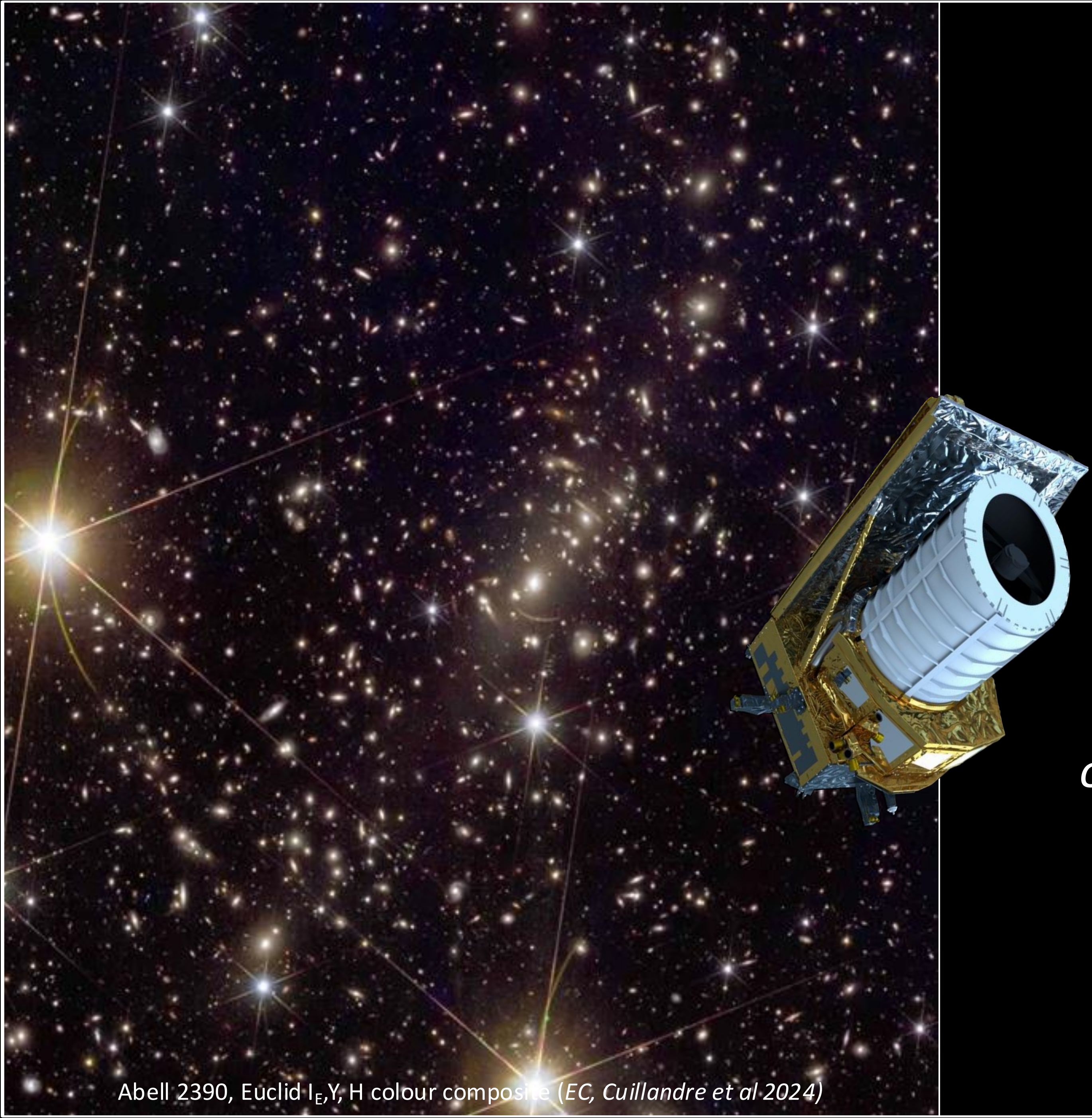


Abell 2390, Euclid I_E,Y, H colour composite (*EC, Cuillandre et al 2024*)

Euclid mission Overview

Sandrine Pires

CEA Paris-Saclay

on behalf of the Euclid Consortium

www.euclid-ec.org

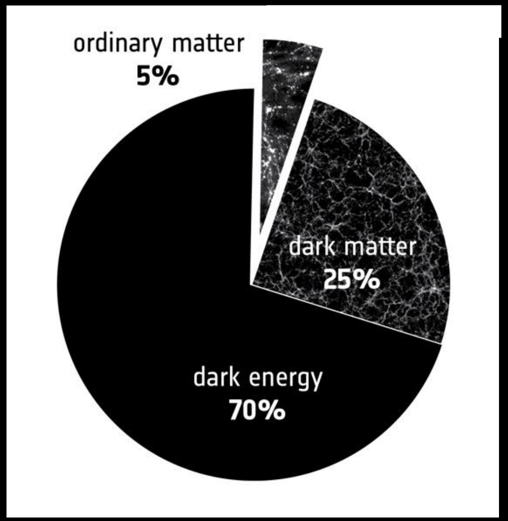
Credits

All the Euclid material shown here is on behalf of and approved by the Euclid consortium and ESA

For more information and proper credit to national space agencies and funding organisations : https://www.euclid-ec.org

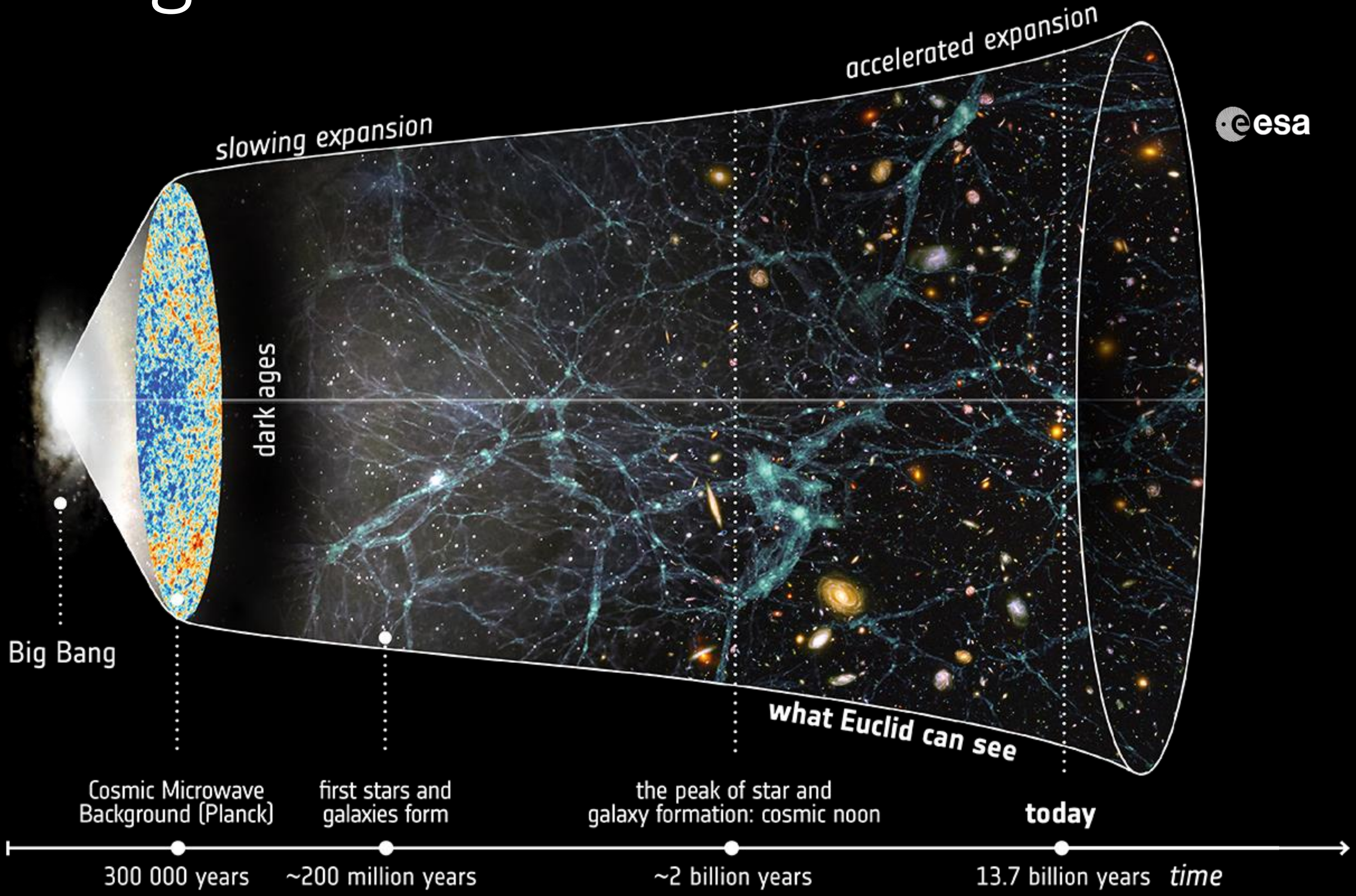
Pictures and movie:
https://www.esa.int/Science_Exploration/Space_Science/Euclid

