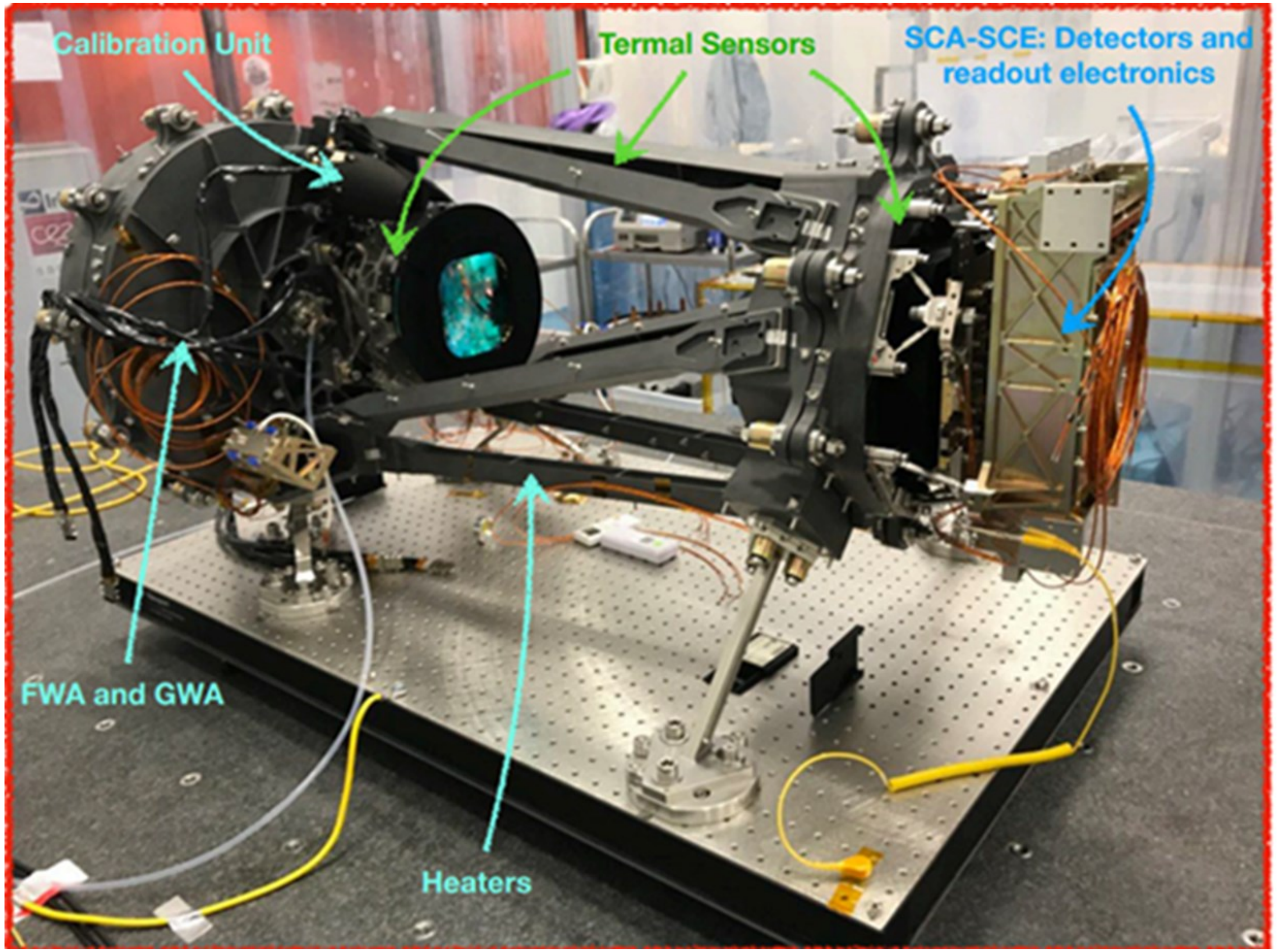


Simulation of a typical slitless observation (left) and its direct image (right) - Courtesy Euclid Consortium/ESA

