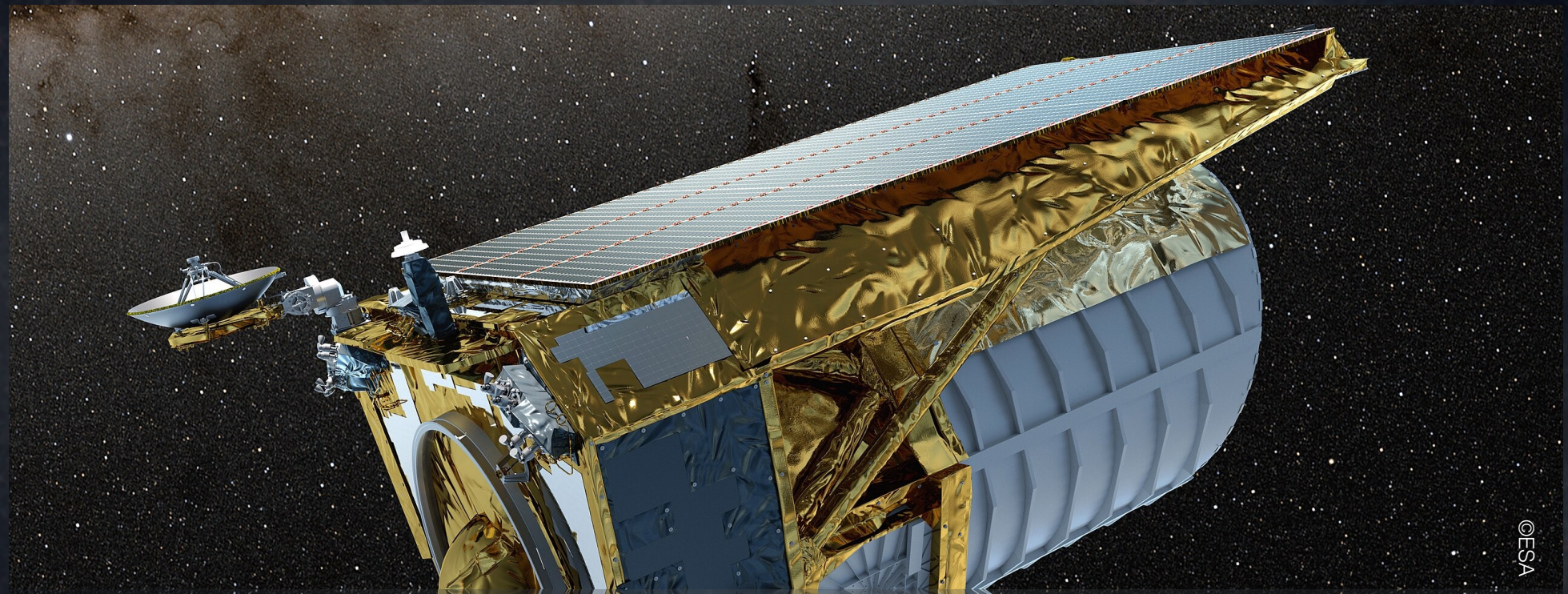


Status of the Euclid mission in flight

Stéphanie ESCOFFIER
CPPM

GDR CoPhy - 21 May 2024

Overview

- The objectives of the mission
- The Euclid design and its instruments
- Status in flight
- Euclid Images and more

©ESA - M. Pedoussaut

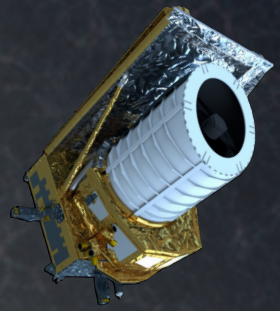
© NASA & ESA
Hubble Ultra Deep Field 2014 - HST • ACS • WFC3

Scientific objectives of the Euclid mission

Unraveling the nature of the dark side of the Universe

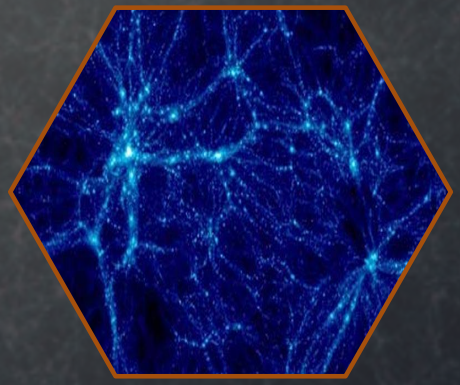
- Understand the reason for the acceleration of the expansion of the Universe
- Unravel the nature of Dark Energy & Dark Matter
- Test beyond General relativity

Stage IV spectroscopic galaxy surveys



Two primary probes:

Galaxy clustering



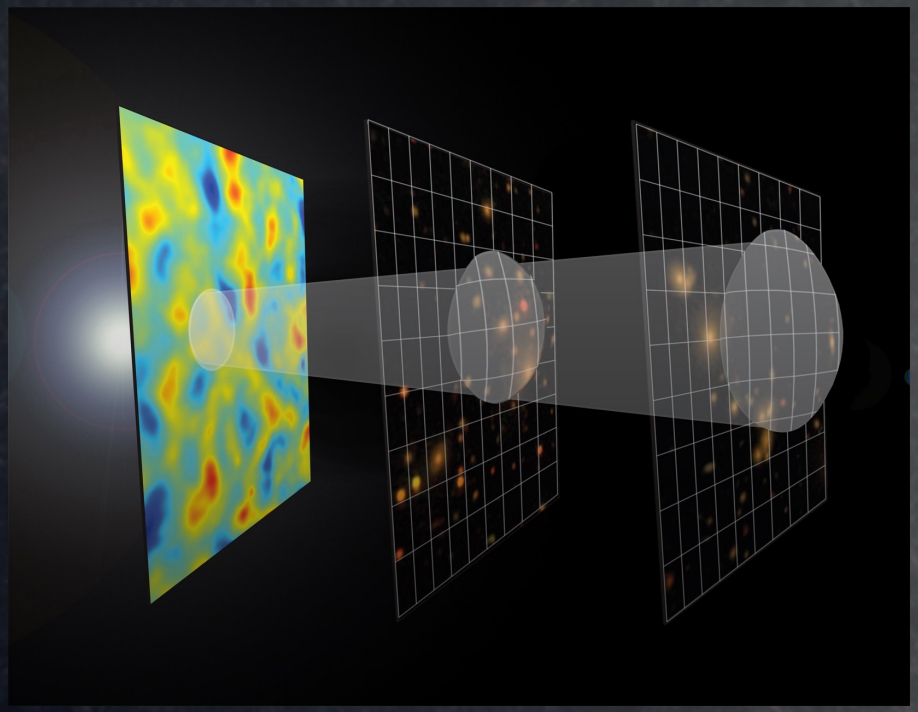
Dark energy

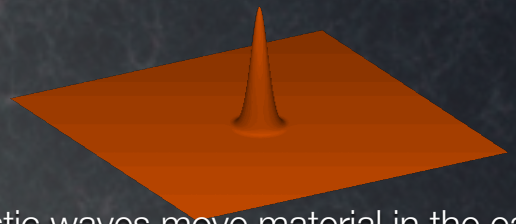
Weak lensing

Dark matter

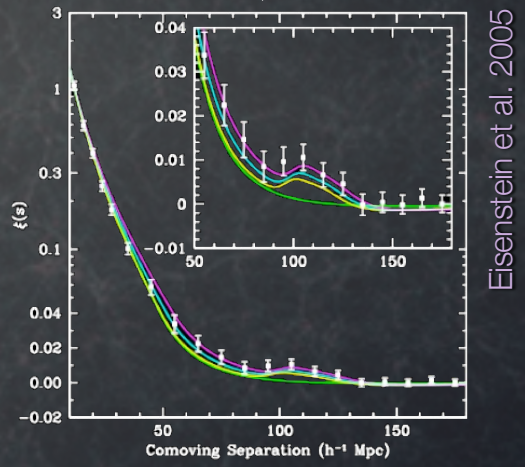
Galaxy clustering

Baryon Acoustic Oscillation (BAO) as a standard ruler





Acoustic waves move material in the early (<300,000 years) universe



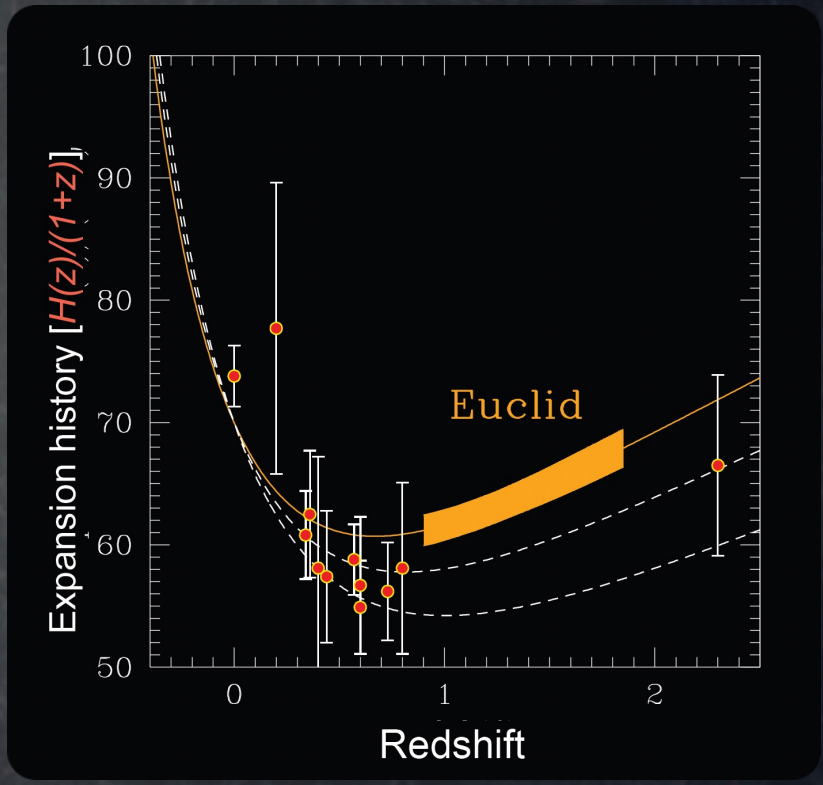
Eisenstein et al. 2005

The projected scale of the acoustic waves gives a standard ruler with which to measure the universe

Galaxy clustering

BAO as a standard ruler

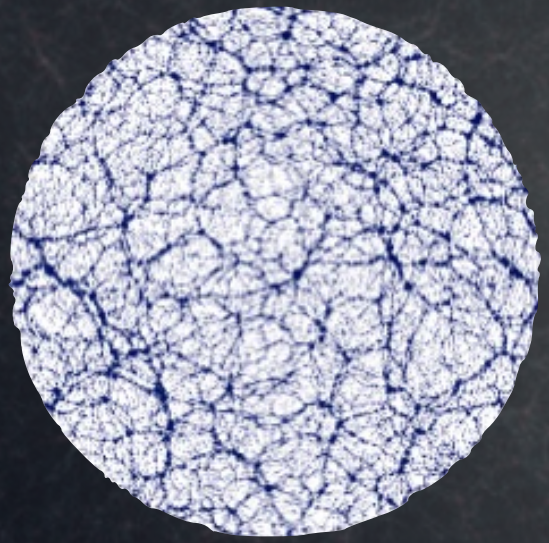
Sensitive to the expansion history H(z) of the Universe and to the angular diameter distance $D_A(z)$



Guzzo et al. Euclid SWG-GC 2016

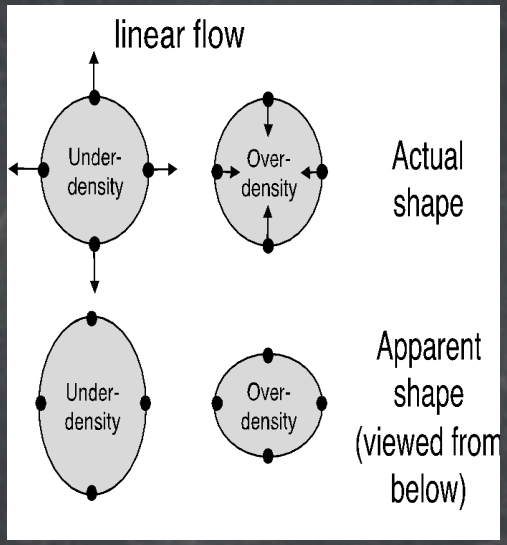
Galaxy clustering

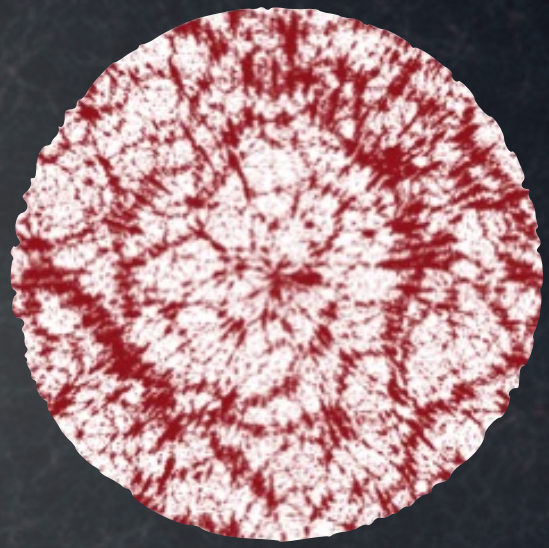
Redshift Space Distortions (RSD)