Standard cosmological model

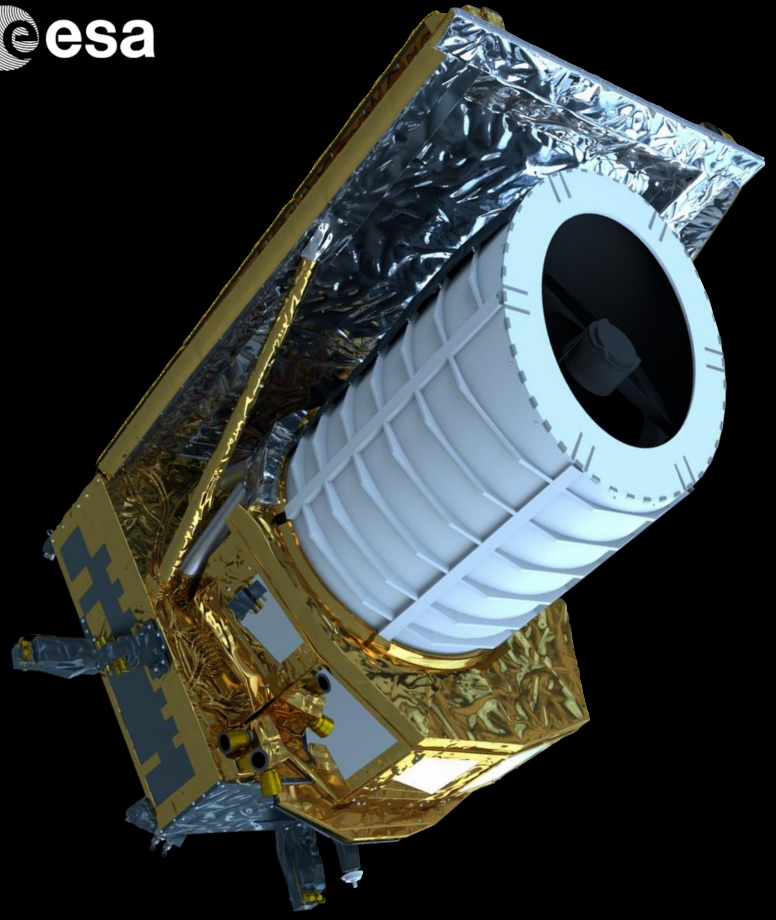


Cosmological paramaters :

H_0 - current expantion rate
Ω_M - matter density
Ω_b - baryon density
Ω_Λ- dark energy density
σ_8 - matter density fluctuations
n_s - scale index of initial fluctuations



Mapping the dark Universe with Euclud



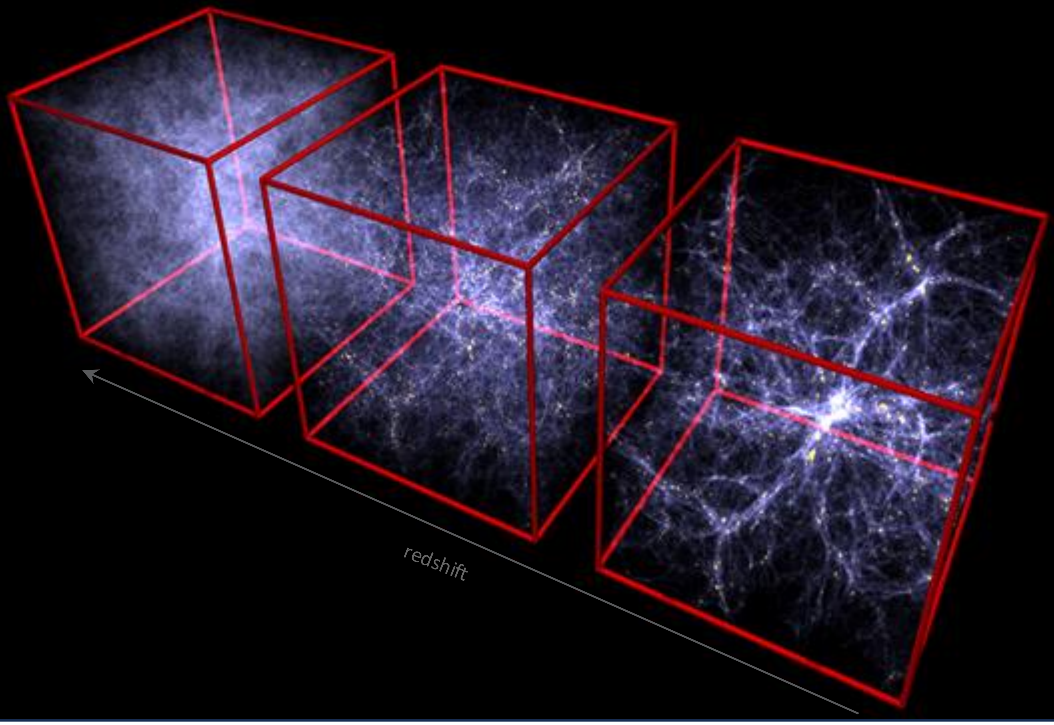
- <u>ESA Cosmic Vision medium-class mission program</u>

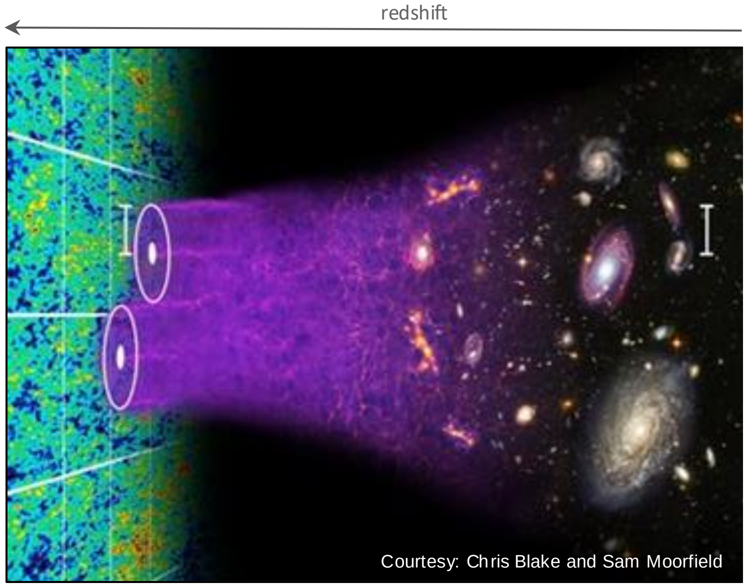
  two original proposals (2007):
  - DUNE (imaging, Refregier et al.)
  - SPACE (spectroscopy, Cimatti et al.)