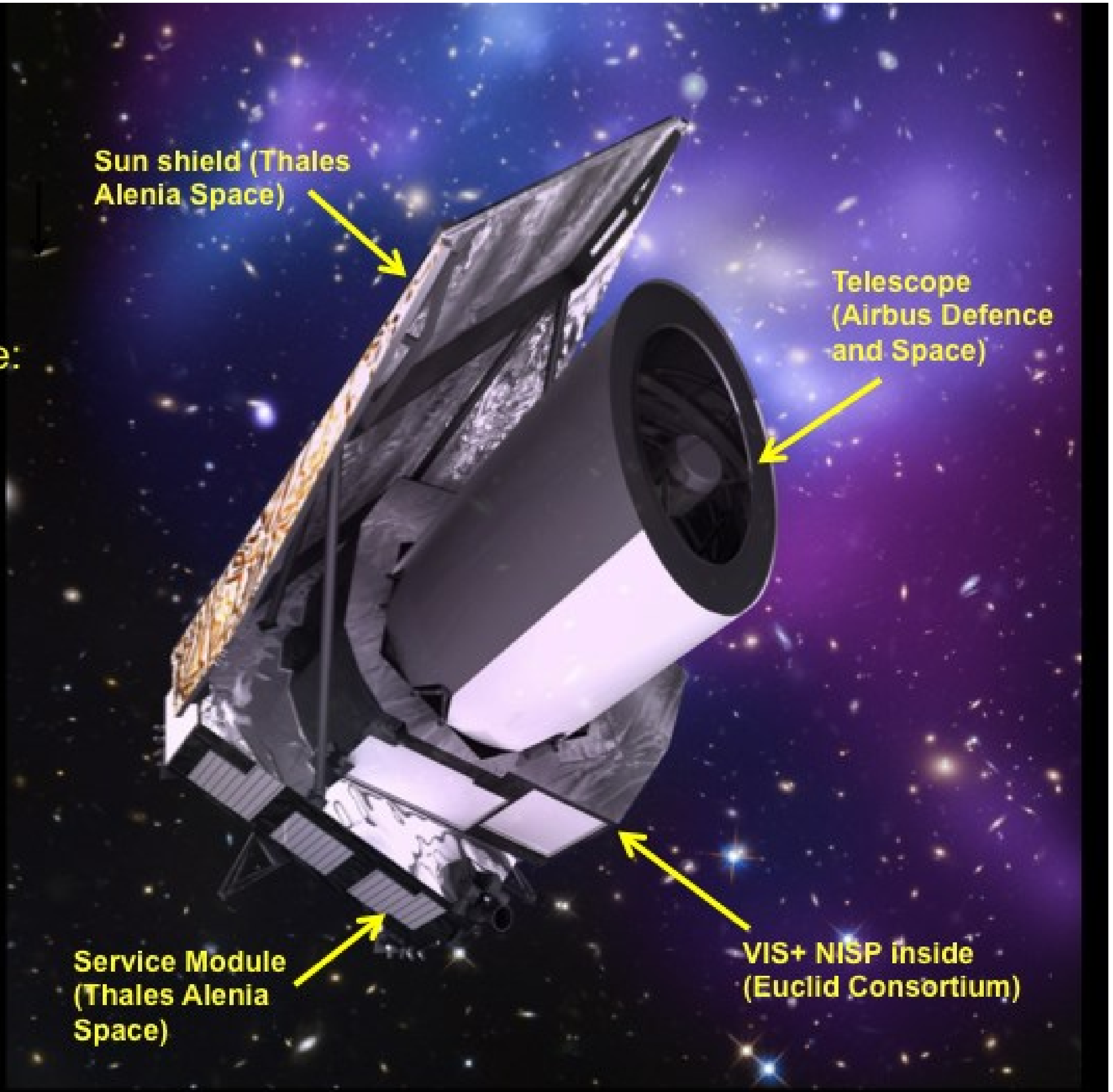


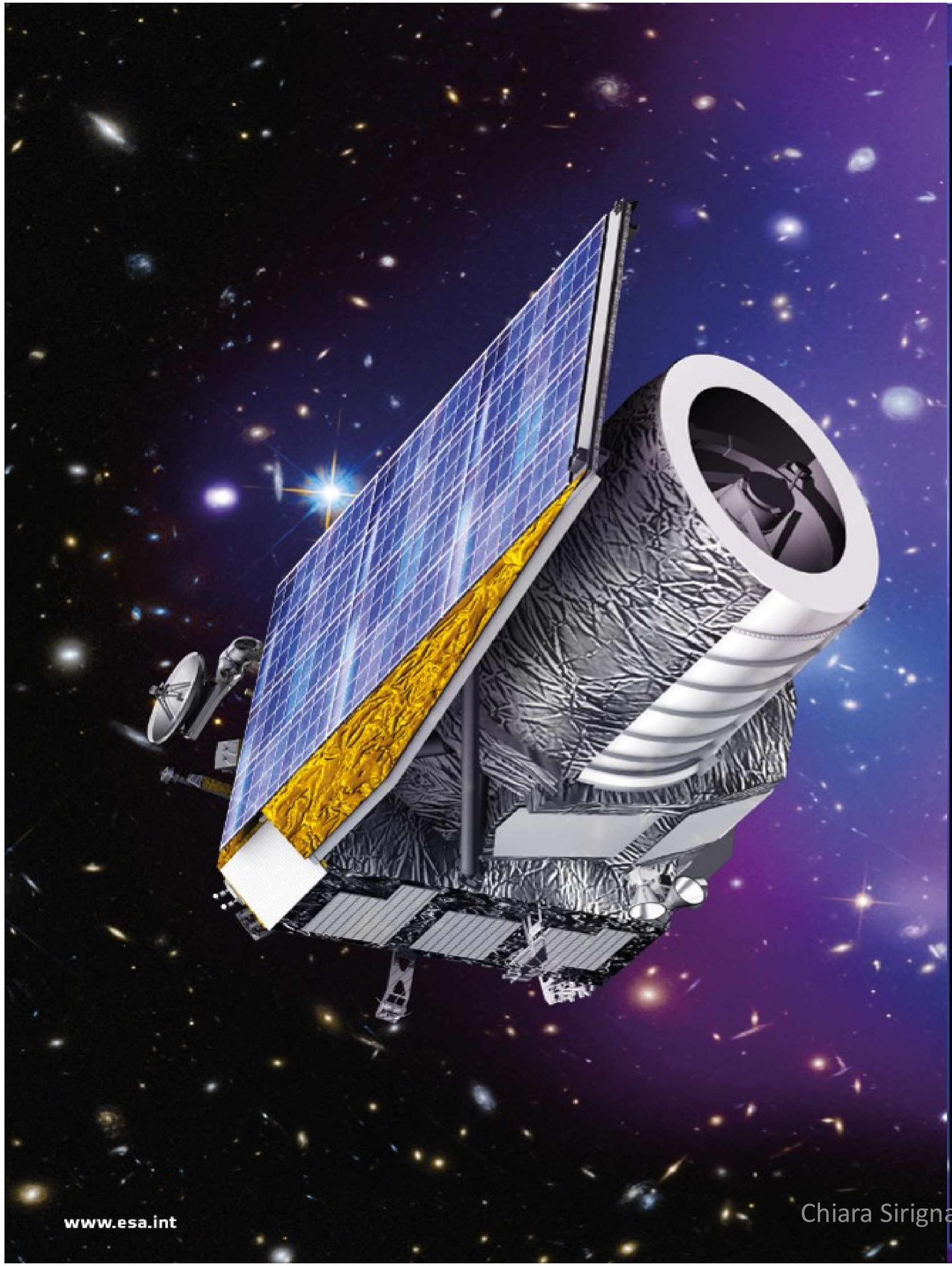
- Total mass satellite:

2200 kg

- Dimensions:

4,5 m x 3 m

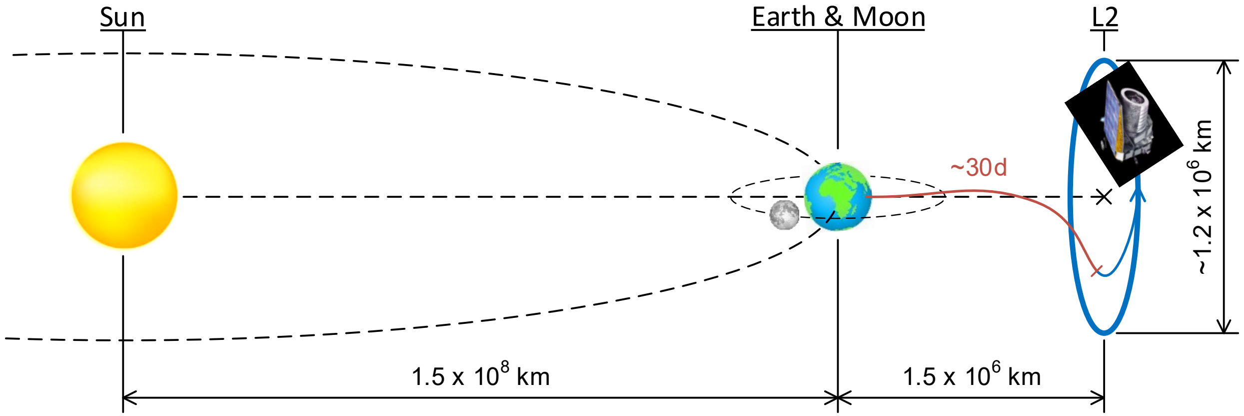




- **ESA mission**
- Selected in Oct. 2011 - Fully funded
- Partners: ESA, TAS, Airbus DS, Euclid Consortium (E
- Overall mass: ~2020 kg, Power : 1920 W (EOL)
- Data rate: 850 Gbit/day
- Telescope (T=125K, passive):
  - 1.2m aperture primary, 3 mirror Korsch anastigmat
- 2 Instruments (VIS, NISP) – T = 100-140 K (passive)
  - Wide field instrument, VIS: 36 e2v 4kx4k CCDs $0.55<\lambda<0.92$ µm, 576 M pixels, 0.11 arcsec/pix, 0.53 deg^2 FoV
  - Photom. (Y, J, H) +spectrom.: 16 H2GR HgCdTe detectors;
  - 64 Mpixels, 0.30 arcsec/pix, 0.53 deg^2 FoV (=VIS)
  - Grism slitless spectro (1B + 3R grisms) $0.92<\lambda<2.05$ µm, R>250
- Downlink Rate: X/X + K-band to Ground Station 55 Mbits/s. 850 Gbit/day to transfer 4hr/day.
- Ground Segment: ESA (50%,) EC (50%, EC leads science and external data): 1.5 billion galaxies for WL, 30 million redshifts, 12 billion sources (3sigma)
- L2 orbit
- Launch Vehicle – Soyuz-Fregat
- Launch date 2023 from Kourou space port
- 6.25 years mission + additional surveys (exopl, SN)
- Main surveys: 15,000 deg^2+40 deg^2 2 mag. deeper
- Science drivers: DE
- Science leads: Euclid Consortium

The Euclid survey strategy

Euclid's survey strategy is based in a step-and-stare mode imaging with a FoV ~ 0.5 deg^2 .
Global wide survey coverage of 14000 deg^2 of extra-galactic sky obtained during the mission lifetime of 6yrs.
Deep-survey with $\sim$2 higher magnitudes than the Wide-survey over an area of $\sim$ 40deg^2 .
The exclusion zones are ±25° Galactic plane latitude to avoid stellar contamination and ±15° Ecliptic plane latitude to avoid zodiac light contamination.