H. A. Feldman
https://feldman.ku.edu/

Real space distribution



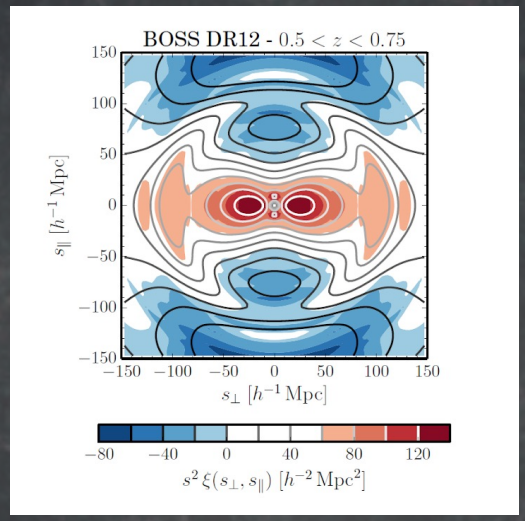


Redshift space distribution

Galaxy clustering

Using RSD to measure structure growth

$\xi(r_p,\pi)$

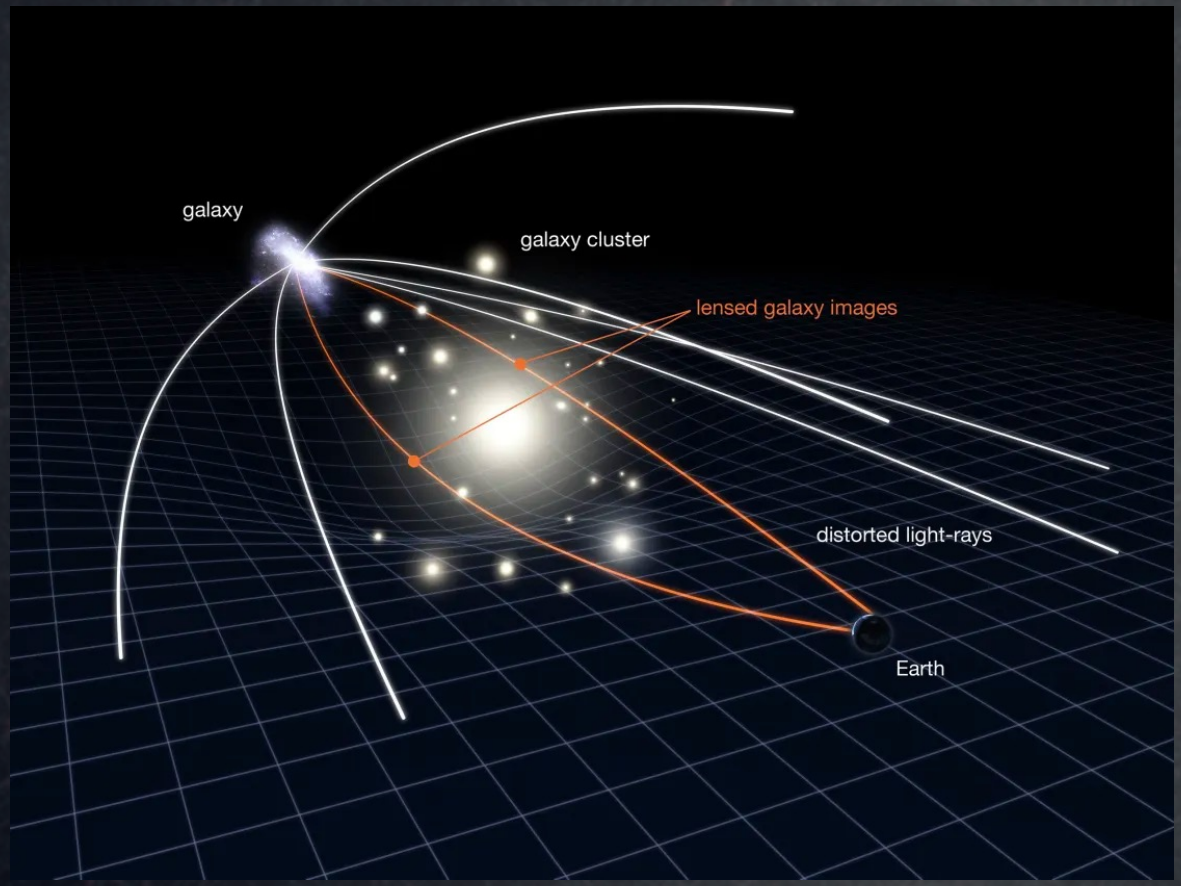


Alam et al 2016 (BOSS)

Ahisotropic BAO ring

RSD probe the growth rate of structure, and density-velocity relation
→ Test beyond general relativity

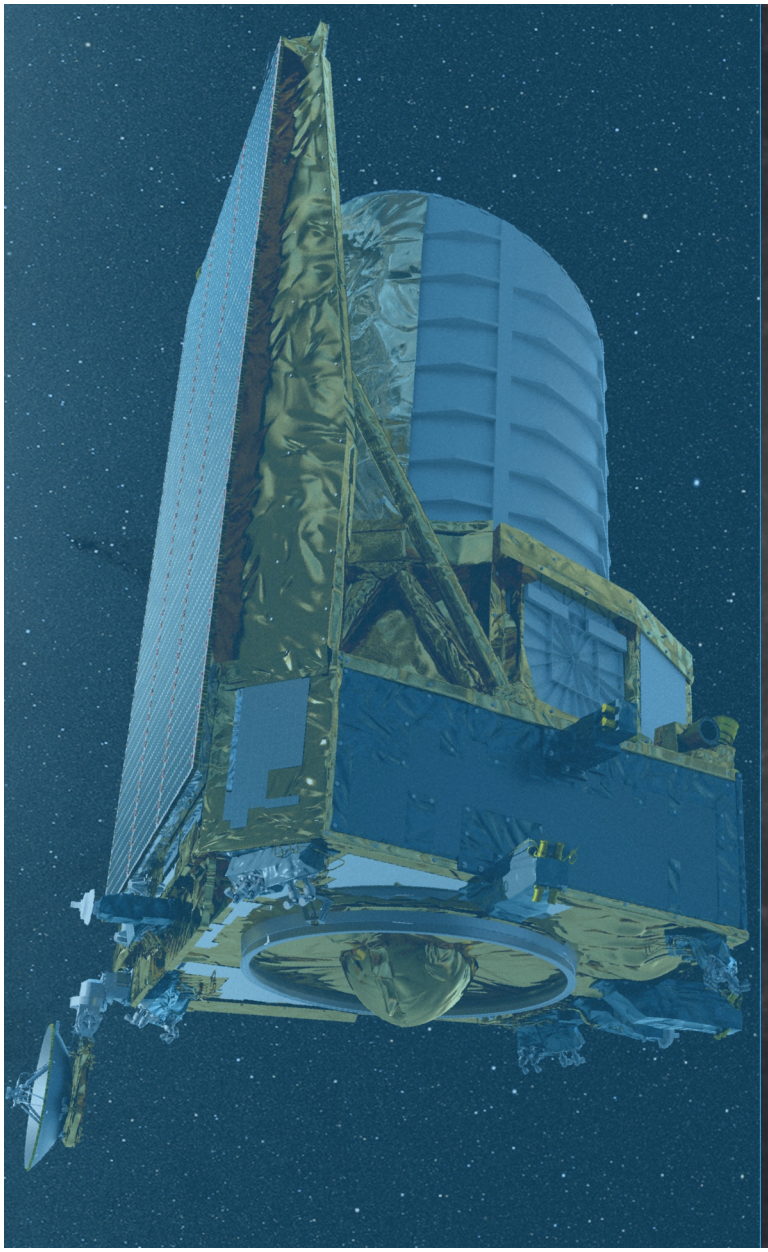
Weak lensing



L. Calcada / NASA/ ESA

Large-scale structures bend light from background galaxy, resulting in a coherent deformation at few arcmin scale at few percent level

- Direct measurement of gravitational potential along the line of sight
- Redshift mass map
- **Sensitivity to growth rate**
- **Sensitivity to expansion history**



The Euclid design & its instruments

Euclid in numbers

European Project

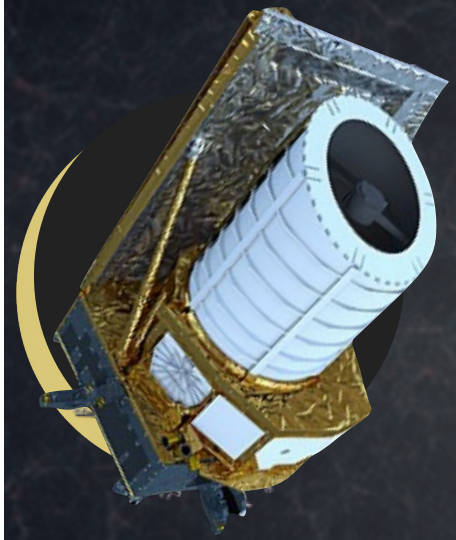
285 Laboratories

2000 Members

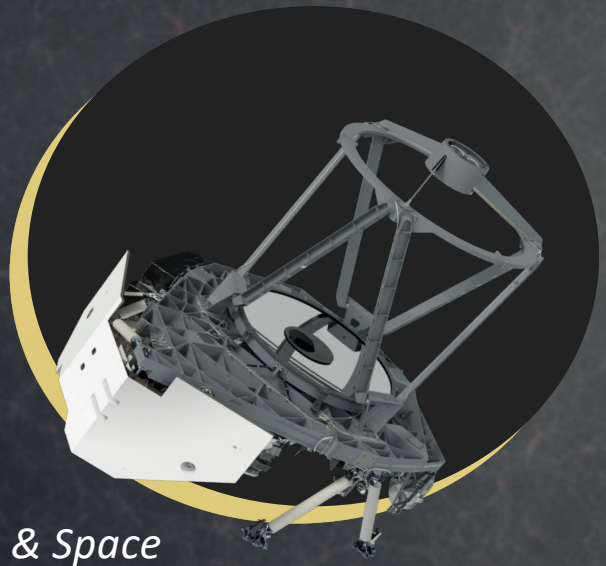
Euclid is a ESA mission
(*European Space Agency*)