- <u>Both accepted and merged into **Euclid**</u>
  - simultaneously map the visible and dark matter distribution over one-third of the sky,
  - using galaxy redshifts and weak gravitational lensing

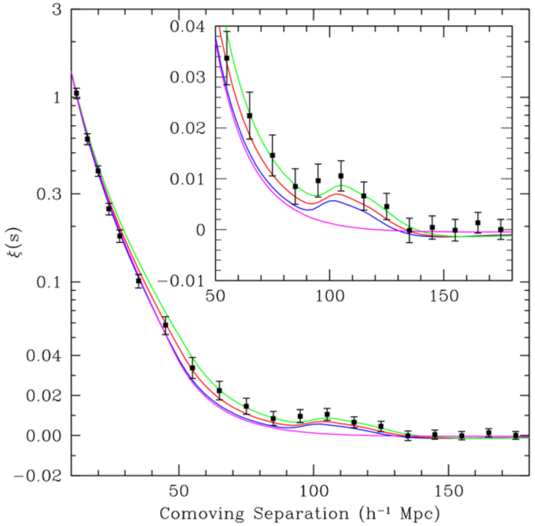
- The mission was selected in 2011 and adopted in 2012

3D Galaxy Clustering

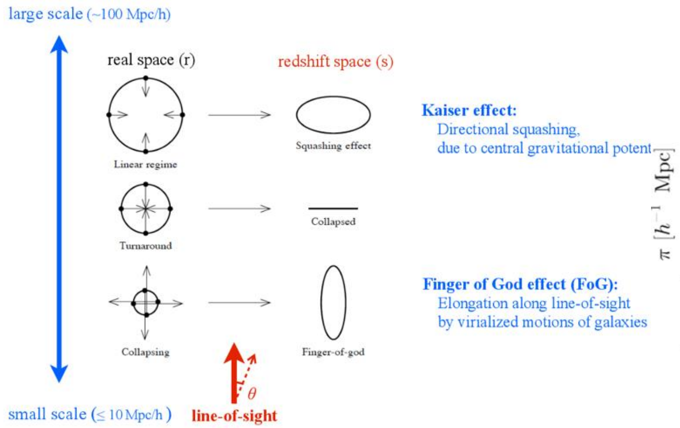




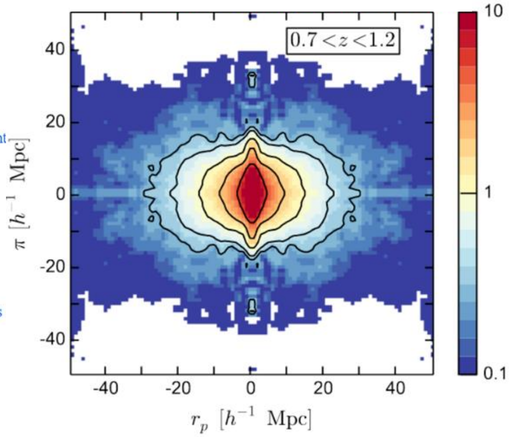
Eisenstein et al. (2005, SDSS)



Baryonic Acoustic Oscillation (BAO) provides a cosmic standard ruler and is sensitive to the expansion history

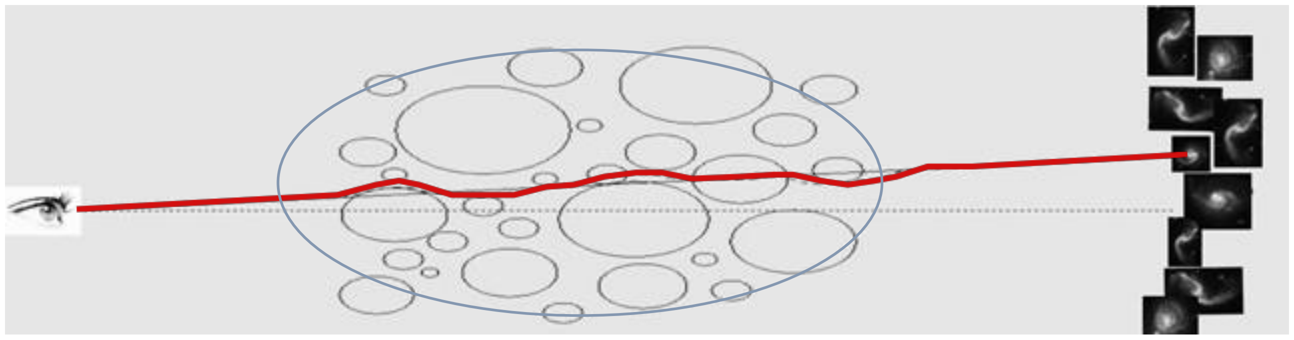


Pezzotta et al. (2017, VIPERS)

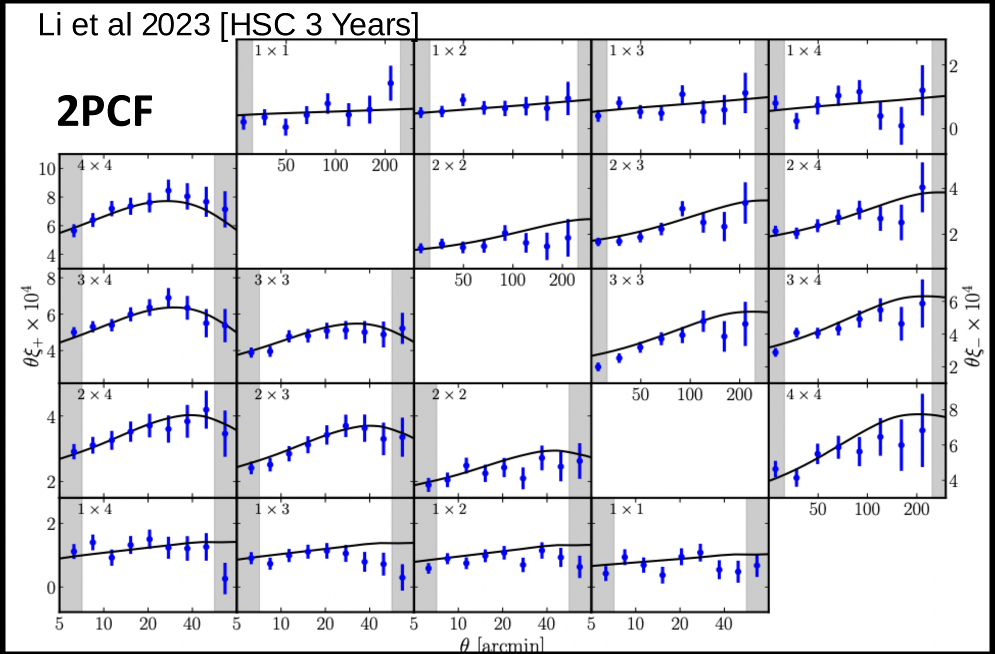


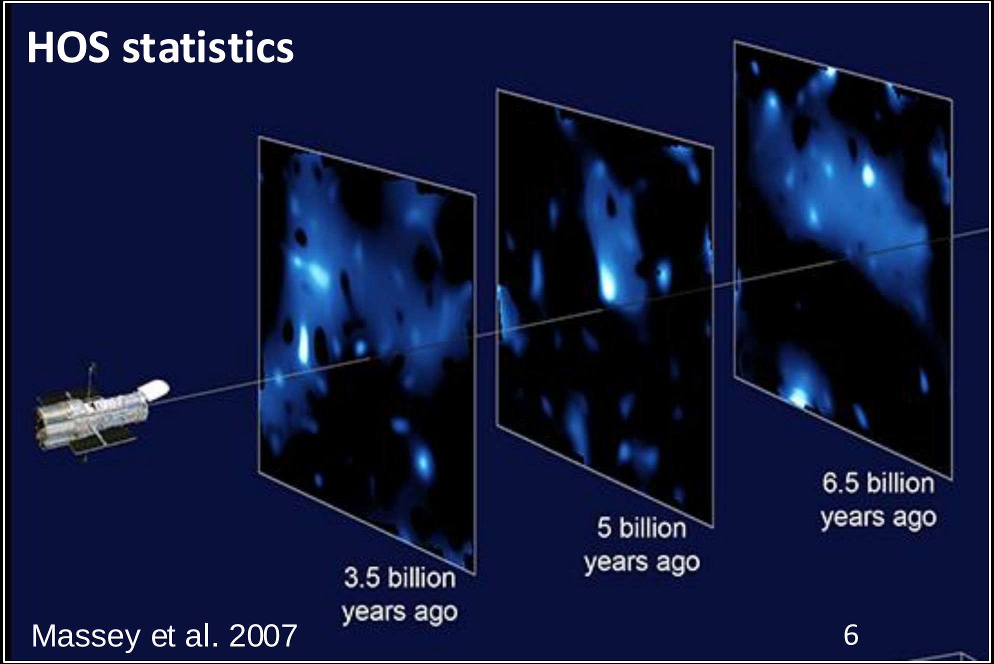
Redshift Space Distortion (RSD) provides constraints on the growth of structure