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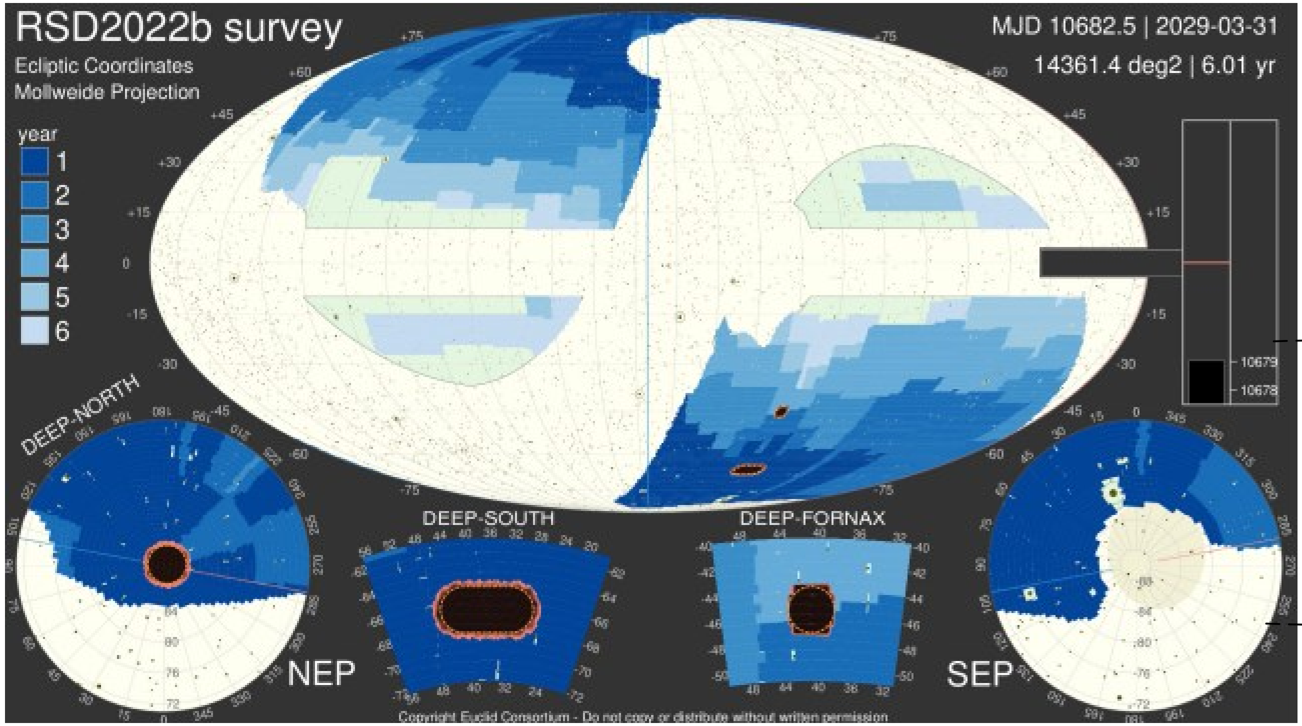
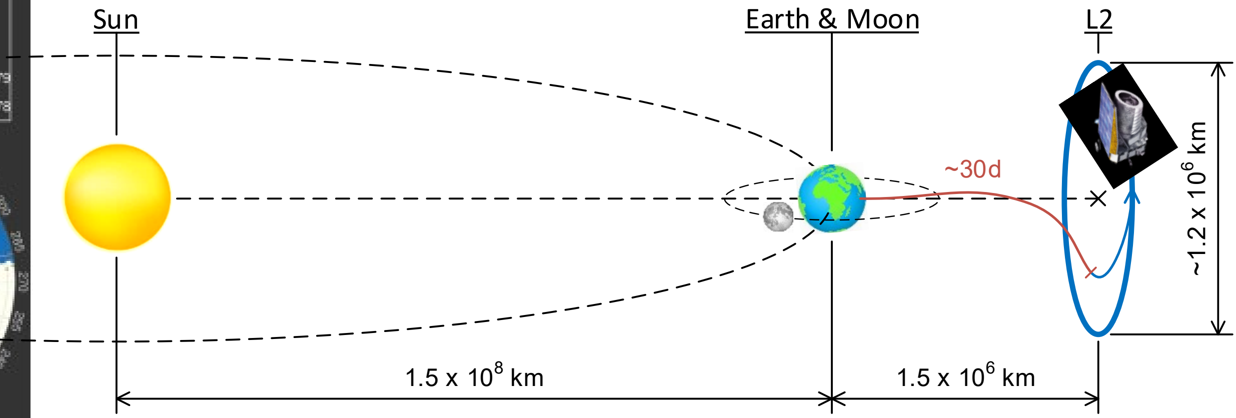
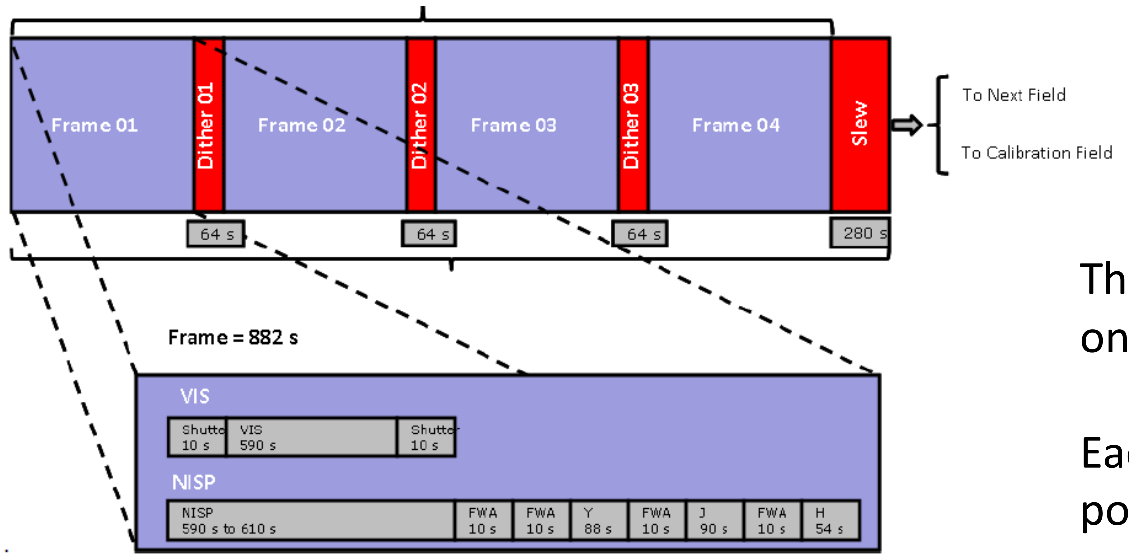