France has its scientific leadership

Euclid in numbers

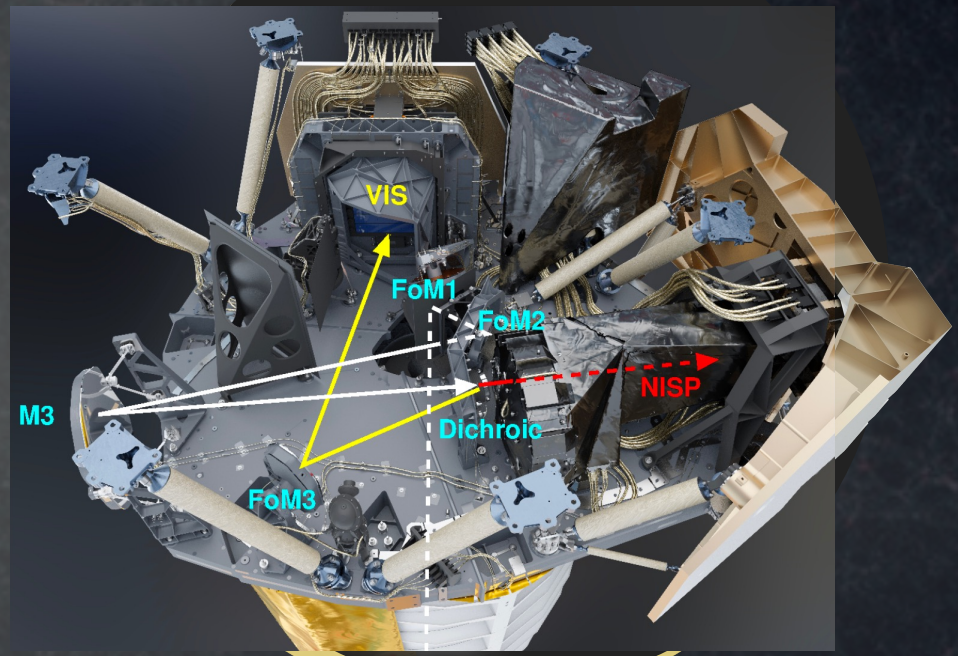


Satellite: *Thales Alenia Space*
2200 kg
4,7m × 3.7m × 3.7m



Mirrors: *Airbus Defence & Space*
Korsch design of 1.2 m in diameter

2 instruments: *scientific consortium*



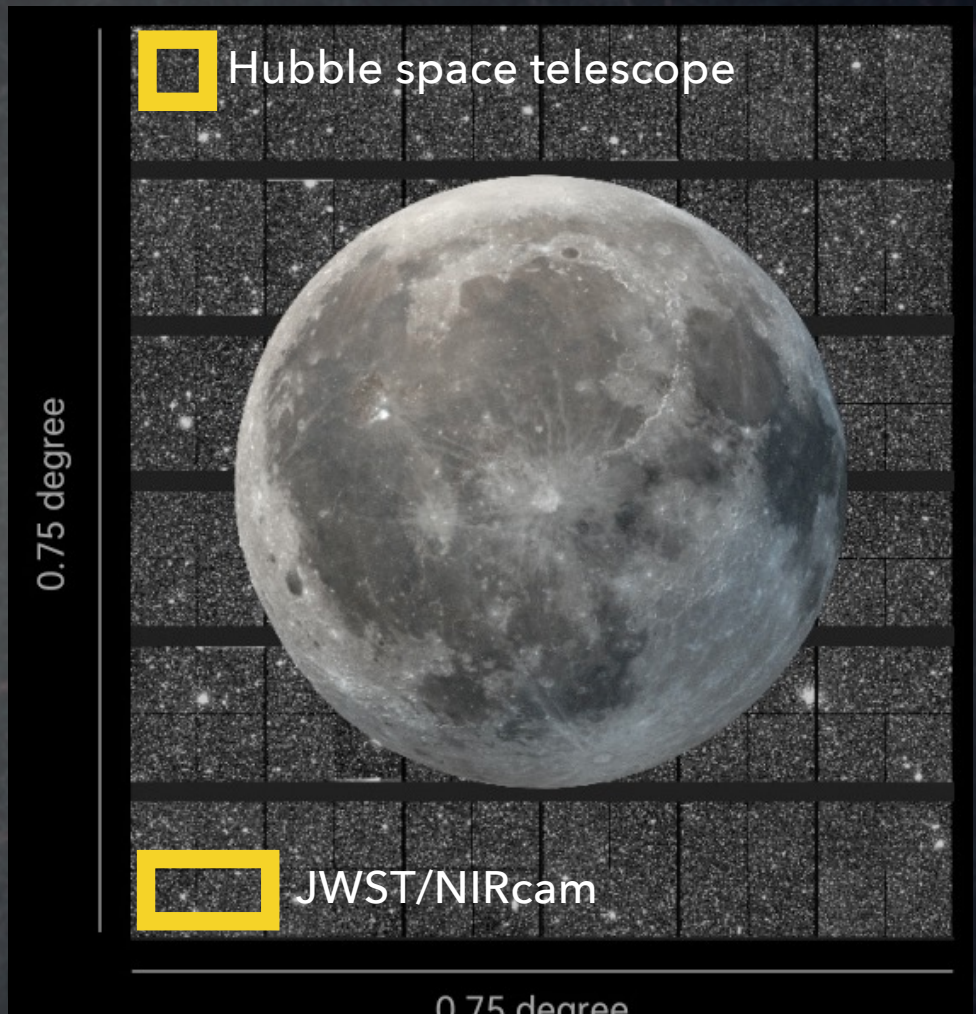
Large field of view

Two large cameras for a large field of view

VIS & NISP share the same field of view of 0.53 deg^2

➡ 100 × Hubble fields of view

➡ > 100 000 Galaxies every square degree



The VIS instrument

Wide band visible imaging camera

36 e2V CCD camera ⇒ 609 Mpx

Angular resolution : 0.1 arcs/px
Spectral range : 530 - 920 nm

Active area

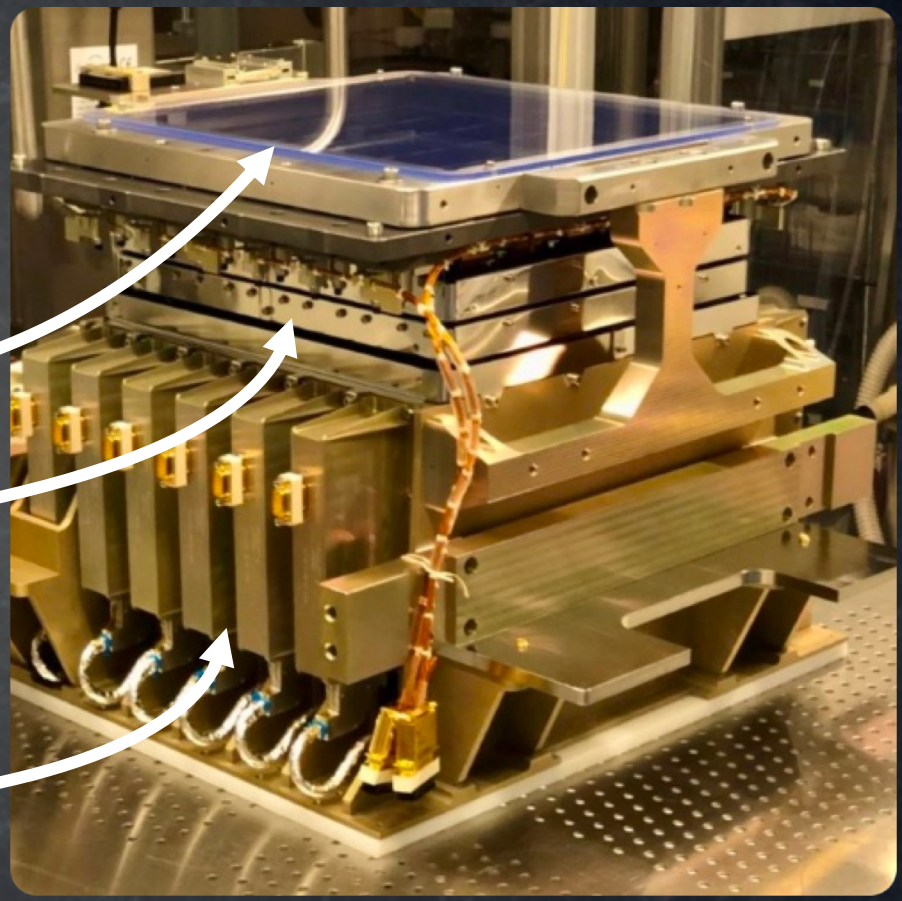
877 cm^2

Thermal isolation layer

Different operational temperatures:
CCD → ≃ 153 K
Read Out Electronic (ROE) → ≃ 270 K

ROE

Signal amplifier + Analog to Digital converter
FPGA for CCD operation

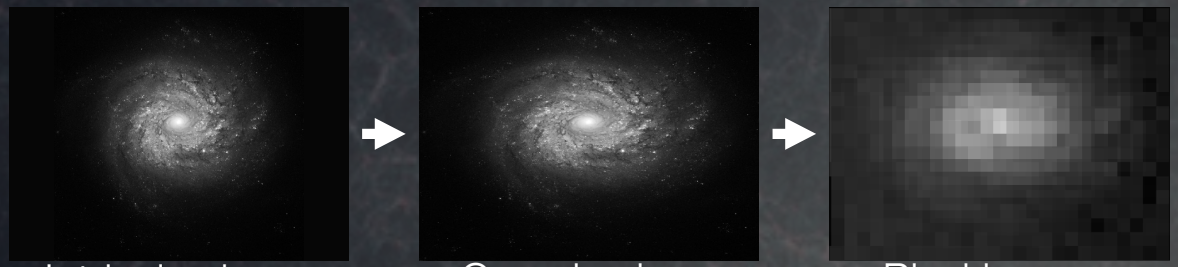


The VIS instrument - **CEA**

Calibration unit
& Shutter not represent on this picture

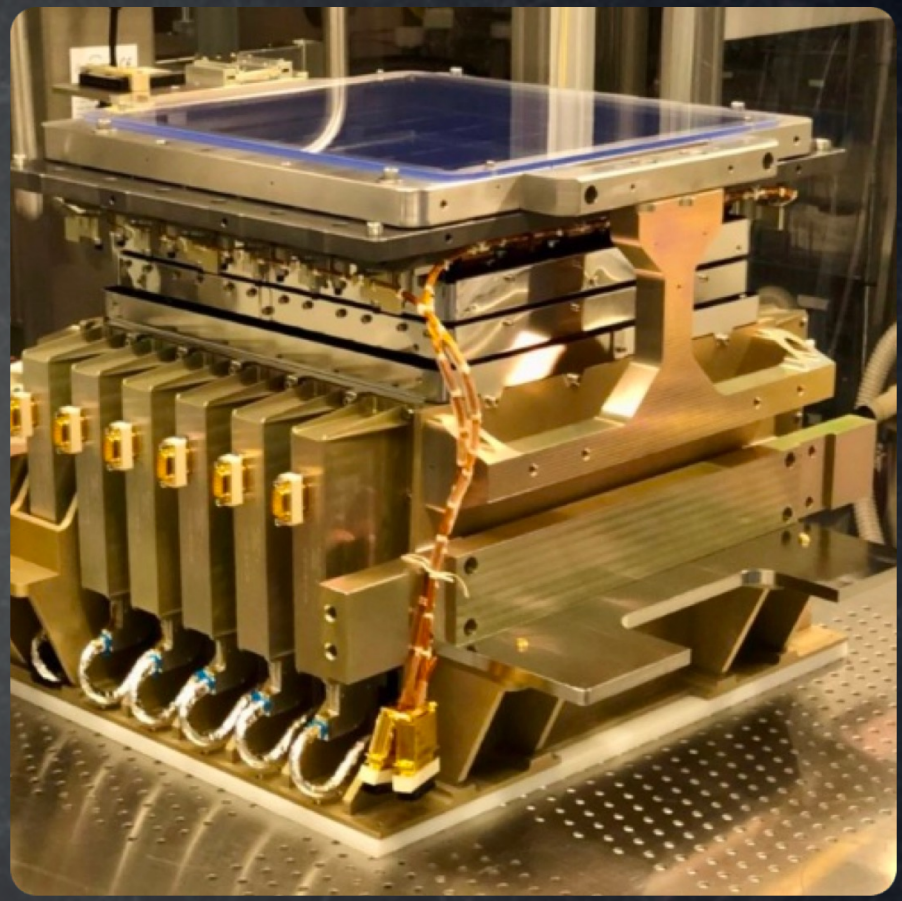
The VIS instrument

Wide band visible imaging camera



Intrinsic shape *(unknown)* → Cosmic shear → Pixel images

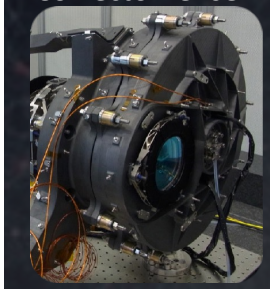
The VIS camera is designed to **measure galaxy ellipticities** with **accurate control on systematics** (optical, instrumental, astrophysical, …)



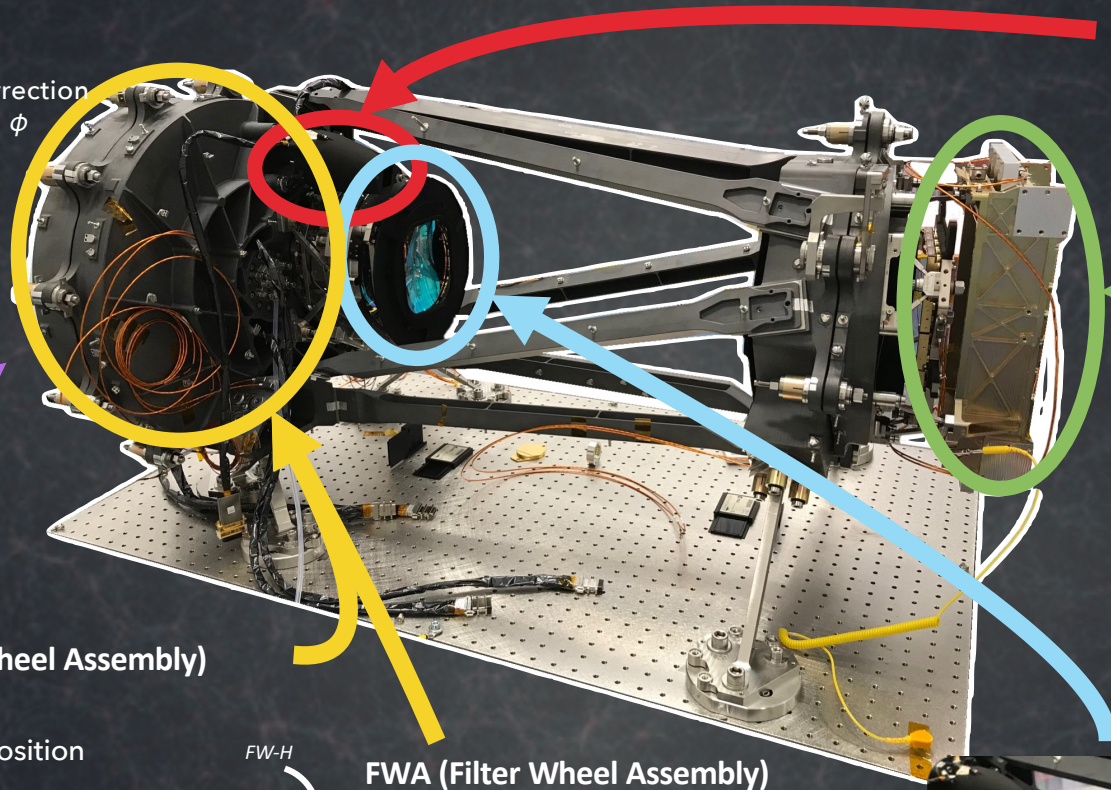
The VIS instrument - CEA

An overview of the NISP instrument

Corrector lense:



- Entrence pupil
- Wave front correction
- Lense ≃ 20 cm ϕ



The NISP calibration unit:

- 2×5 LED → 5λ
- Used for flat field and detector calibration
- 2 set of LED for redundancy

The NISP focal plane:

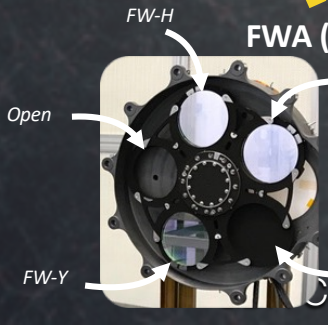
- 16 Near IR detectors
- 2k×2k pixels/detectors
- Cooled down to T≃ 95 K