Weak Gravitational Lensing



Gravitational lens



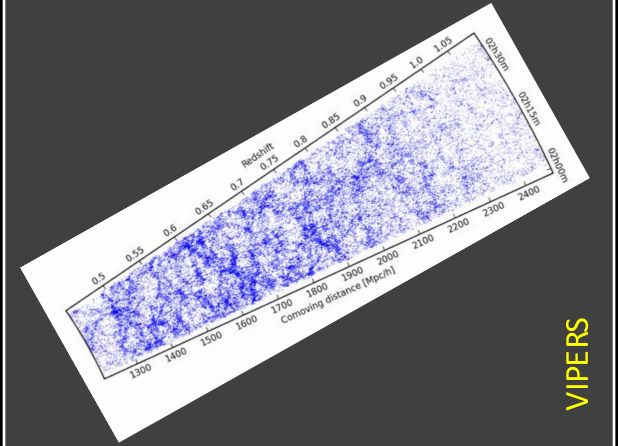


Euclid : Unveiling gravity and dark energy

Φ

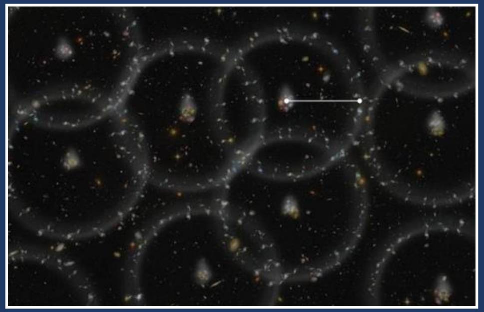
Governs the dynamic of non-relativistic objects

Galaxy clustering



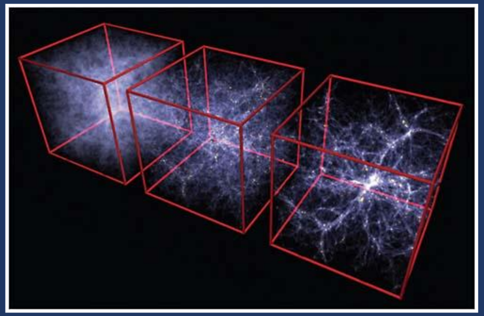
VIPERS

Expansion history



SDSSIII BOSS

Growth of structure

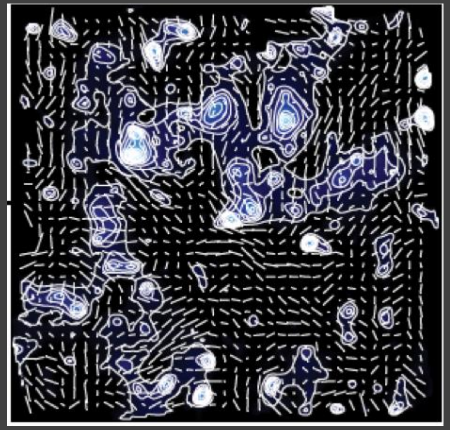


MPA/Millennium

Ψ_w

Governs the light propagation

Weak lensing



COSMOS

- **More than 2700 registered scientists; EC Lead Y. Mellier**
- **15 European countries + USA + Canada + Japan**
- **Responsible for the two Euclid instruments and the reduction and analysis of the data (Science Ground Segment)**

Spacecraft

- Satellite: Thales-Alenia Space
- Payload (telescope): Airbus Defence and Space

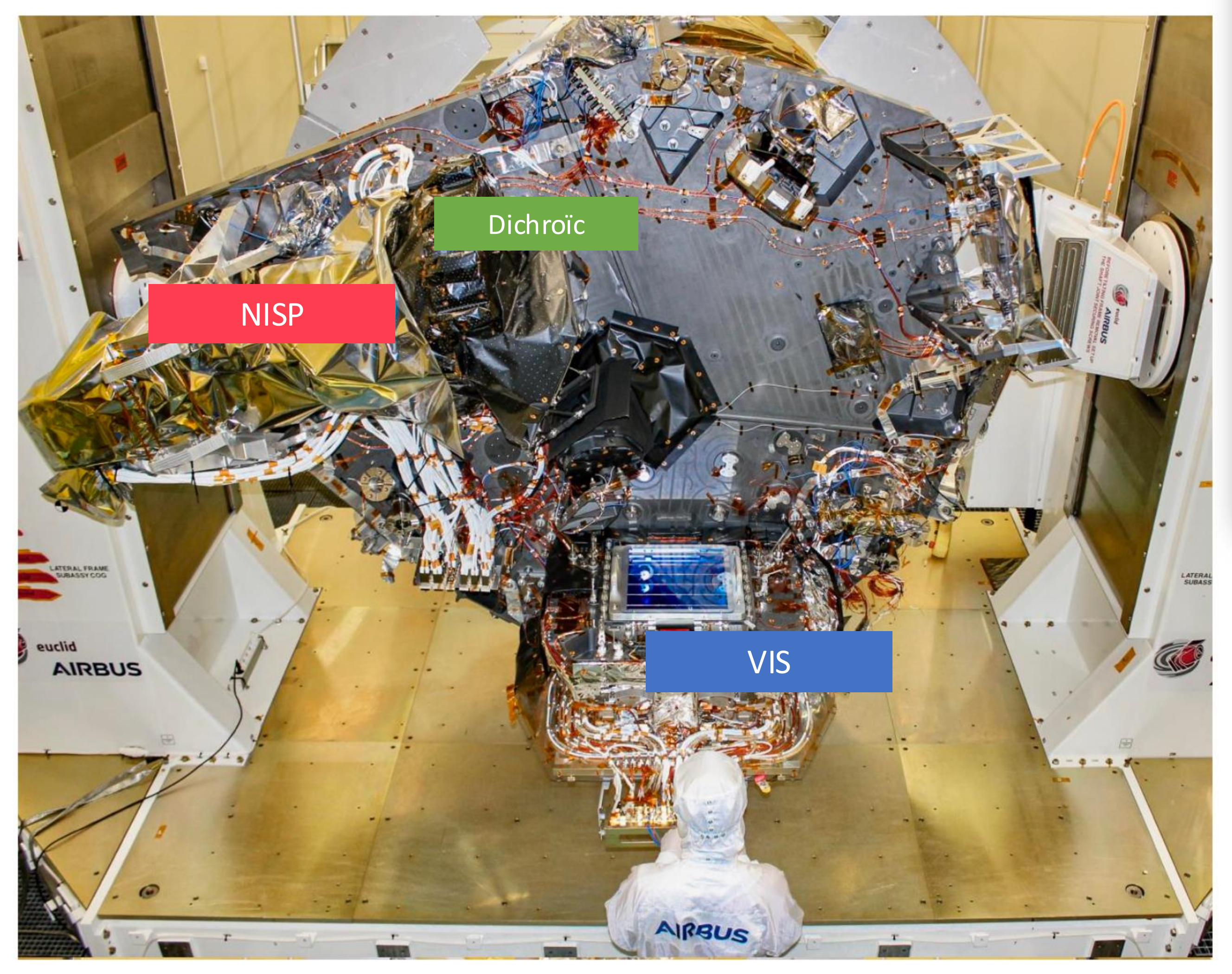
- Launch mass: 1988 kg
- Propellant: 137 kg hydrazine, lasting 14 years
- Data downlink: 4h / day, 820 Gbit