Image courtesy of J. Dinis

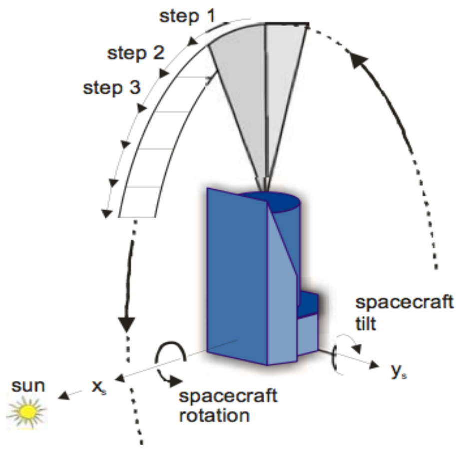


The Euclid observation strategy



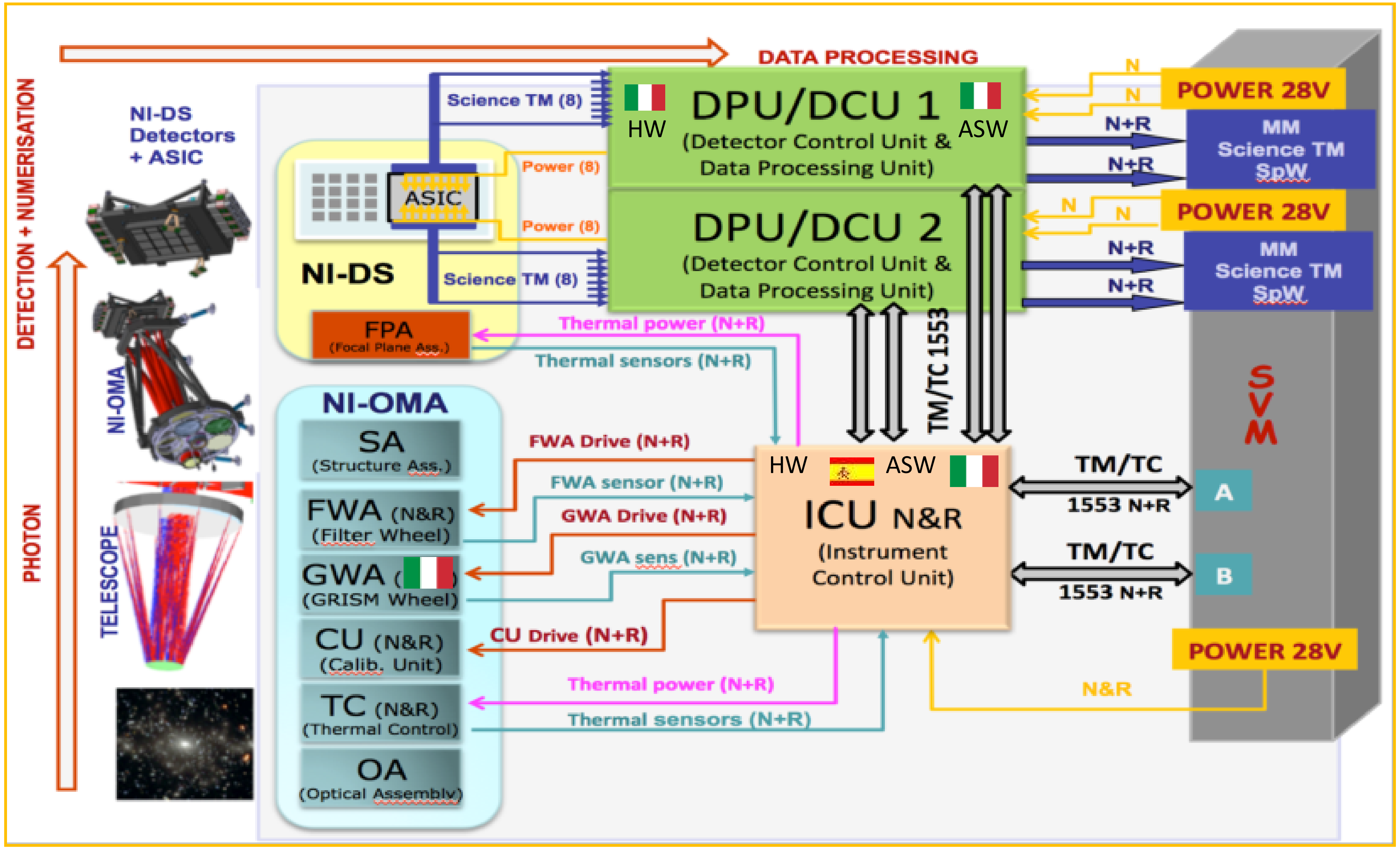
The Dithering technique is used to correct instrumental effects on the images and to get rid of dead areas in the FoV.

Each observation is done after a slight change in the telescope pointing (Dither slew).



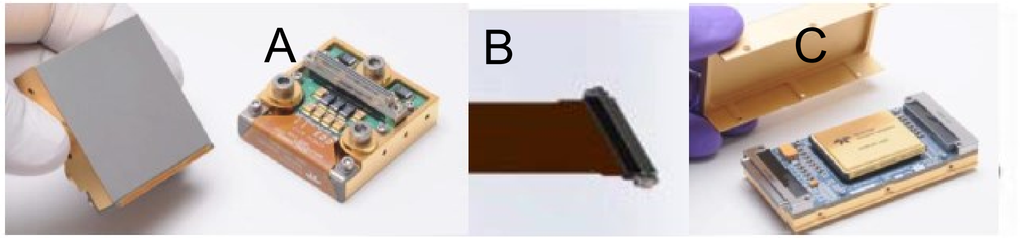
NISP architecture

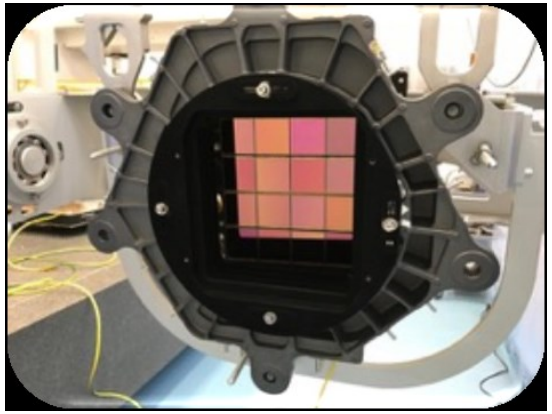
Detector ← NISP Warm Electronics → Spacecraft



NISP detectors and data acquisition

The NISP focal plane is composed by 16 H2RG detectors 2048 × 2048 pixels, 0.3 arcsec/pixel, by Teledyne, coupled with a dedicated readout electronics (SIDECAR ASIC)