The largest Near Infrared focal plane in space

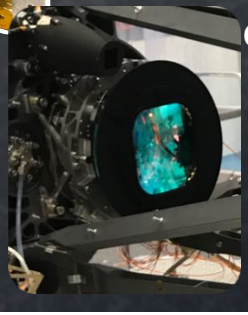
GWA (Grism Wheel Assembly)

- 4 Grism
- 1 Open position

FWA (Filter Wheel Assembly)



- 3 Filters
- 1 Open position
- 1 Close position

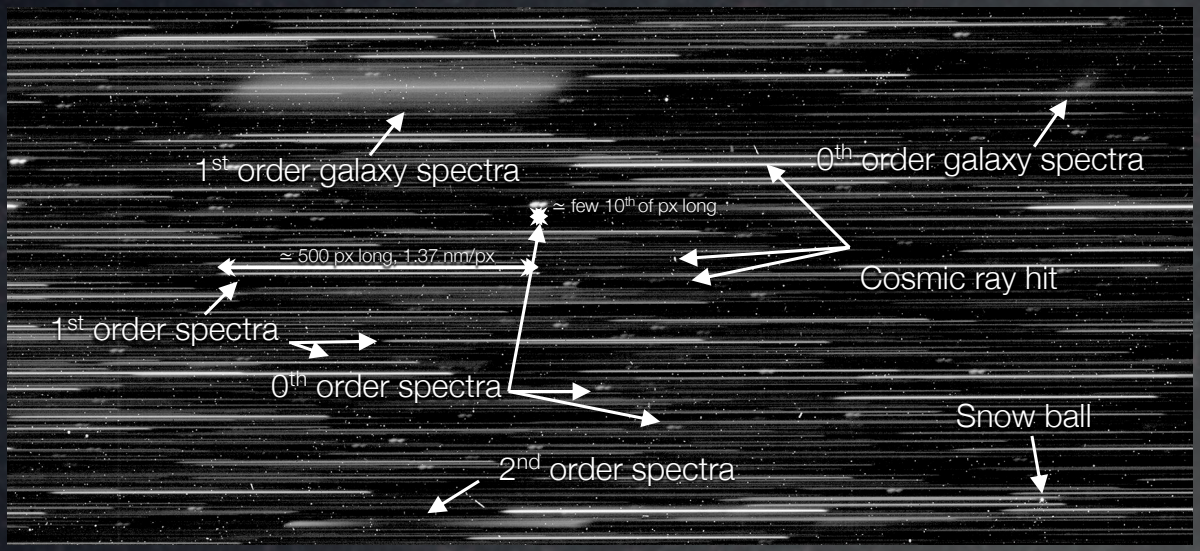


Camera lense:

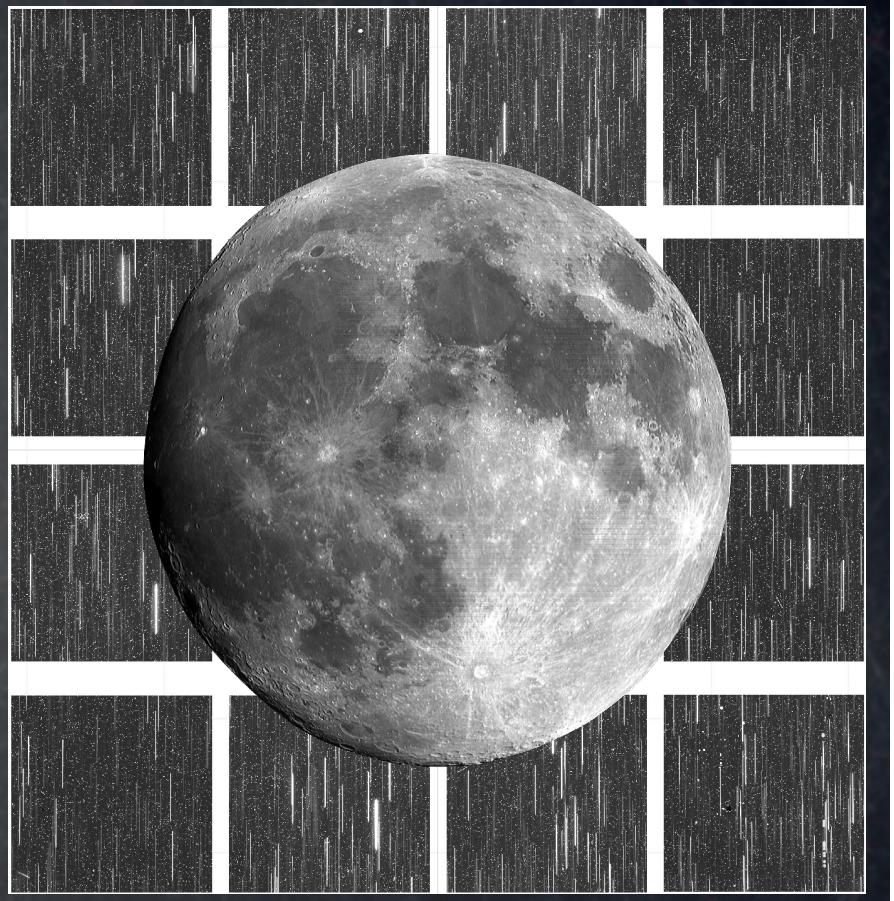
- Collimate light onto focal plane array
- Combination of 4 lenses of 20 cm ϕ
- Heaviest lense = 1.5 kg

Among the largest and heaviest lenses ever sent to space.

Slitless spectroscopy with NISP



ESA/Euclid/Euclid Consortium/NASA, CC BY-SA 3.0 IGO



ESA/Euclid/Euclid Consortium/NASA

Advantage:

- ➡ Spectrogram for all visible sources in the field of view.
- ➡ > 1700 redshift measurements every square degree

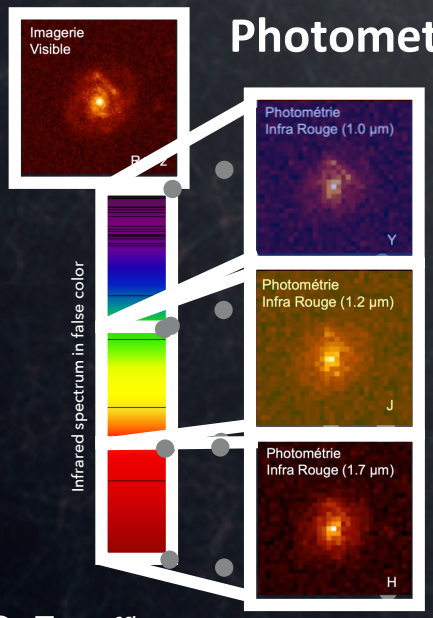
Drawback:

- ➡ Spectrograms overlap each other → contamination
- ➡ Spectral resolution limited by object size → self-contamination

Photometry with NISP

Near Infrared Spectro-Photometer

Angular resolution : 0.3 arcs/px
Spectral range : 950 - 2000 nm

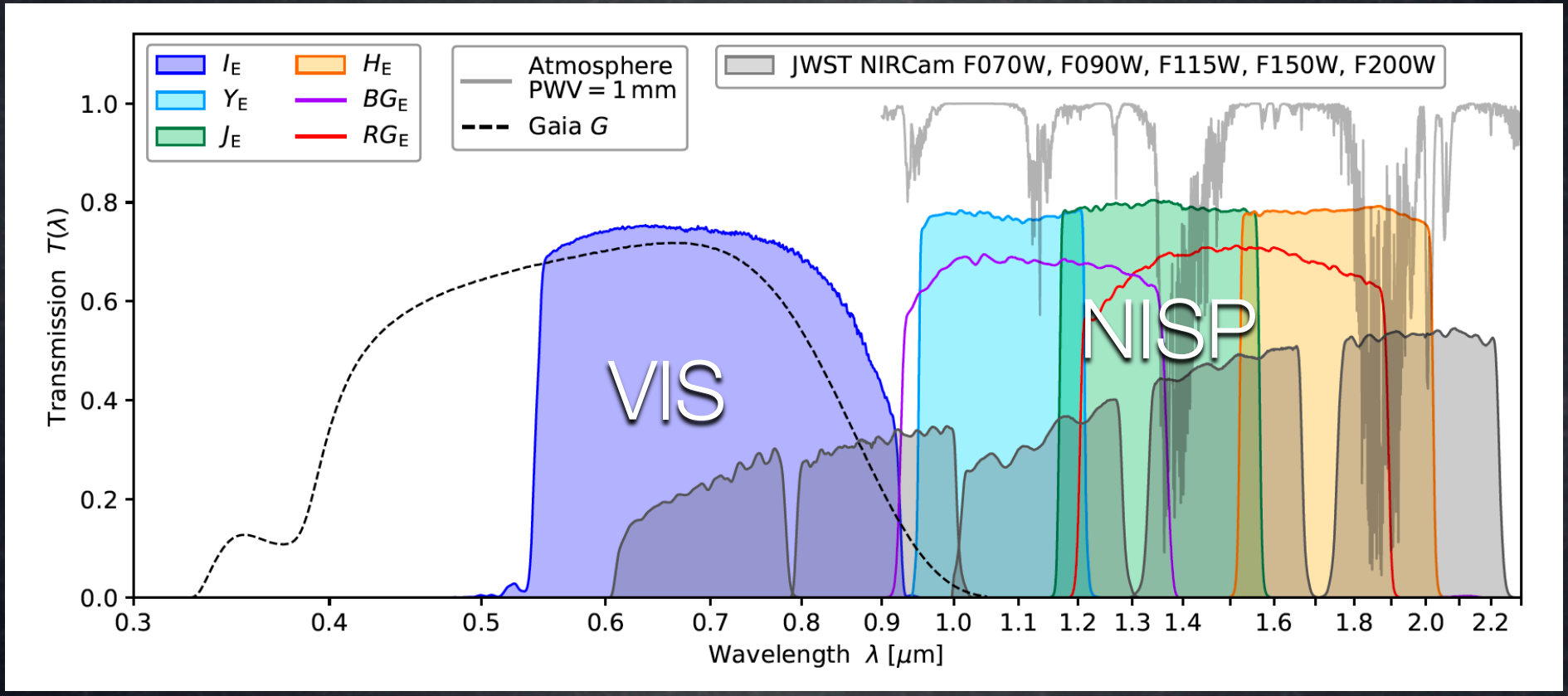


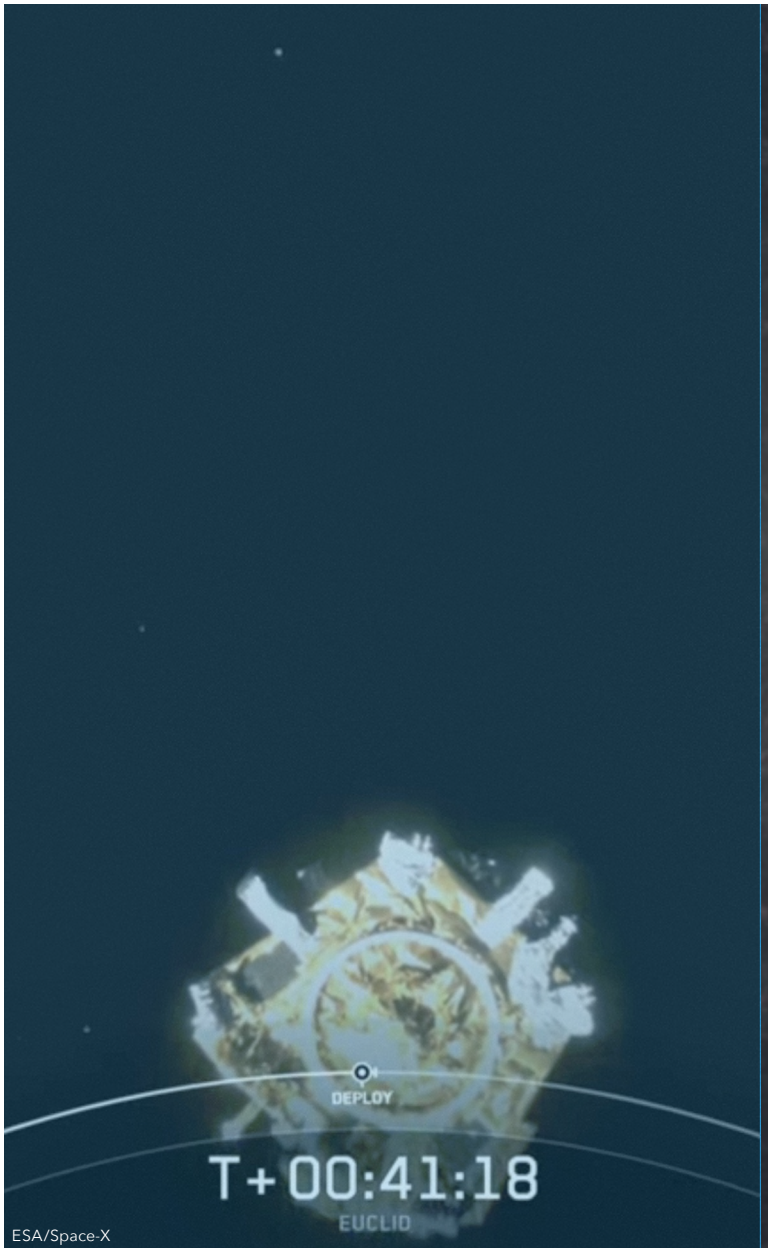
Photometer :