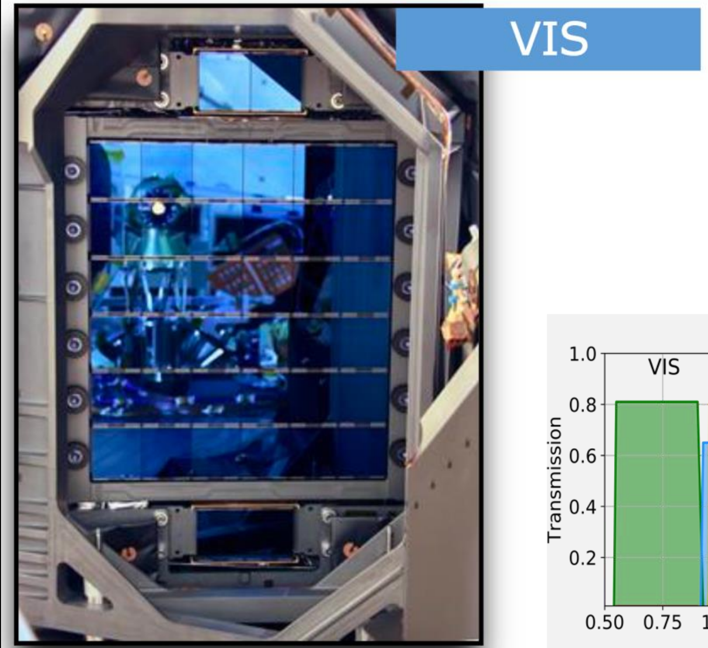
- 1.2m Korsch telescope in off-axis configuration
- Field of view 0.7 x 0.7 degrees

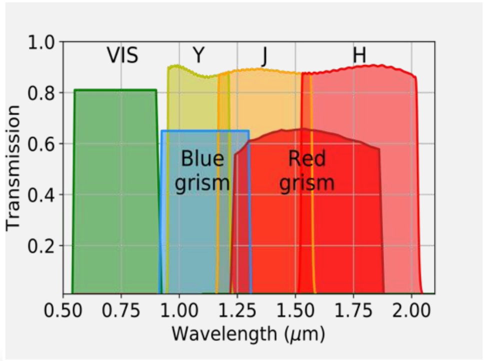
- Simultaneous observations (dichroic beam splitter)
- VIS (optical imaging)
- NISP (NIR imaging and slitless spectroscopy)

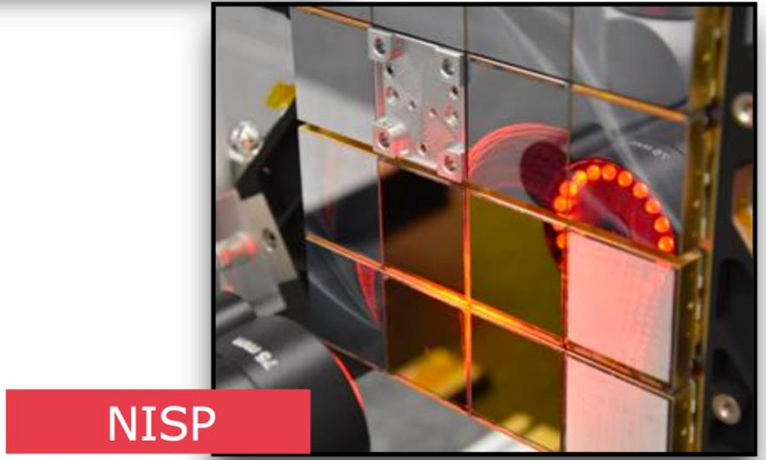
Euclid in Cannes / France, February 2023
Credit: ESA / M. Pedoussaut