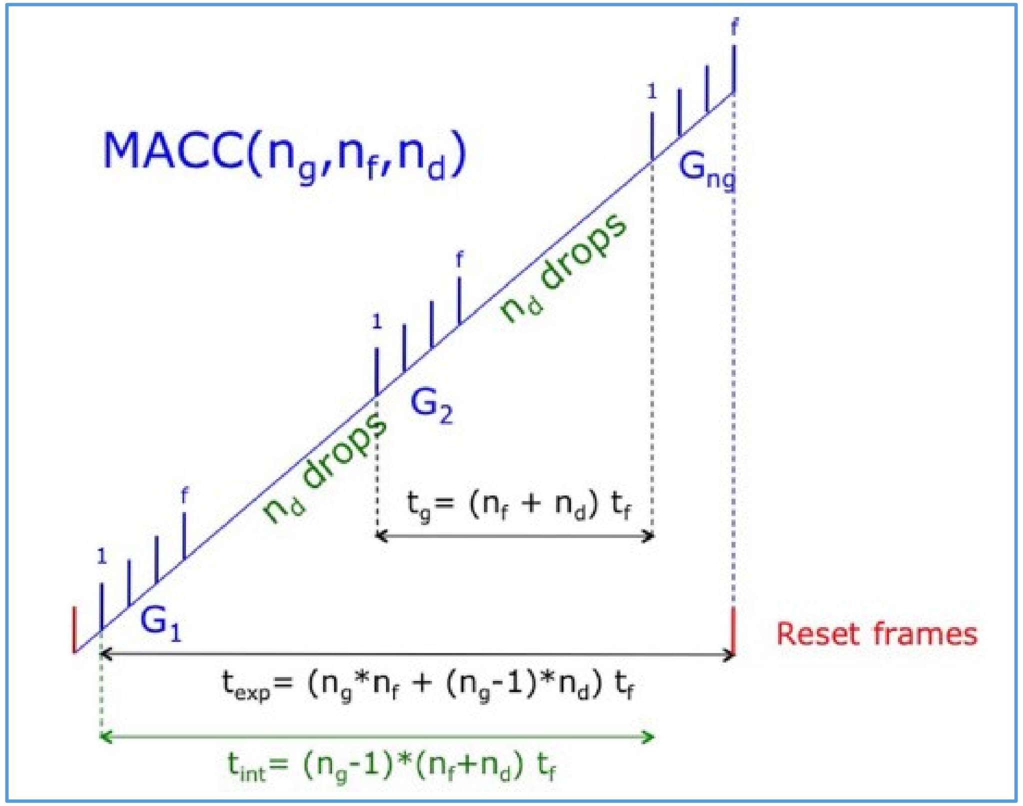
Detector triplet (SCS):

A - Sensor Chip Assembly (SCA) Teledyne HAWAII2RG
B - Flex Cryo Cable
C - Sensor Chip Electronic (Sidecar ASIC)

Each pixel can be read independently and the reading is non-destructive, so it is possible to perform several successive measurements and to average them in order to reduce the noise. (Multi Accumulation MACC)
SCE supports a readout mode that uses 32 parallel output amplifiers. Each output addresses a 64 × 2048 vertical sub-array in the SCA. The acquisition firmware yields a minimum exposure time of 1.41 s with a pixel rate of 100 kHz.

NISP detectors and data acquisition

The readout technique is a multiple accumulated sampling MACC(n_g, n_f, n_d); n_g is the number of equally spaced groups sampled UTR, n_f is the number of frames per group and n_d is the number of dropped frames between two successive groups. Readout frames in the same group are mediated. This is called ***coadding,*** it has the advantage of reducing the Gaussian distributed pixel readout noise.

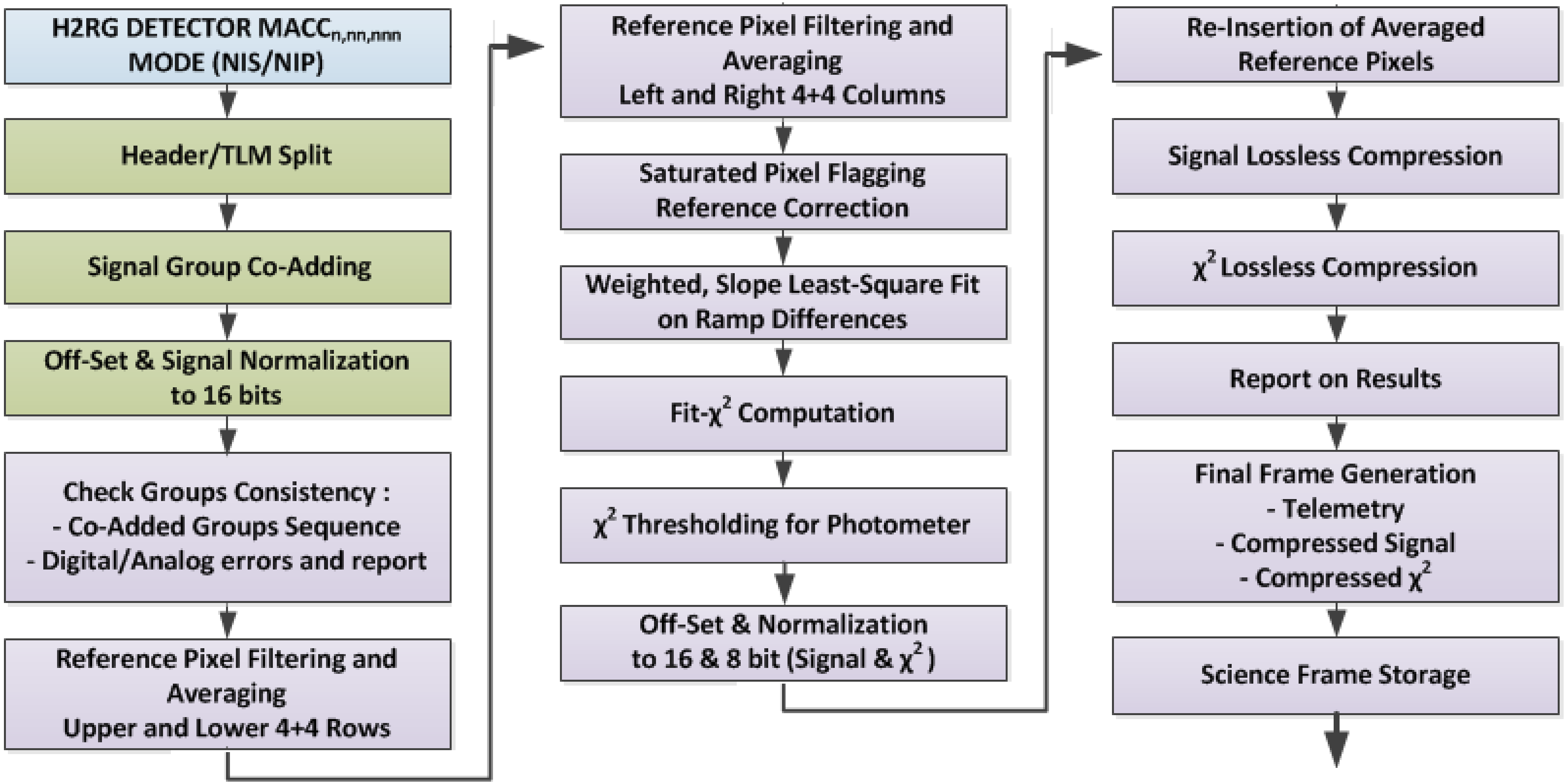


The signal read for each group is fitted and the slope and Quality parameter is evaluated for each pixel.