Measure galaxy photon flux (photometry) and provides Photo-z

The NISP instrument - Euclid / NISP / LAM

Spectral response of Euclid's imaging and spectroscopic channels



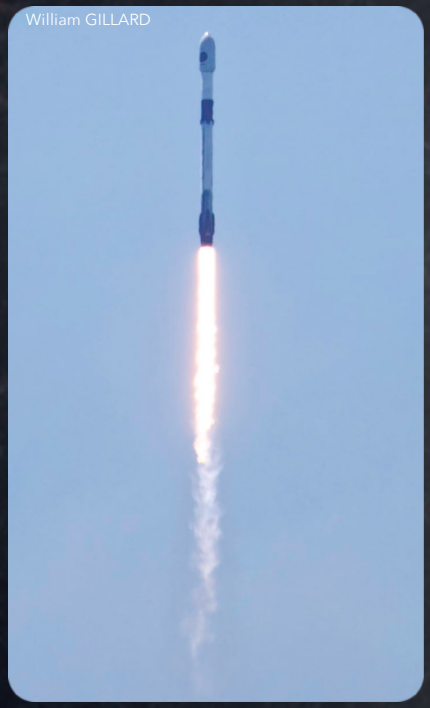


ESA/Space-X

News from L2

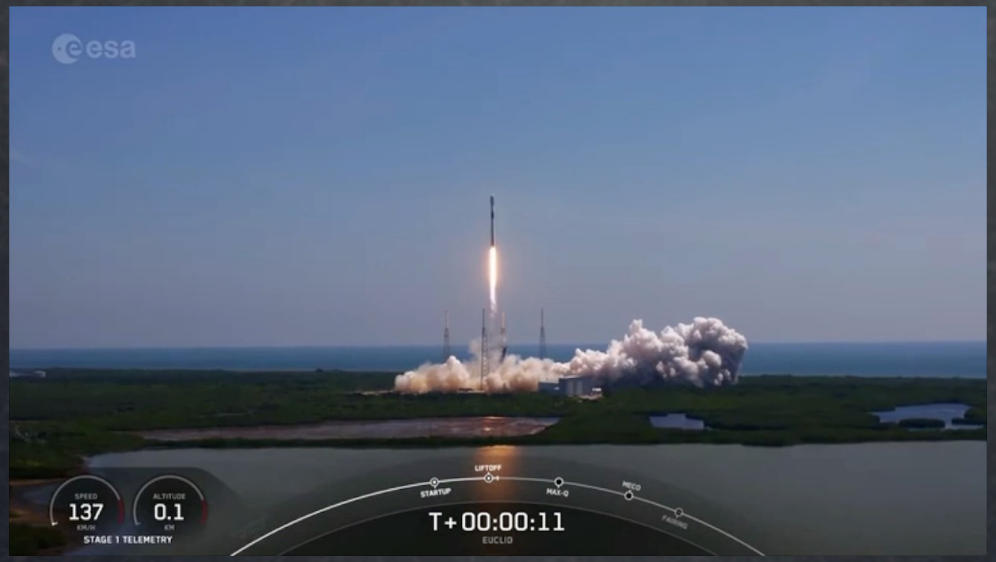
Euclid launch

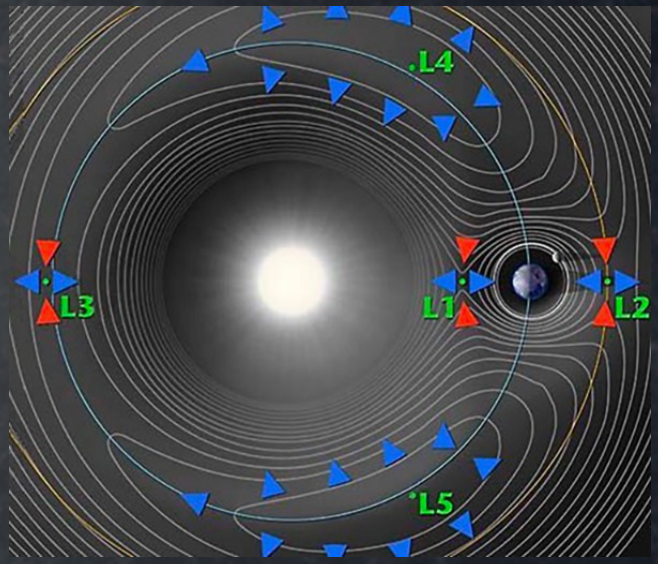
Successfully launched on 1st July 2023



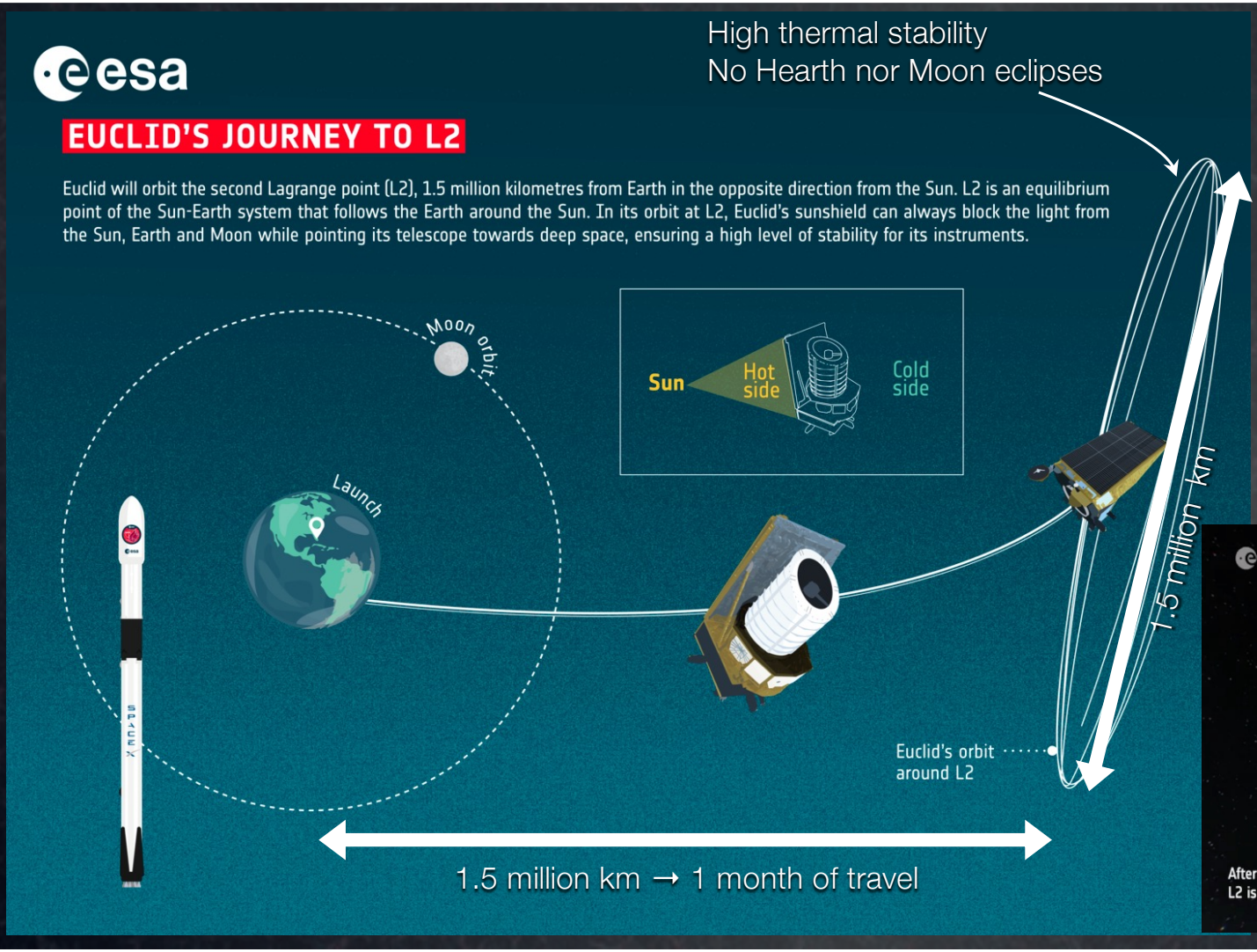
Launcher : Falcon 9
from Cape Canaveral Space Force Station

- Lift-off
- Ascent phase
- Separation & Injection to L2 (Space-X)
- Fine tuning and correction manoeuvres (ESA)s
- Transit to L2 → 1.5 million km from Earth …





Transit to Lagrange 2



Euclid reached L2 at the end of July 2023:

- Orbit radius : 1.5 M km
- Commissioning started during transit

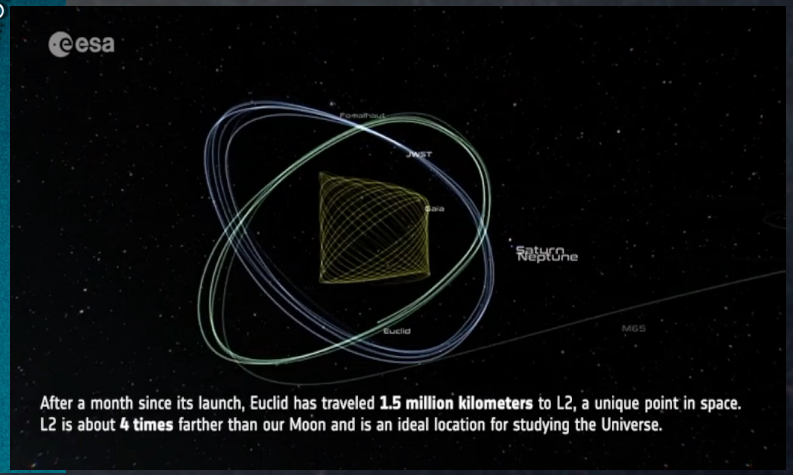
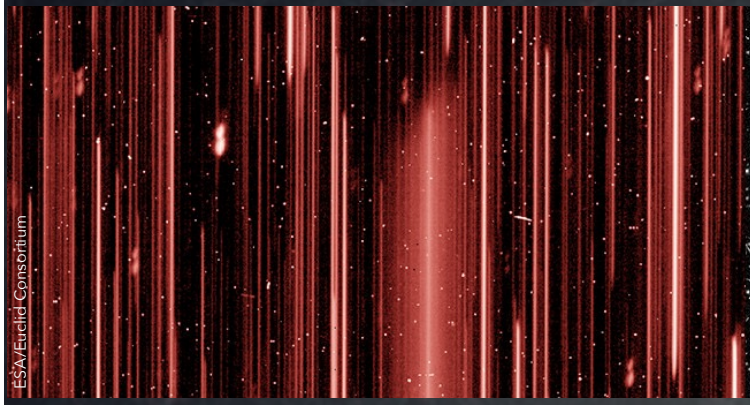


Image Quality



NISP Spectroscopy

Visible VIS image

Near infrared Y NISP image

Euclid First light images exhibit very high image quality

- Dense spectra forest
- Sharp VIS images
- Sharp NISP images

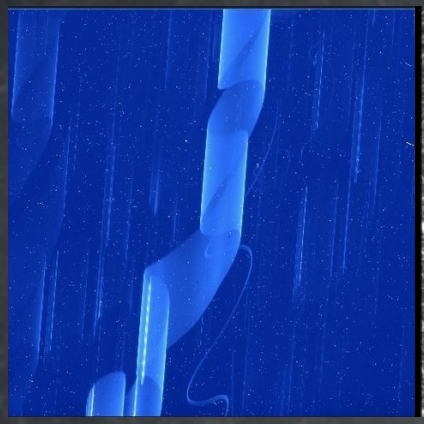
Raw data : No calibration, no cosmetic
→ All detector defects and cosmic-ray hits visible.

But some issues…

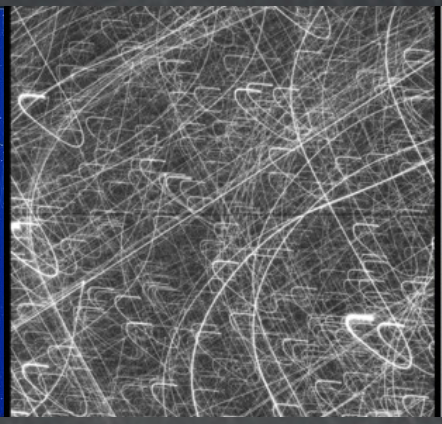
Euclid dancing Boogie-Woogie

Fine guiding sensor failure :

➡ Fine guiding sensor loose its guiding stars under heavy cosmic-ray hits …



NISP Spectroscopy



Visible VIS image

No despair yet, at least one could make art gallery

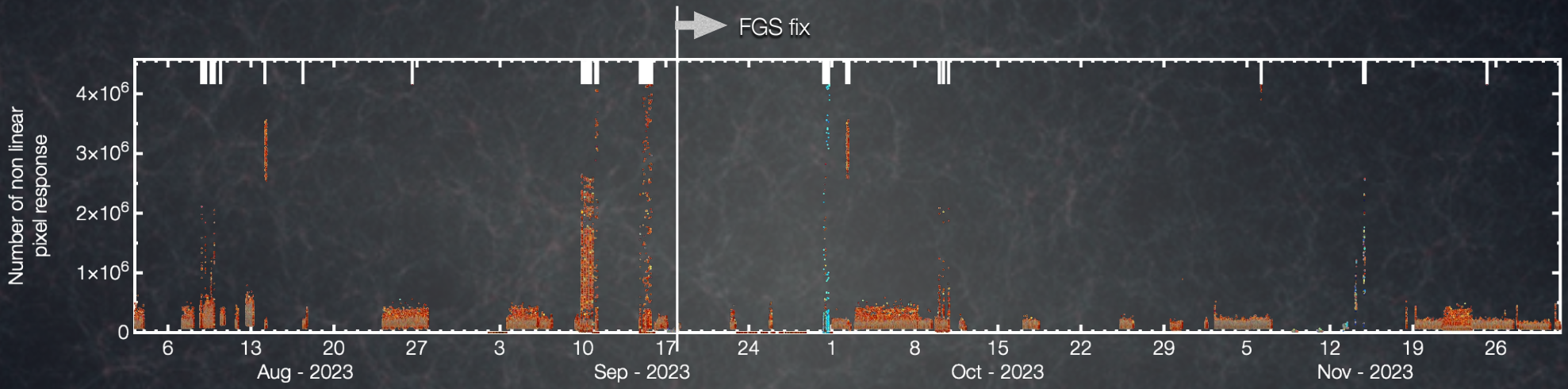
➡ Onboard software had to be updated … 2 months of work !