Instruments

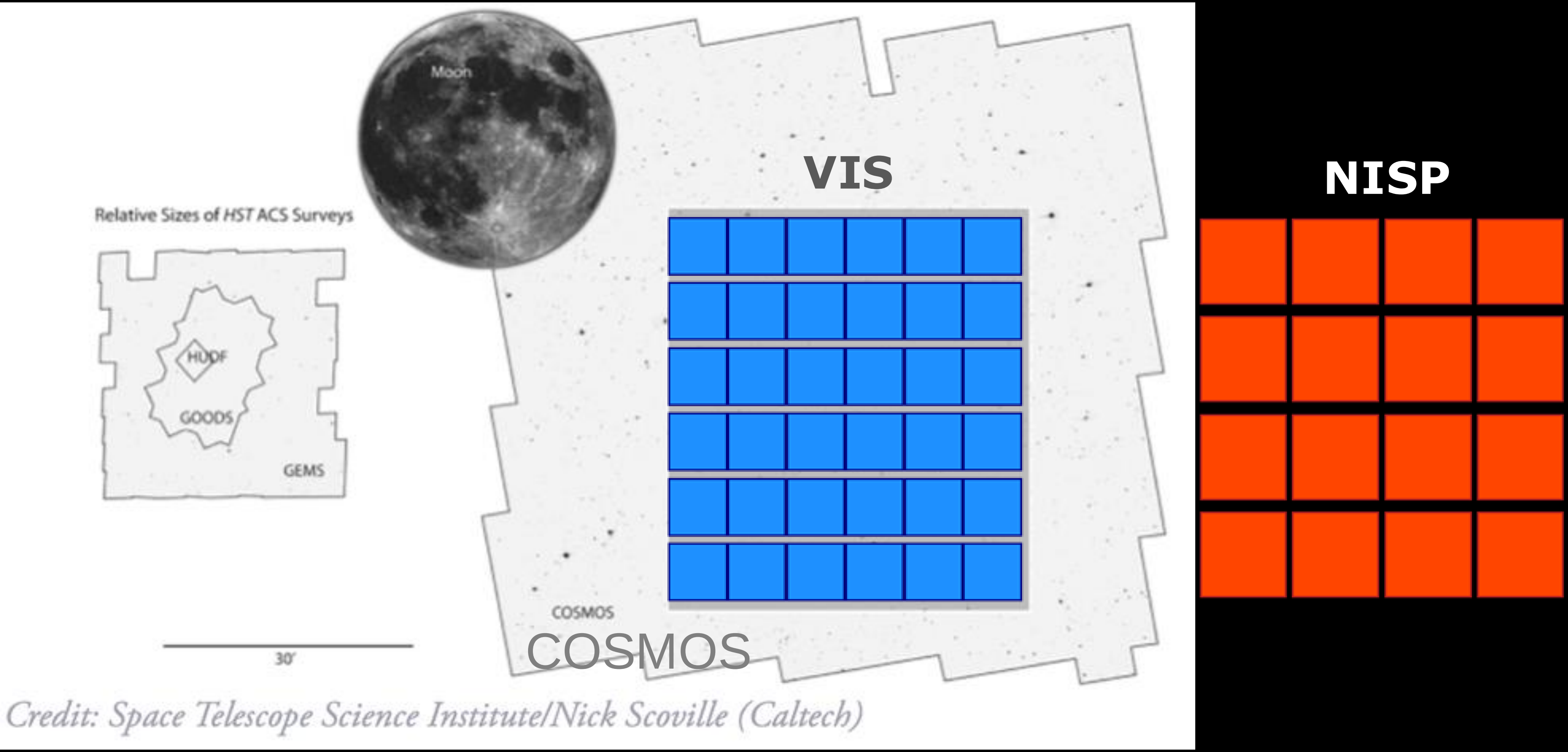








Twin wide-field imagers and NIR spectrograph

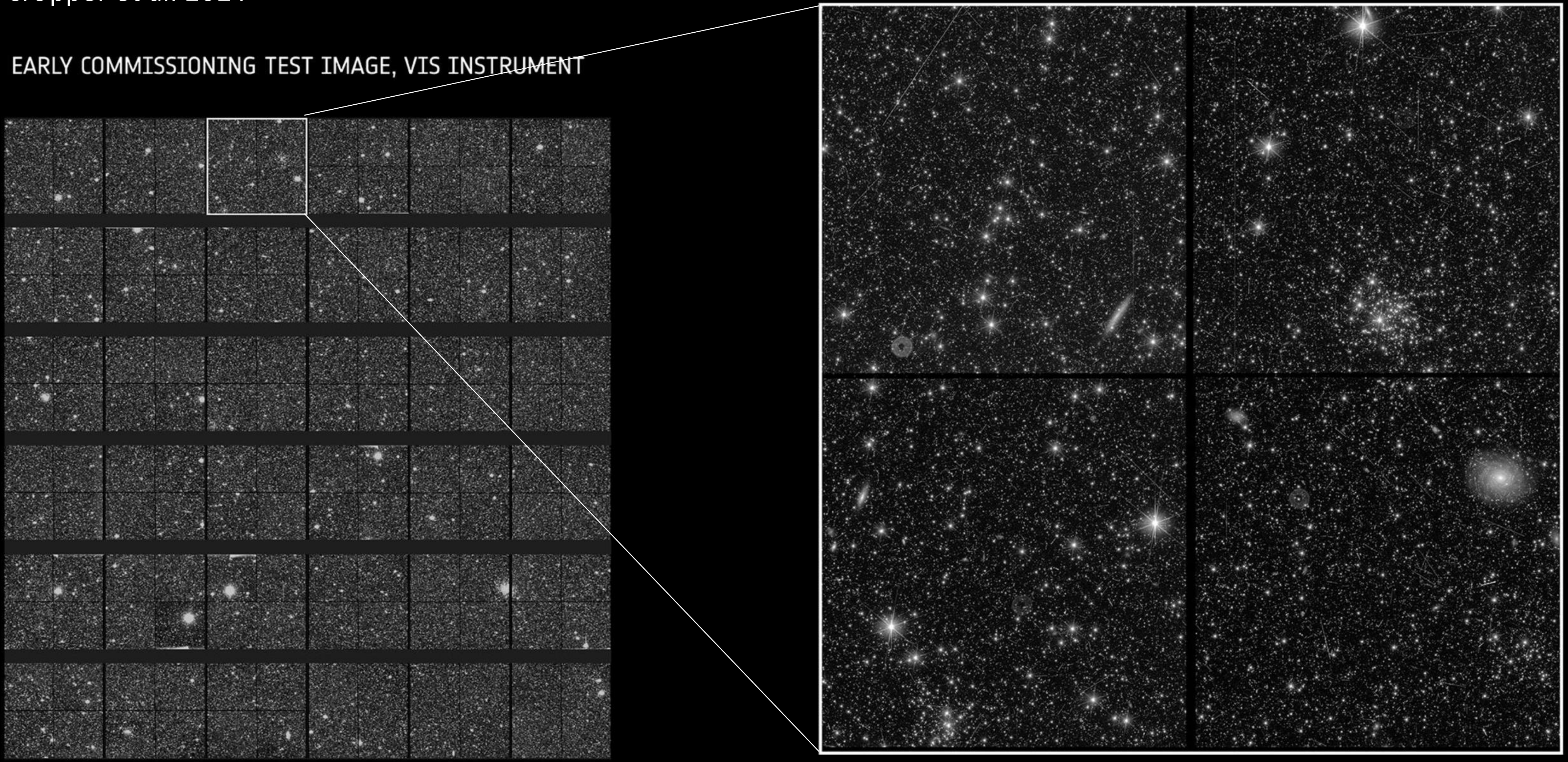


Euclid is the first panoramic space telescope ever: 10 deg^2 / day in the Wide survey
Euclid field = 0.54 deg^2