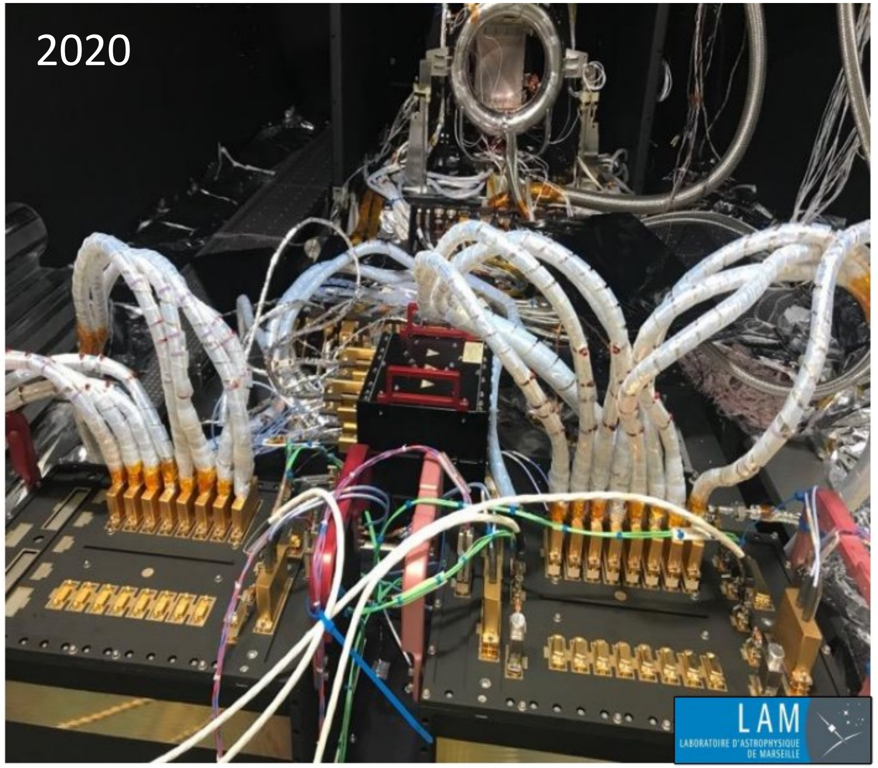
Such processing is performed on board and only reduced Data (slope + quality parameter) are copied to satellite memory and then to ground.

MACC parameters are optimized for the wide survey, Photo mode Exposures are 112s and Spectro mode are 576s.

NISP on-board data processing



NISP performance tests on ground



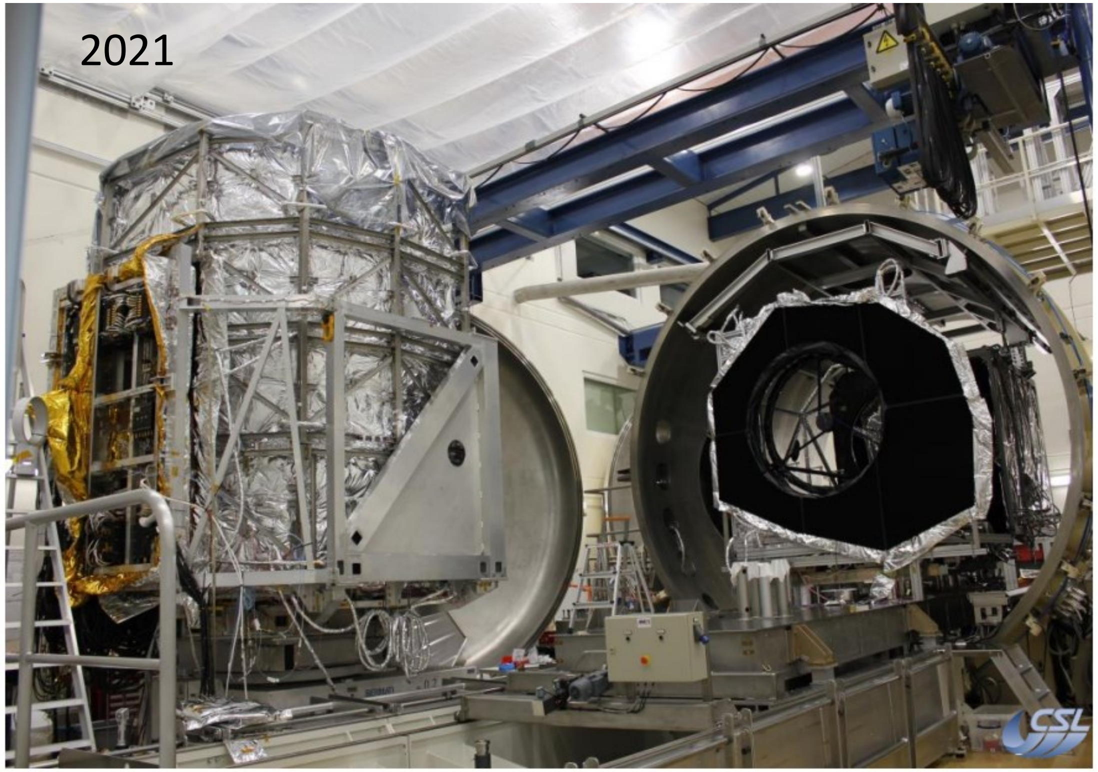
Laboratoire d'Astrophysique di Marseille, France (NISP tests):

- Detector characterization

- Optical system & detector performances (TV3)

~40K commands executed, ~19K images acquired per detector

~300K transferred files, continuous 72h of wide survey



SPIE

Centre Spatial de Liège, Belgium (end-to-end tests):

- end-to-end Telescope-PLM performances

1 month of nominal continuous operations:

NISP/VIS autocompatibility and common focus

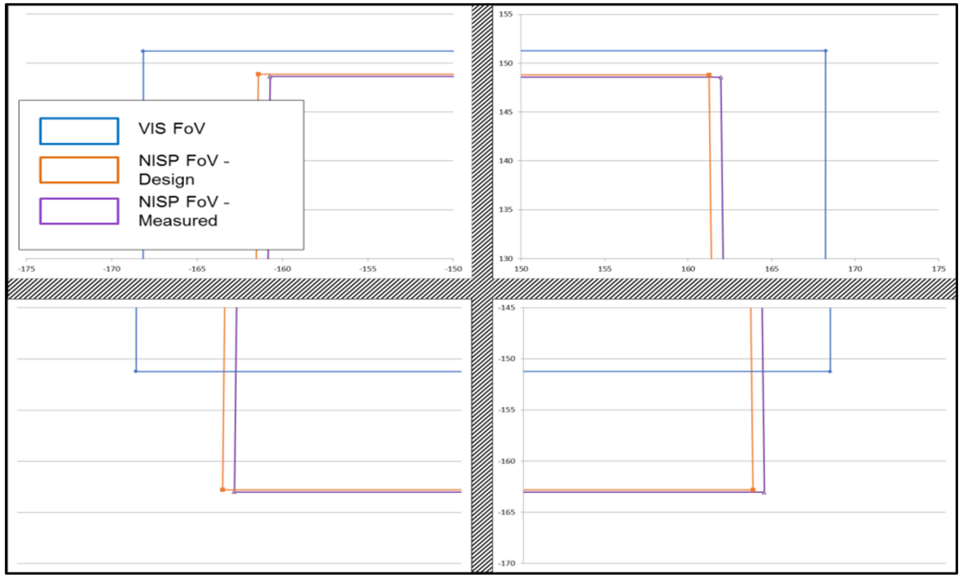
NISP photometric PSF verification and spectrometric dispersion verification