- Investigation and development of CR rejection algorithm compatible with hardware limitation (EC+Industry)
- Test and validation on avionic model on ground (Industry)
- Upload new firmware to Space-craft (ESA+Industry)
- Test and Validate on flight (EC+Industry+ESA)

Euclid dancing Boogie-Woogie

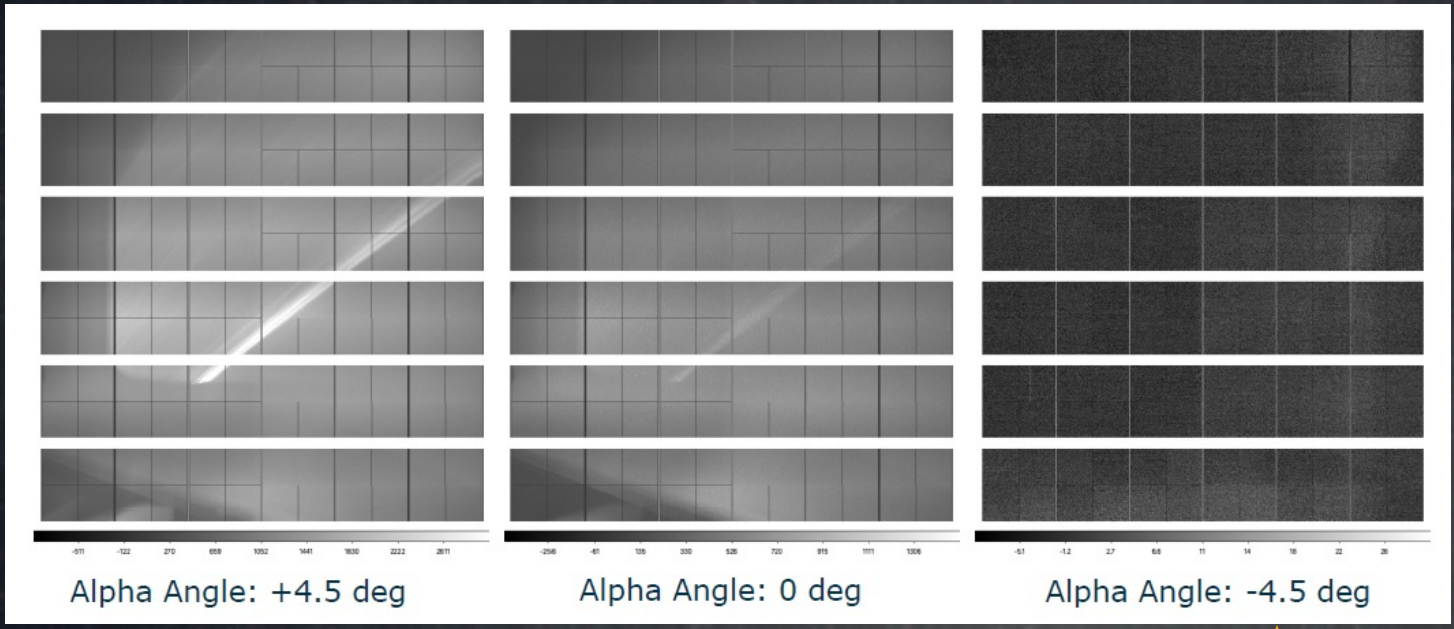
Fine guiding sensor failure :

➡ Fine guiding sensor loose its guiding stars under heavy cosmic-ray hits …



➡ Clear improvement after correction. Still a few FGS tracking failures, particularly in fields with very low stellar density where few guiding stars are available.

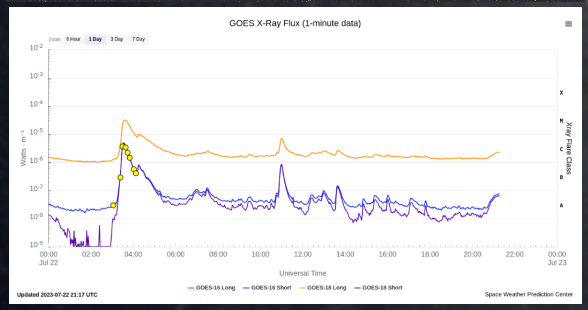
Straylight in VIS



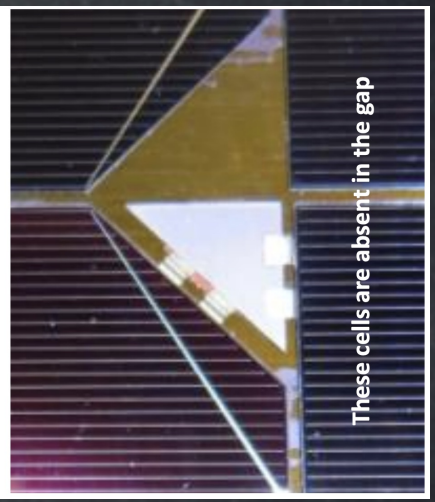
Sunlight is reflected into the instrument cavity at specific angles :

- ➡ The spacecraft should avoid those angles
- ➡ Smaller operating windows
- ➡ Survey has to be redesigned …. 6 month of works by the Survey team

Euclid radiography through X-Ray

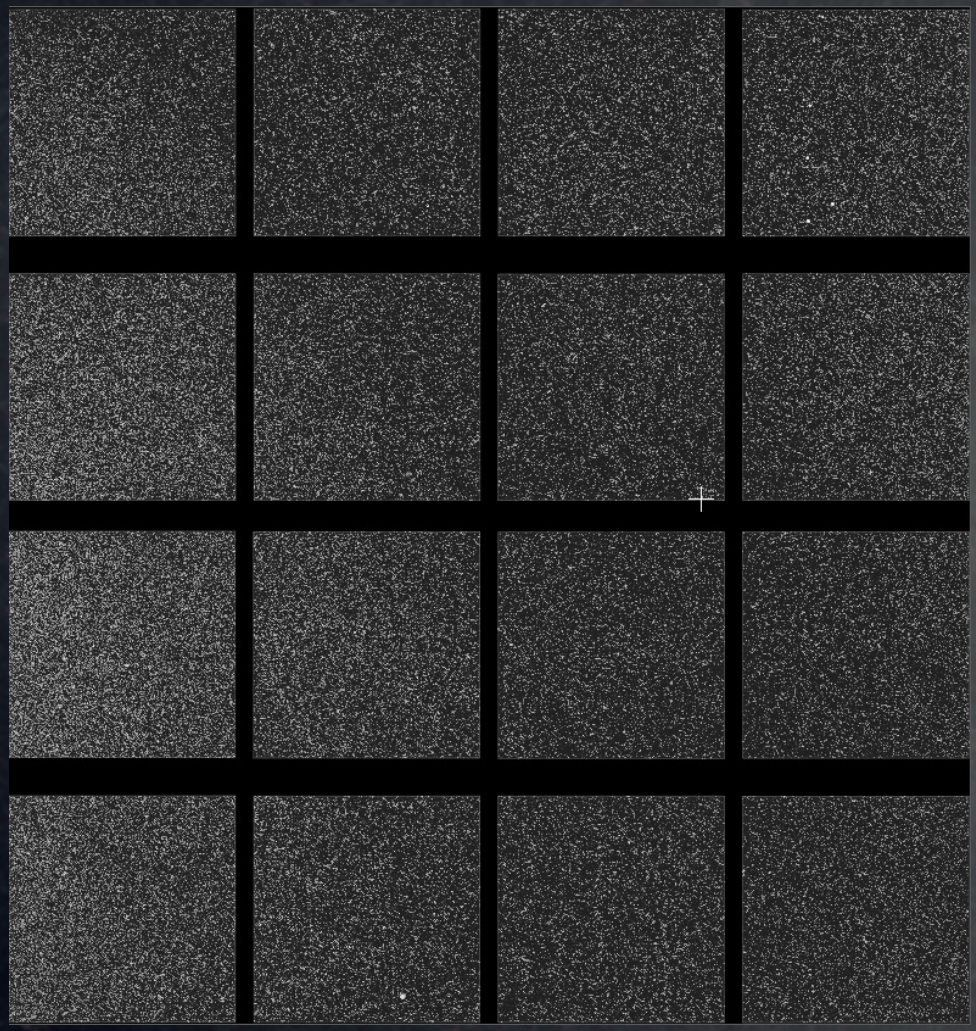


➡ X-Ray solar flares leave their fingerprints on the VIS detector. Shadows are cast by denser materials in front of the VIS instrument which absorbs X-Ray.



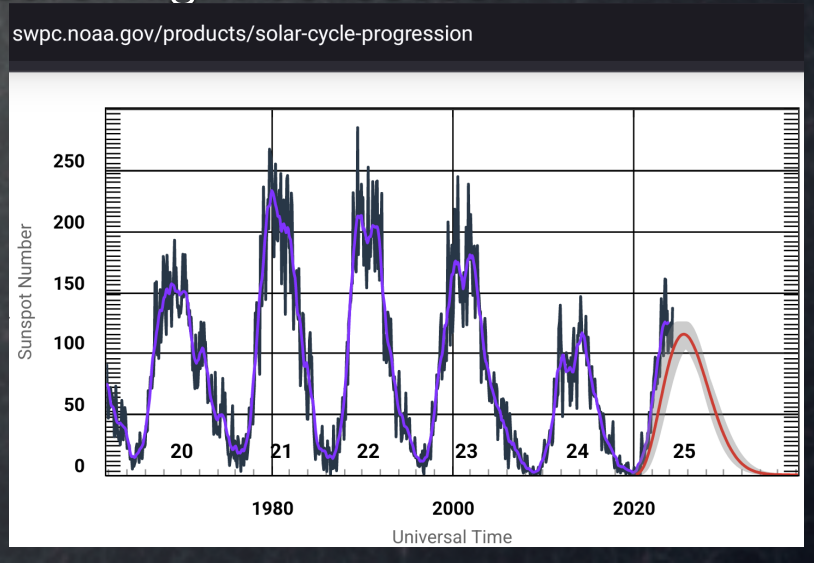
➡ NISP not affected because more materials (optics mechanical structures, …) are located in front of the detectors.

Coronal mass ejection

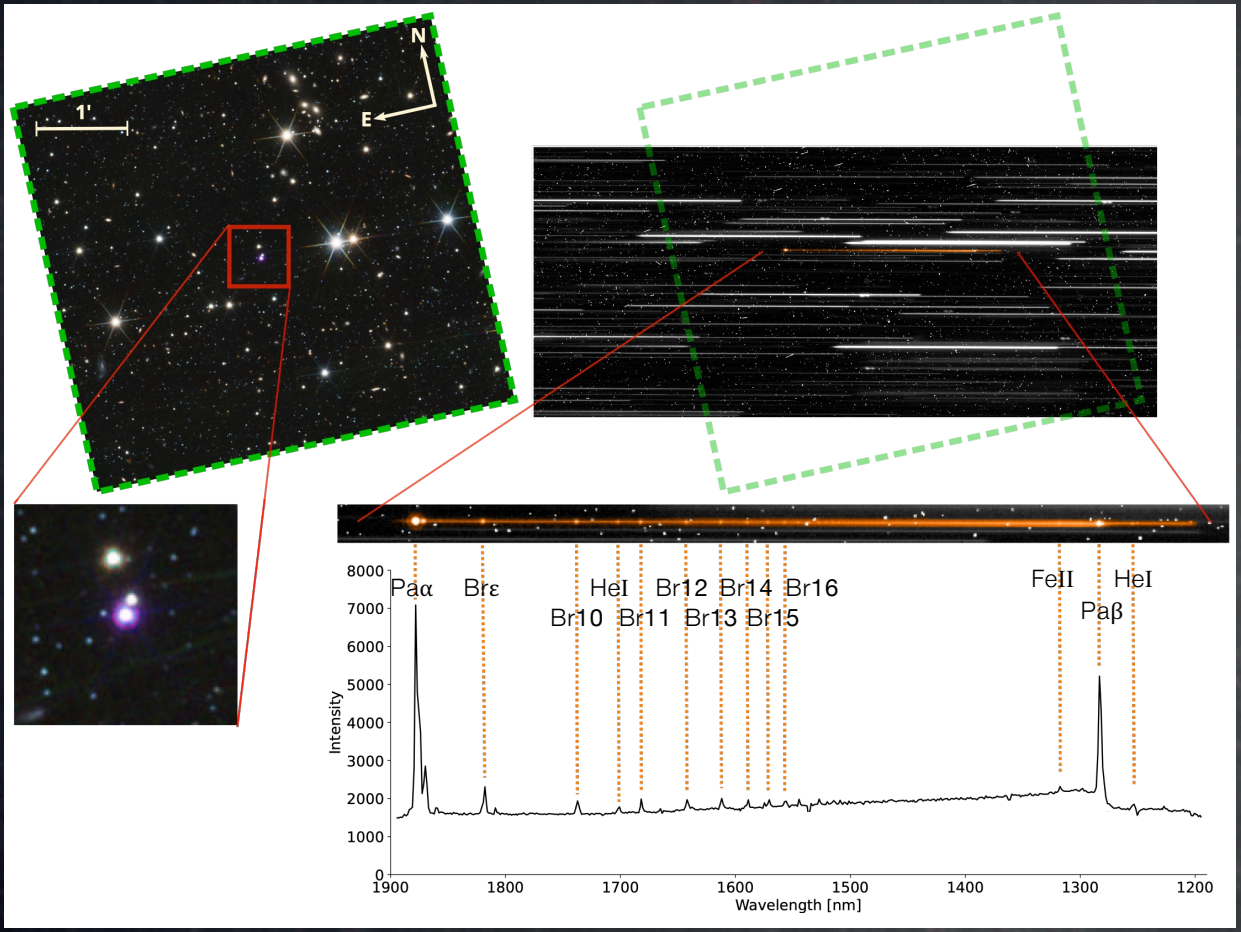


But Coronal Mass ejection (solar flare with ejection of matter → high energetic protons) do affect the NISP as well as the VIS.