VIS instrument

Cropper et al. 2024

Credit : EC VIS team

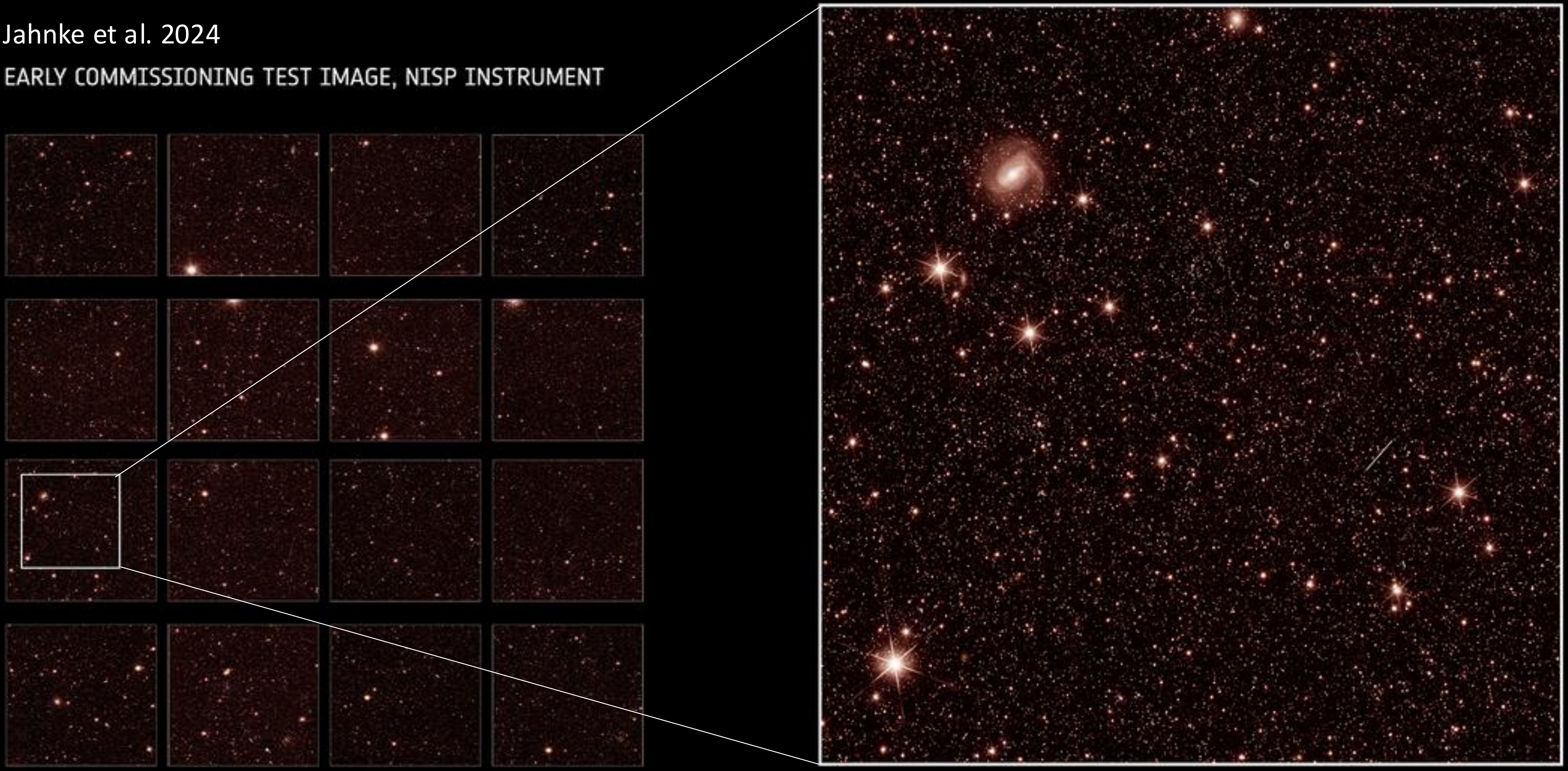


NISP Intrument

Jahnke et al. 2024

EARLY COMMISSIONING TEST IMAGE, NISP INSTRUMENT

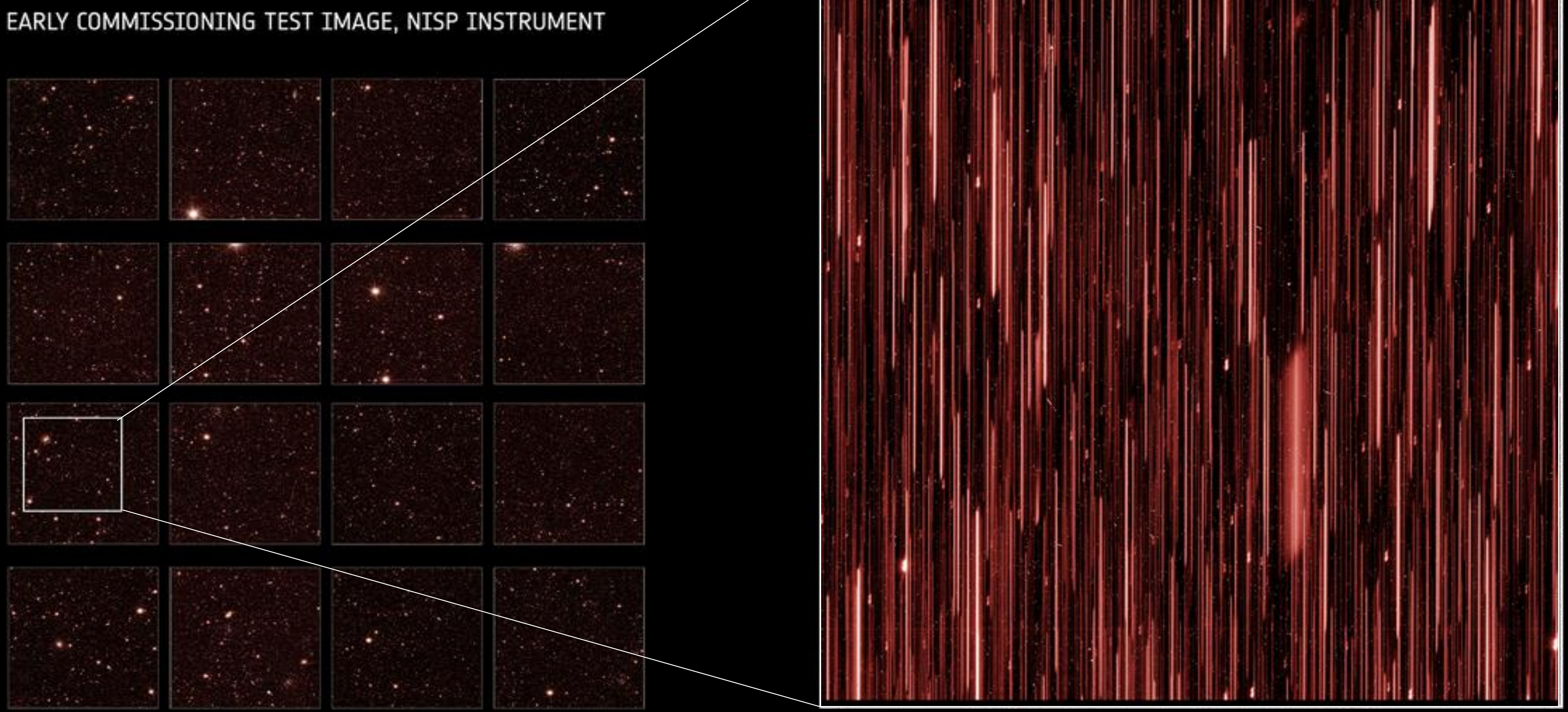
Credit : EC NISP team



NISP Intrument

Jahnke et al. 2024

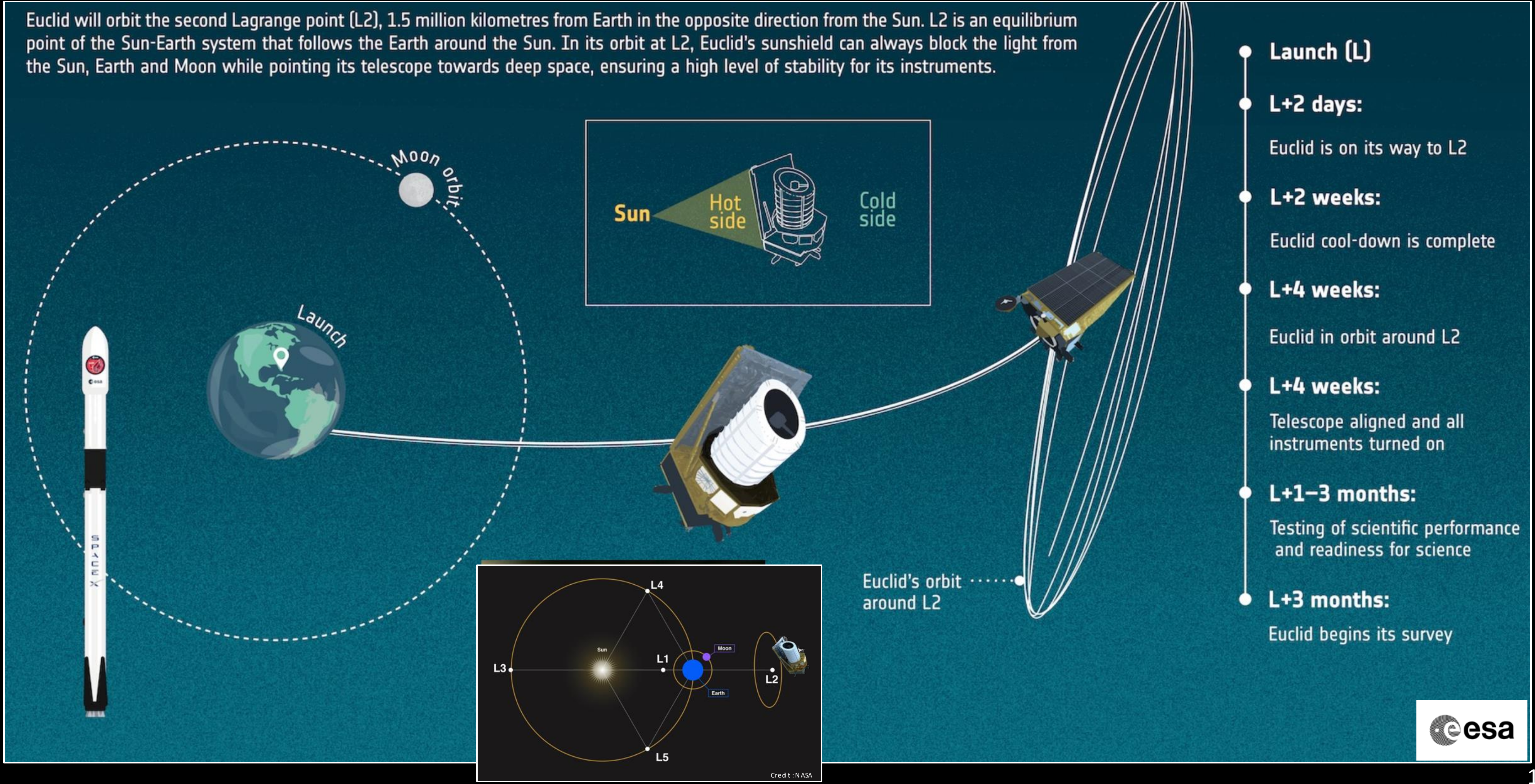
Credit : EC NISP team



Euclid launch: 1st July 2023

Euclid launched on a Falcon 9 on 1st July 2023, from Cape Canaveral. (Credits: ESA, NASA & Space-X)

Euclid journey to L2



Early Release Observations (ERO)