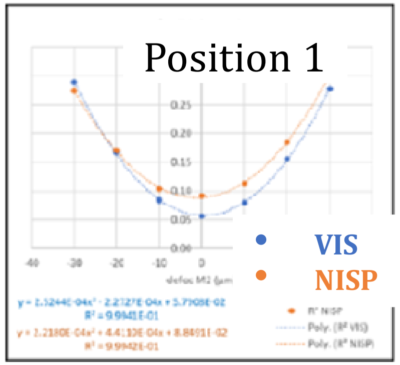
NISP performance tests on ground

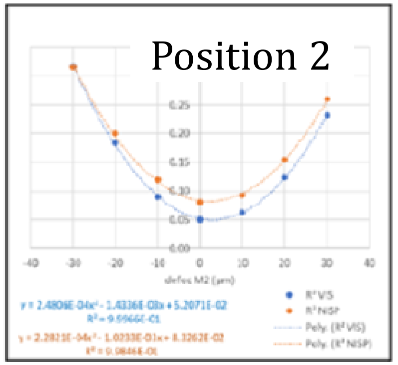
- evaluate thermal background noise (dark exposures), flat field and persistence (all in spec)
- identify problematic pixels (disconnected, noisy, bad quality factor) maps over the focal plane
- Confirm common focus for VIS and NISP
- reconstruct the PSF photo and spectro mode using monochromatic light sources
- evaluate the spectral resolution using a polychromatic light source

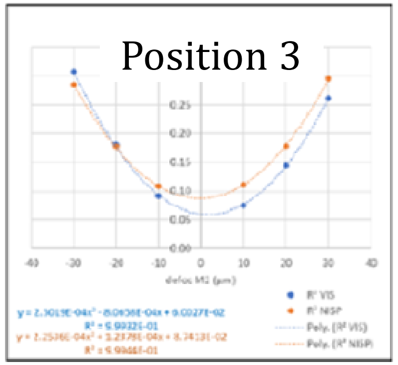
VIS-NISP co-alignment and common FoV

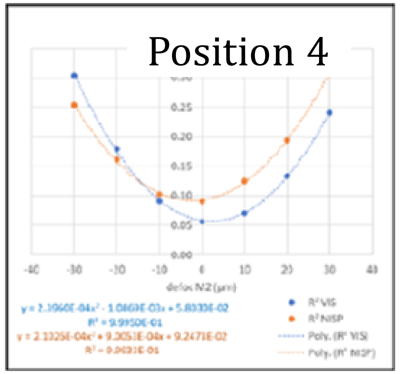
The relative defocus between both channels has been found to be at maximum 166µm at the edges of the FoV, (< 400µm required)

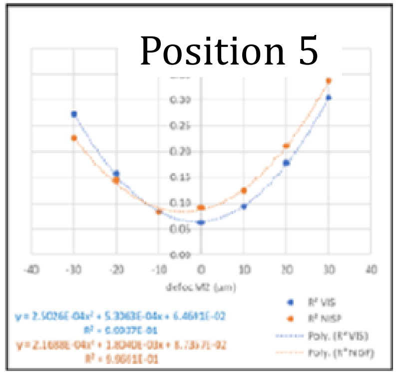










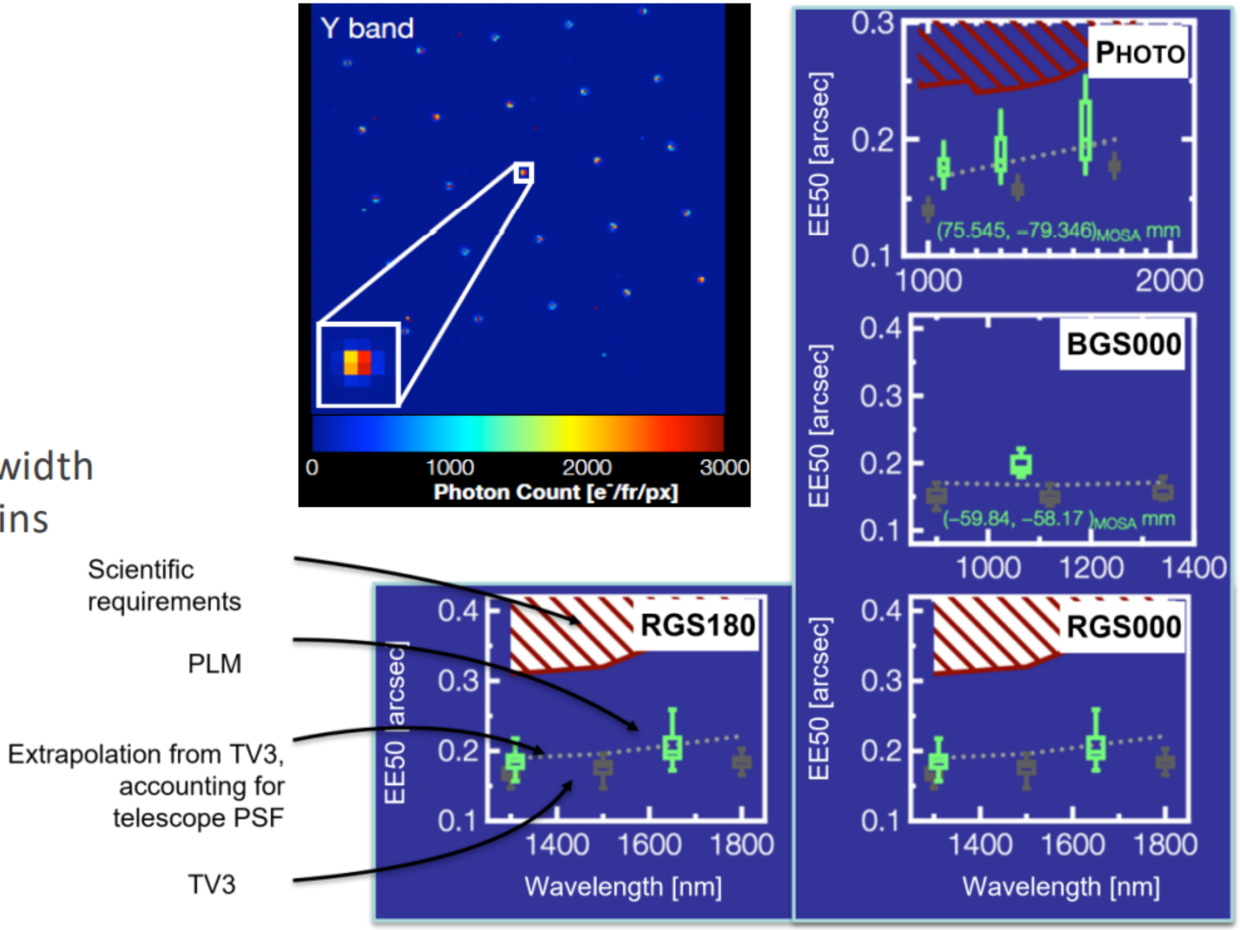


Courtesy ADS

NISP performance tests on ground

- 1 long exposure with 25 PSF flashes at different location (monochromatic point-like source)
- NISP well aligned with (M2 mirror is focalized on VIS)
- PSF modelled by 2D asymmetric Erf function (Gaussian px integration)
- 50% Encircling Energy radius (EE50) deduced from the width of the Gaussian (centroid position of the PSF that contains the 50% of the total PSF's energy)