When X-Ray or CME occurs during science observation all or part of the exposure might be losses.



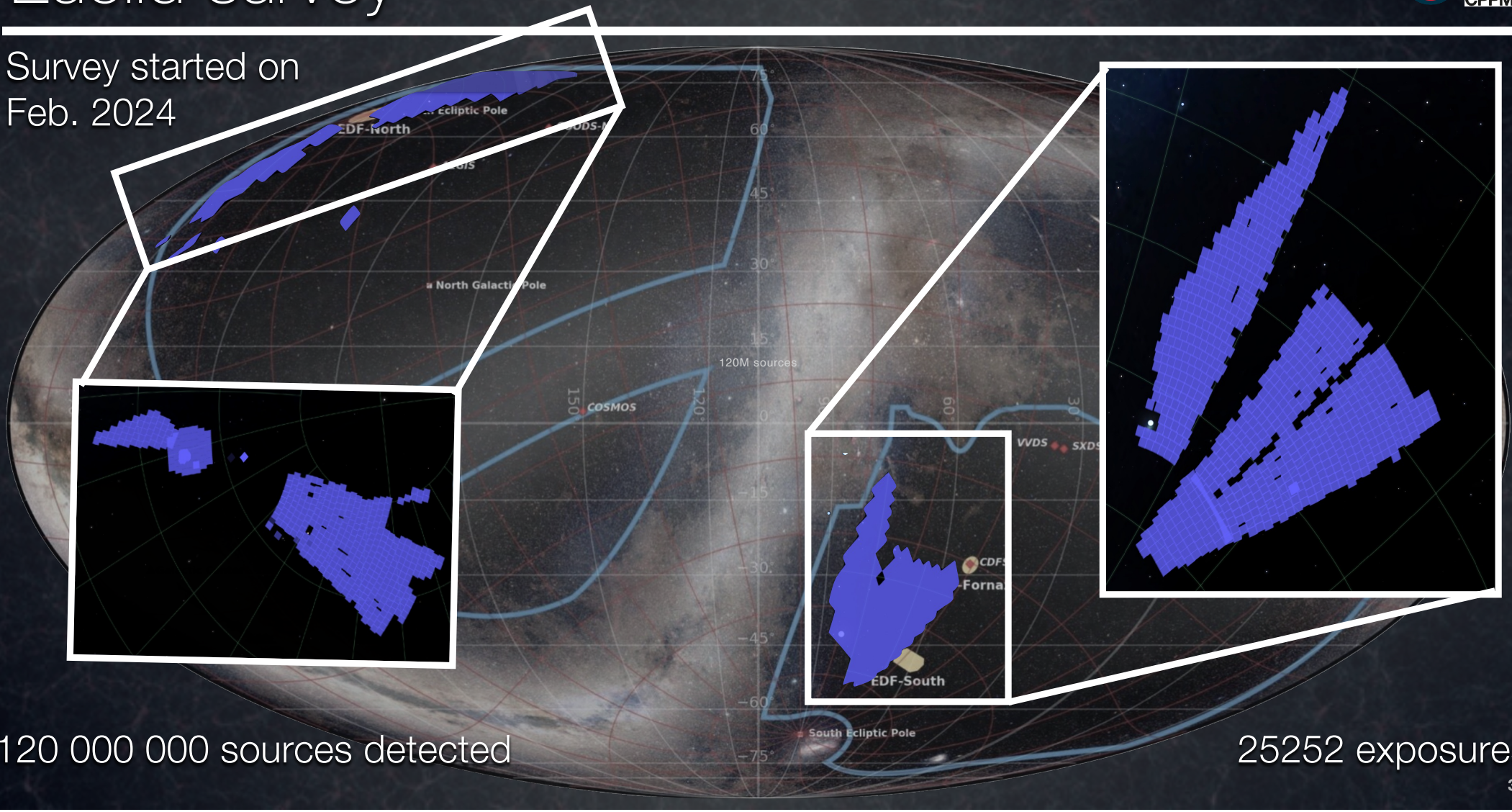
Despite all challenges : very High-Quality dataset !!



- Spectral dispersion of the order of 13.7 nm/px, as designed !
- Resolving power > 500
- High image quality over large field of view

Euclid survey

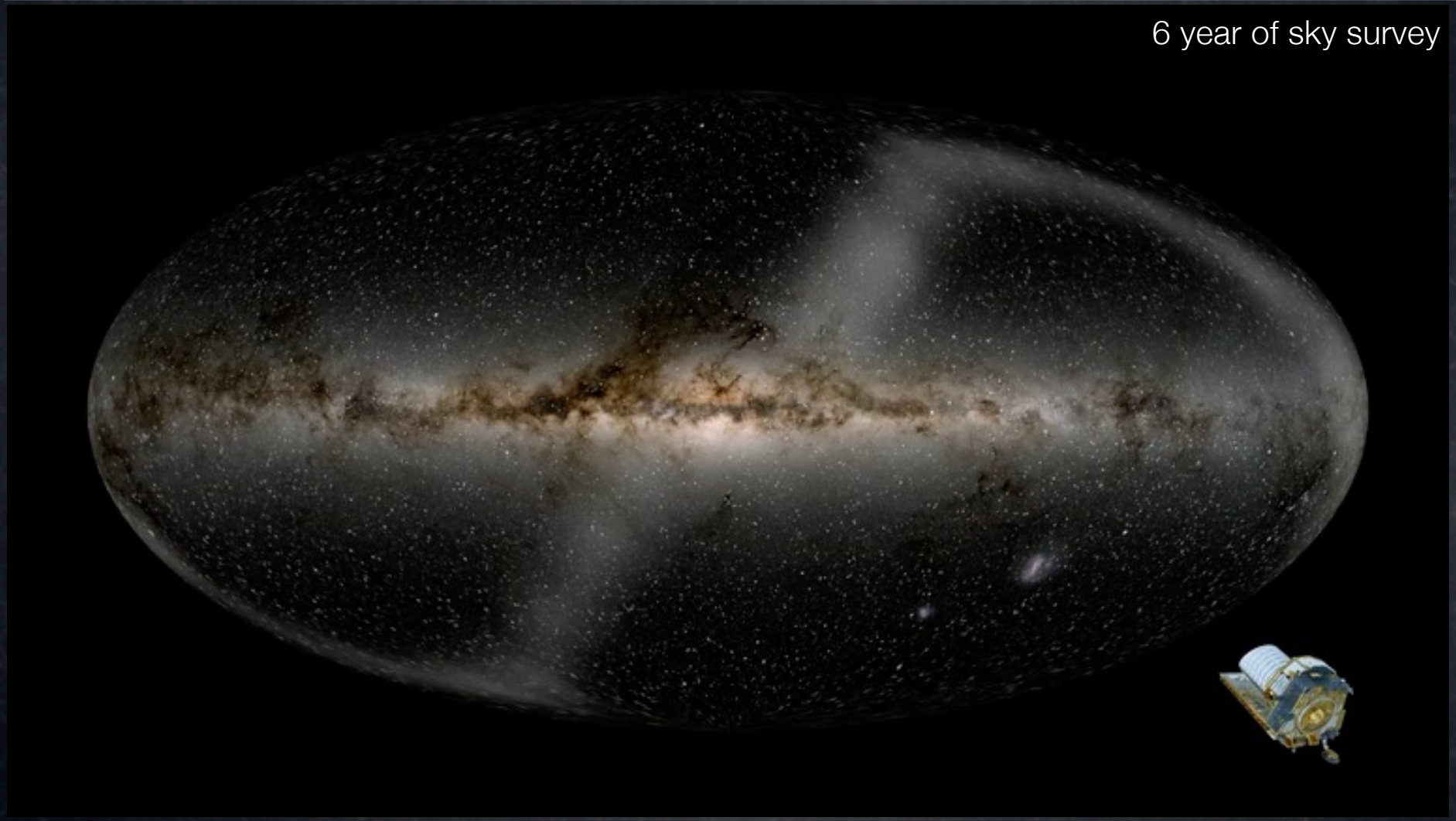
Survey started on
Feb. 2024



120 000 000 sources detected

25252 exposures

Euclid survey



First images / First Science

Early Release Observations

ERO images show ordinary matter, and concern "legacy science", science not directly related to Euclid's fundamental science.

ERO images highlight the high performance of the telescope and instruments

Total observing time for the entire ERO program: 1 day

Use of standard 70-minute observation blocks (ROS), covering 0.7x0.7 deg2

- 4 channels: VIS (visible), 3 NISP infrared bands (Y, J, H bands)
- False colors: Blue = VIS , Green = Y , Red = H

Early Release Observations

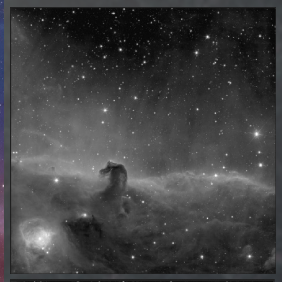
A first ERO in Nov 2023 with 5 images

The horse head nebula (IC434)

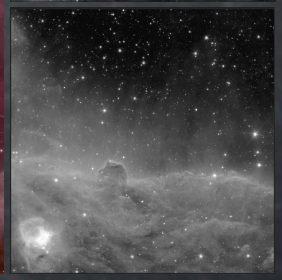
ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, CC BY-SA 3.0 IGO

- 1 hour exposure time
- VIS + Y_E + H_E

Bleu = VIS

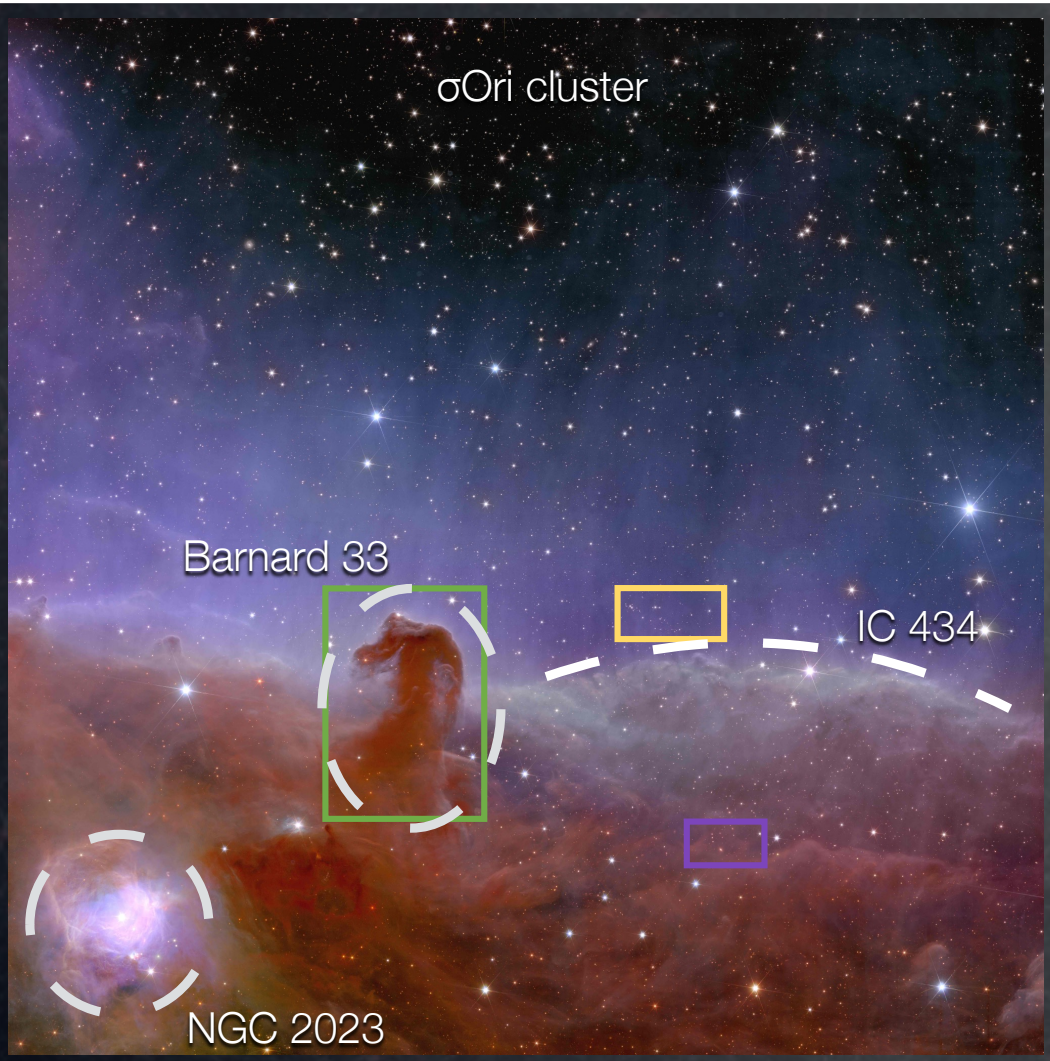


Vert = Y_E



Rouge = H_E

The horse head nebula (IC434)