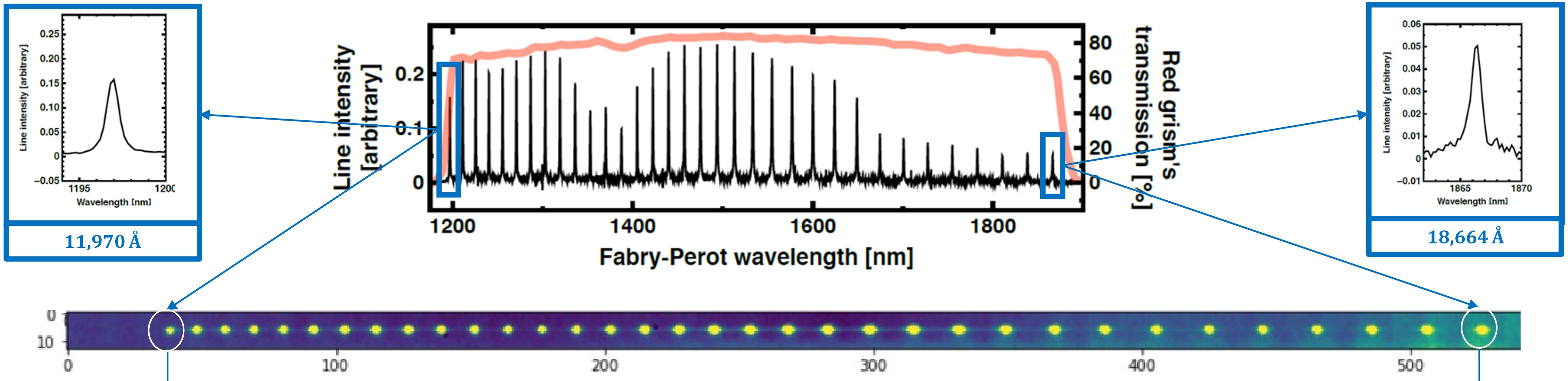
<u>NISP PSF EE50 better than scientific requirement!</u>



Courtesy of W. Gillard - CPPM

NISP performance tests on ground

NISP spectral calibration was assessedusing **a polychromatic light source (33 peaks)**



10 Å/px ≤ 13.7 Å/px ≤ 16 Å/px*

$\lambda_{obs} = \lambda_{int}\,(z + 1)$ and $\Delta z/z \leq 0.001$ for Hα at z = 1.5 translates into an accuracy required of **9.85 Å ⇔ 0.71 pixel**

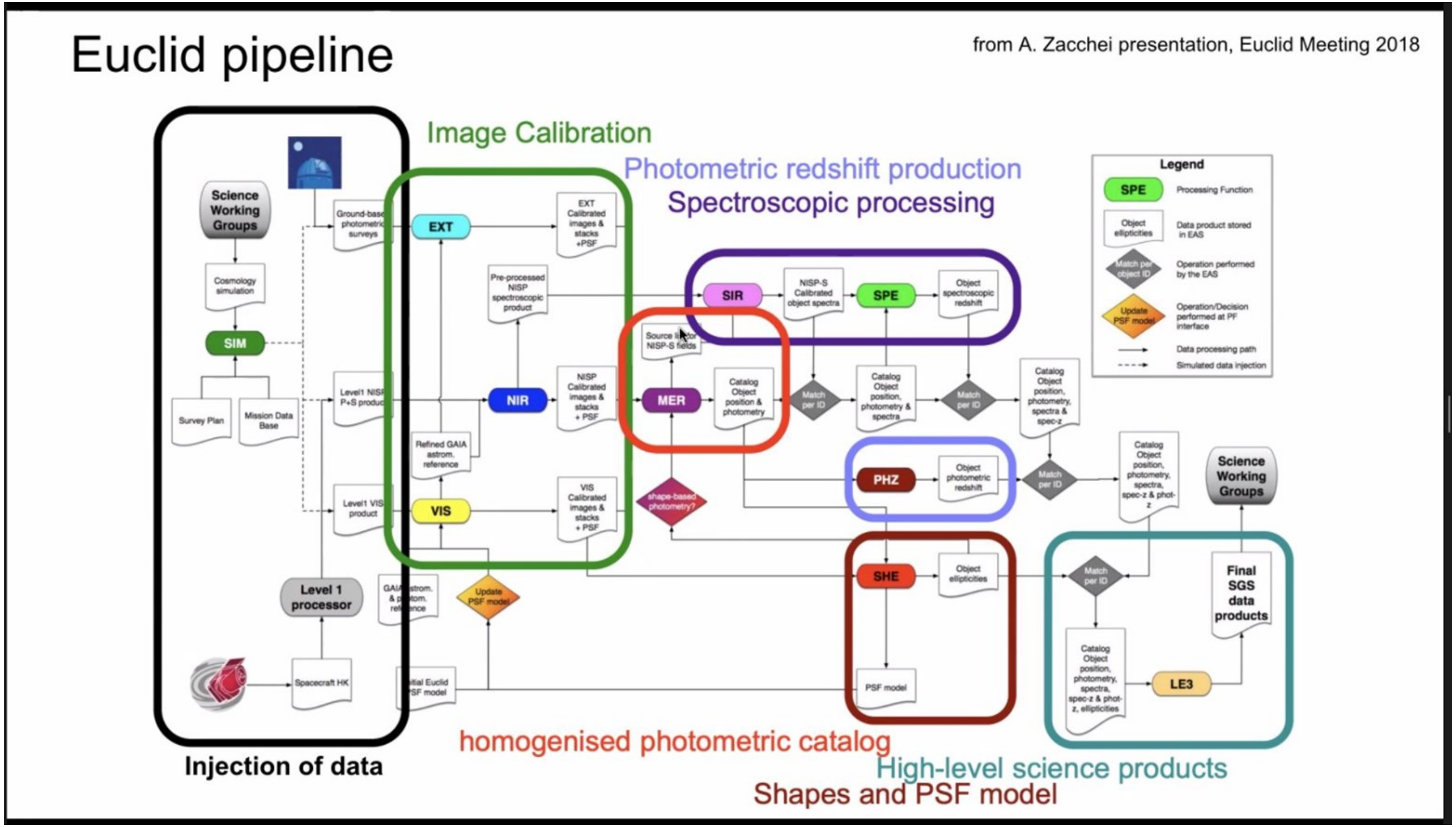
$\Delta z/z \leq 0.001$ ⇔ $\boldsymbol{\sigma_\lambda < 1}$ **pixel!**

*Mean resolution measured on an image taken with the RGS180 on detector 41 within the NISP specifications.

Resolution Validated for:

- BGS000 (12.4 Å/px)
- RGS000 (13.7 Å/px)
- RGS180 (13.7 Å/px)

Euclid data processing



Euclid path before launch

After PLM performance tests the satellite has been assembled in Torino by TASI and shipped to Cannes for the final Thermal-Vacuum functional tests (…about to start next week), this will be the last step before launch.

Euclid roadmap after Launch

The launch is technically feasible in 2023…..so stay TUNED !!