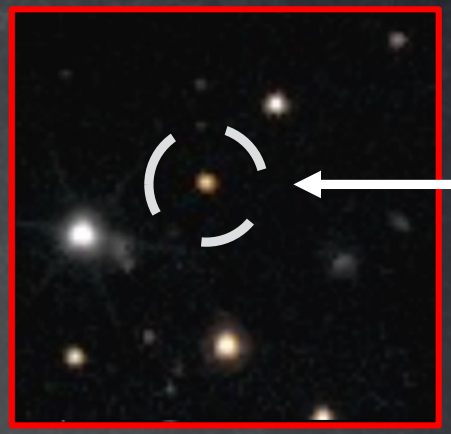


ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, CC BY-SA 3.0 IGO

The horse head nebula (IC434)

ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, CC BY-SA 3.0 IGO

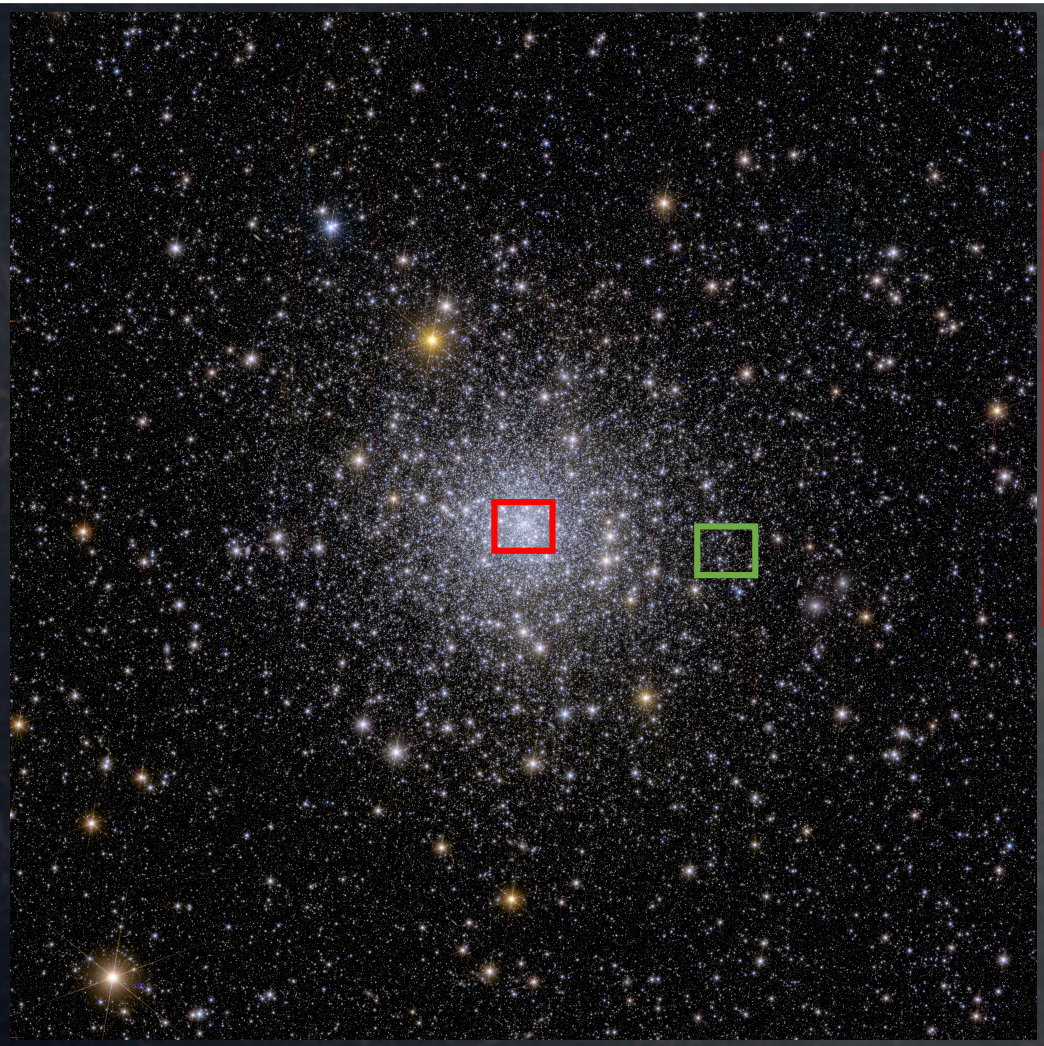
Free floating planets



Known free floating Jupyter like planet.

- Euclid is able to detect free floating planet down to 4×Mj
- +5 new free floating planets discovered by Euclid

Closest Globular Cluster : NGC 6397



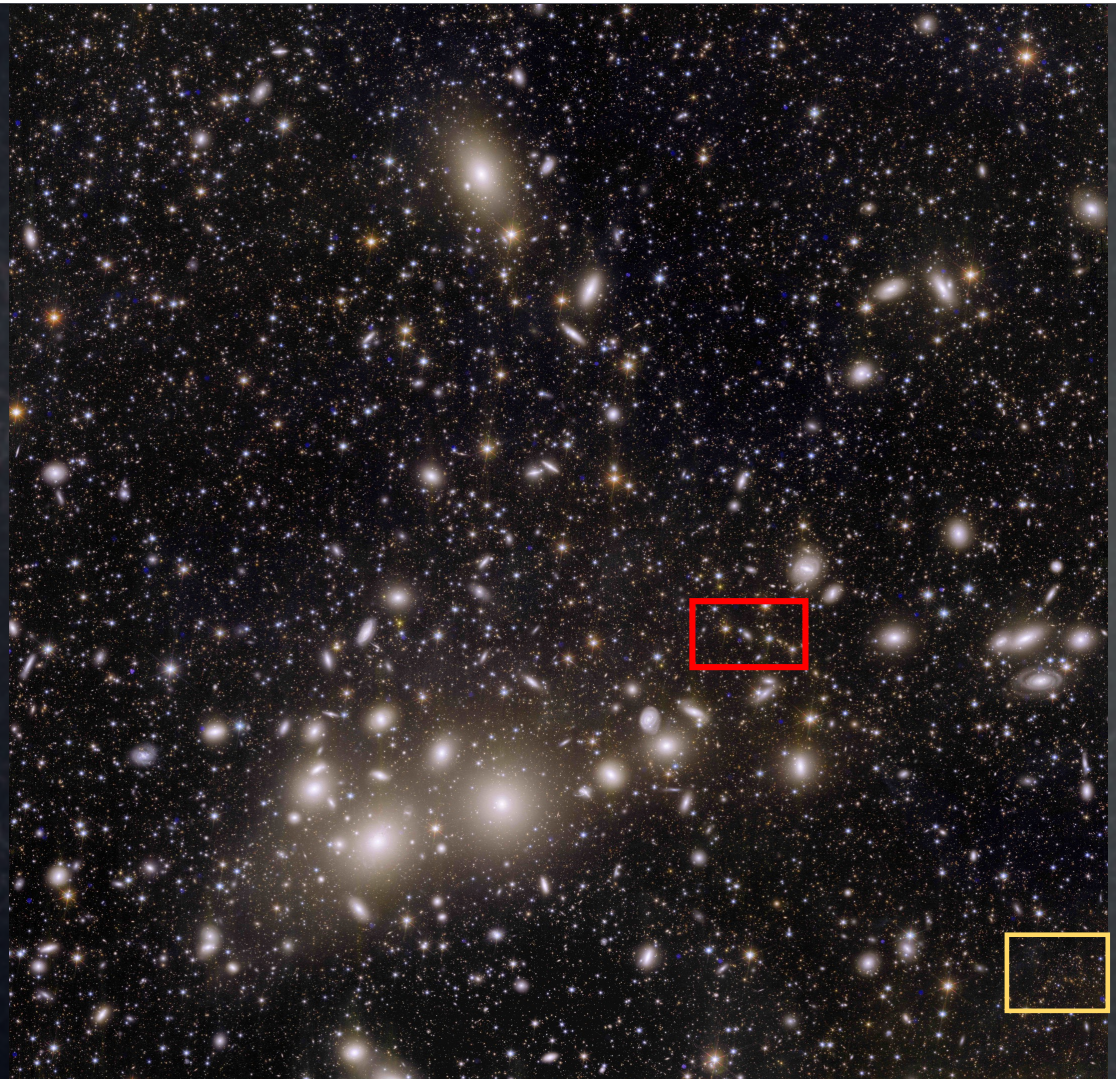
ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, CC BY-SA 3.0 IGO

- 1 hour exposure time
- VIS + Y_E + H_E

Resolving all the stars in the core

Discovering galaxies in the background

Cosmology with Euclid : Perseus cluster



ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, CC BY-SA 3.0 IGO

- 2 hours exposure time
- VIS + Y_E + H_E

Cosmology with Euclid : Perseus cluster

ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, CC BY-SA 3.0 IGO

- 630 new galaxies candidates identified to be gravitationally links to the Perseus clusters
- ≃70 000 Globular cluster candidates identified in the Intra-cluster medium.

Early Release Observations

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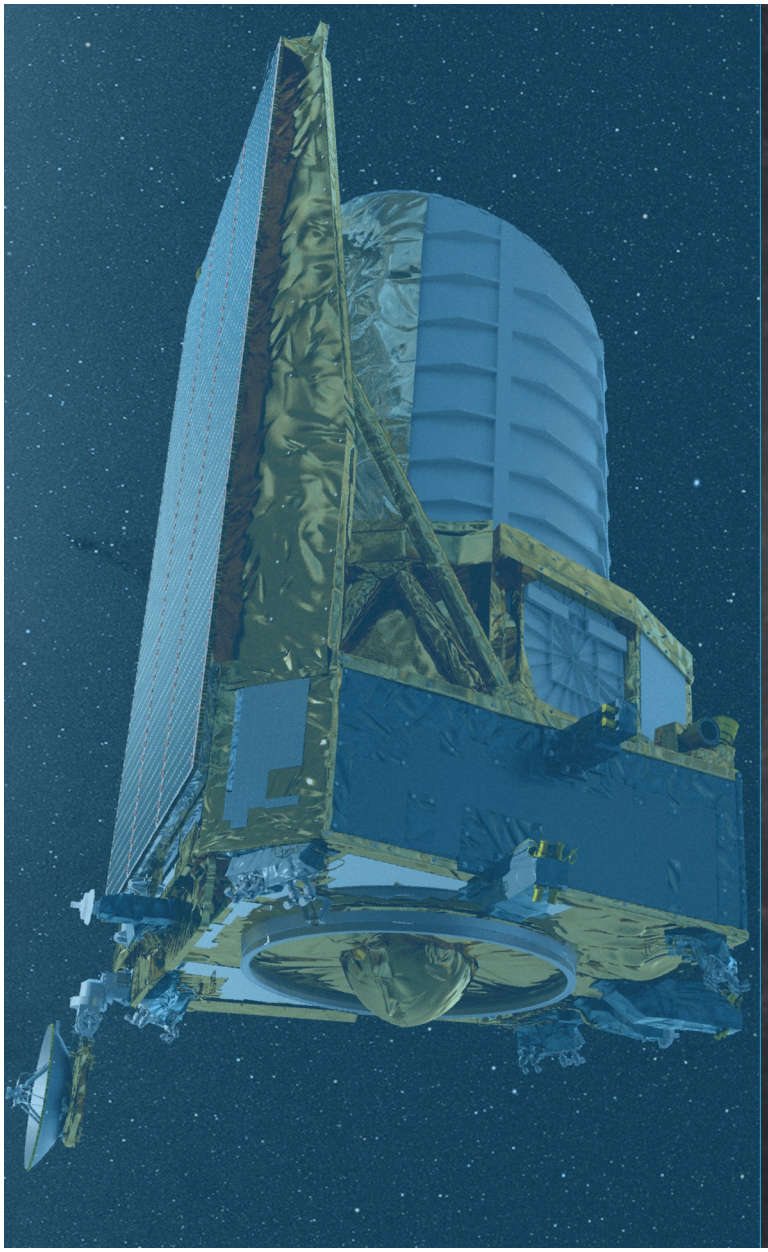
10 scientific papers currently under the review of the collaboration

New ERO release on the 23rd of May 2024 !



Conclusion

Euclid

Euclid successfully launched on July 1st, 2023

Euclid survey started survey operation in February 2024 after nearly 6 month of commissioning and calibration.

Early observations demonstrate the unique capability for **Euclid** to **probe a large field of view** combined to **high spatial resolution**

Wide survey : 12 billion sources in total
1.5 billion galaxies and
35 million of spectrometric redshifts:
0.7 < z < 1.85

Deep survey :
1.5 million galaxies and
150 000 of spectrometric redshifts:
0.7 < z < 1.85

New release of ERO images on the 23rd May, 2024, 12:00

Stay tune into ESA Web TV directly https://www.esa.int/ESA_Multimedia/ESA_Web_TV