Credits: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi

Euclid on sky

Euclid consortium "On Sky" paper release:

www.euclid-ec.org/science/publications/

- 5 survey and instrument reference papers
- 10 papers on early release observations (ERO) results

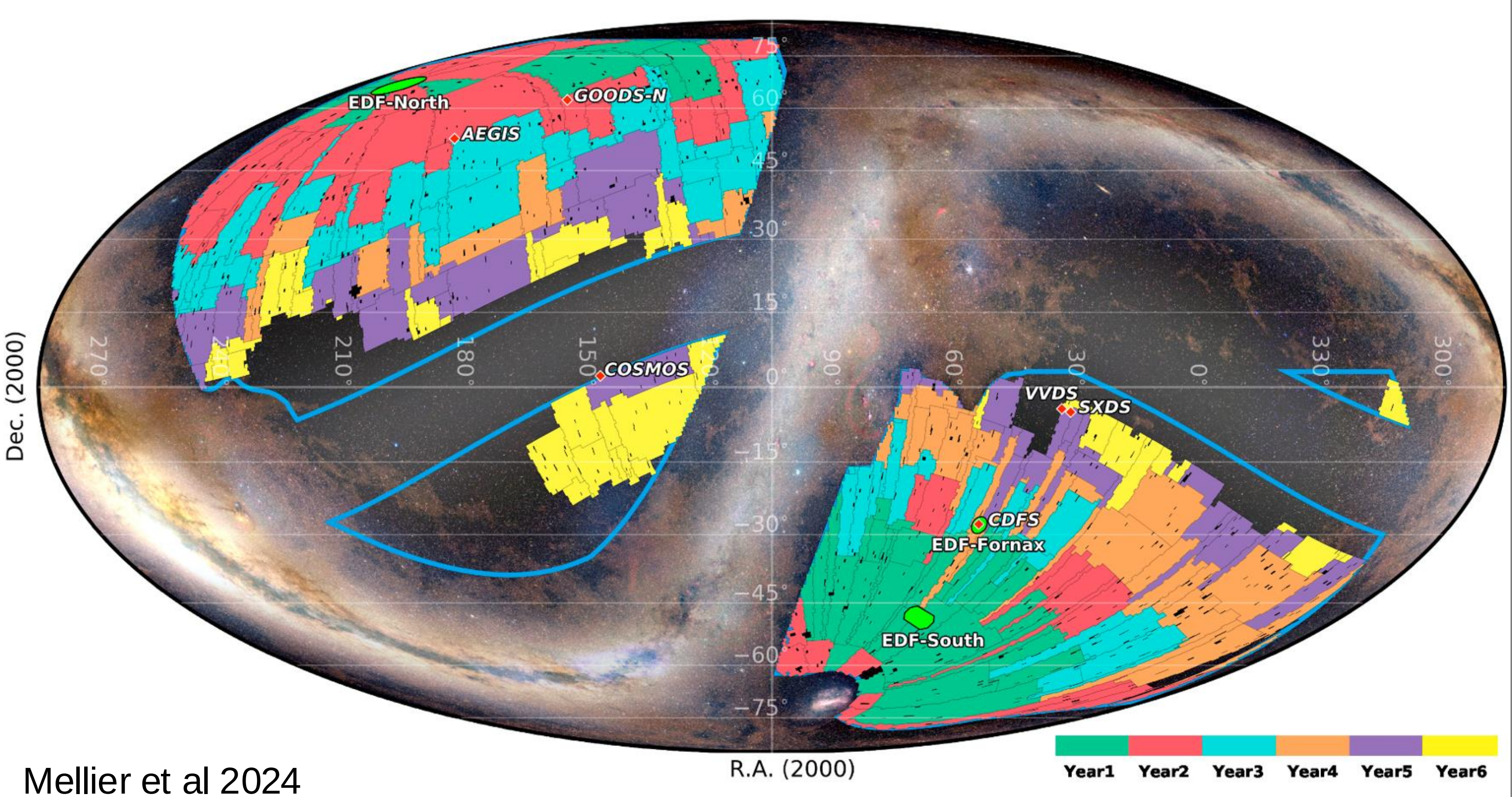
Coordinated Release "Euclid on Sky," May 2024

- Euclid Collaboration: Mellier et al., 2024, *"Euclid. I. Overview of the Euclid mission"*
- Euclid Collaboration: Cropper et al., 2024, *"Euclid. II. The VIS Instrument"*
- Euclid Collaboration: Jahnke et al., 2024, *"Euclid. III. The NISP Instrument"*
- Euclid Collaboration: Hormuth et al., 2024, *"Euclid. IV. The NISP calibration unit"*
- Euclid Collaboration: Castander et al., 2024, *"Euclid. V. The Flagship galaxy mock catalogue: a comprehensive simulation for the Euclid mission"*

- Cuillandre et al., 2024, *"Euclid: Early Release Observations -- Programme overview and pipeline for compact- and diffuse-emission photometry"*
- Martin et al., 2024, *"Euclid: Early Release Observations -- A glance at free-floating new-born planets in the σ Orionis cluster"*
- Massari et al., 2024, *"Euclid: Early Release Observations -- Unveiling the morphology of two Milky Way globular clusters out to their periphery"*
- Hunt et al., 2024, *"Euclid: Early Release Observations -- Deep anatomy of nearby galaxies"*
- Saifollahi et al., 2024, *"Euclid: Early Release Observations -- Globular clusters in the Fornax galaxy cluster, from dwarf galaxies to the intracluster field"*
- Cuillandre et al., 2024, *"Euclid: Early Release Observations -- Overview of the Perseus cluster and analysis of its luminosity and stellar mass functions"*
- Marleau et al., 2024, *"Euclid: Early Release Observations -- Dwarf galaxies in the Perseus galaxy cluster"*
- Kluge et al., 2024, *"Euclid: Early Release Observations -- The intracluster light and intracluster globular clusters of the Perseus cluster"*
- Atek et al., 2024, *"Euclid: Early Release Observations -- A preview of the Euclid era through a magnifying lens"*
- Weaver et al., 2024, *"Euclid: Early Release Observations -- NISP-only sources and the search for luminous z=6-8 galaxies"*

Euclid consortium

Euclid reference survey



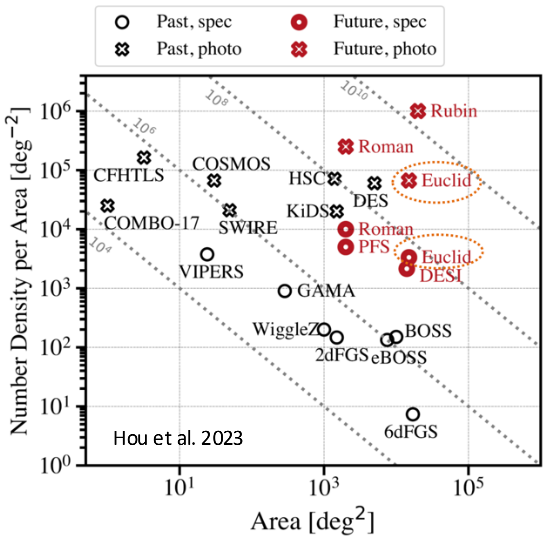
Mellier et al 2024

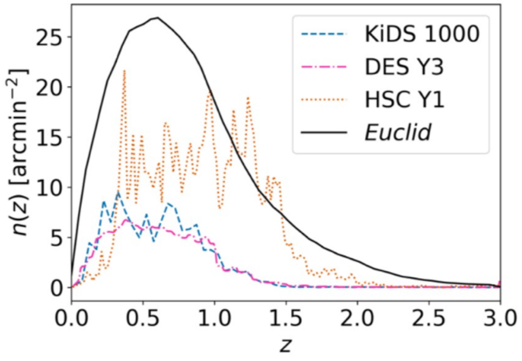
- Duration: 6 years survey
- Euclid will observe 10 deg^2/day of the Euclid Wide Survey
- 12% of Euclid time is spent on Euclid Deep Survey

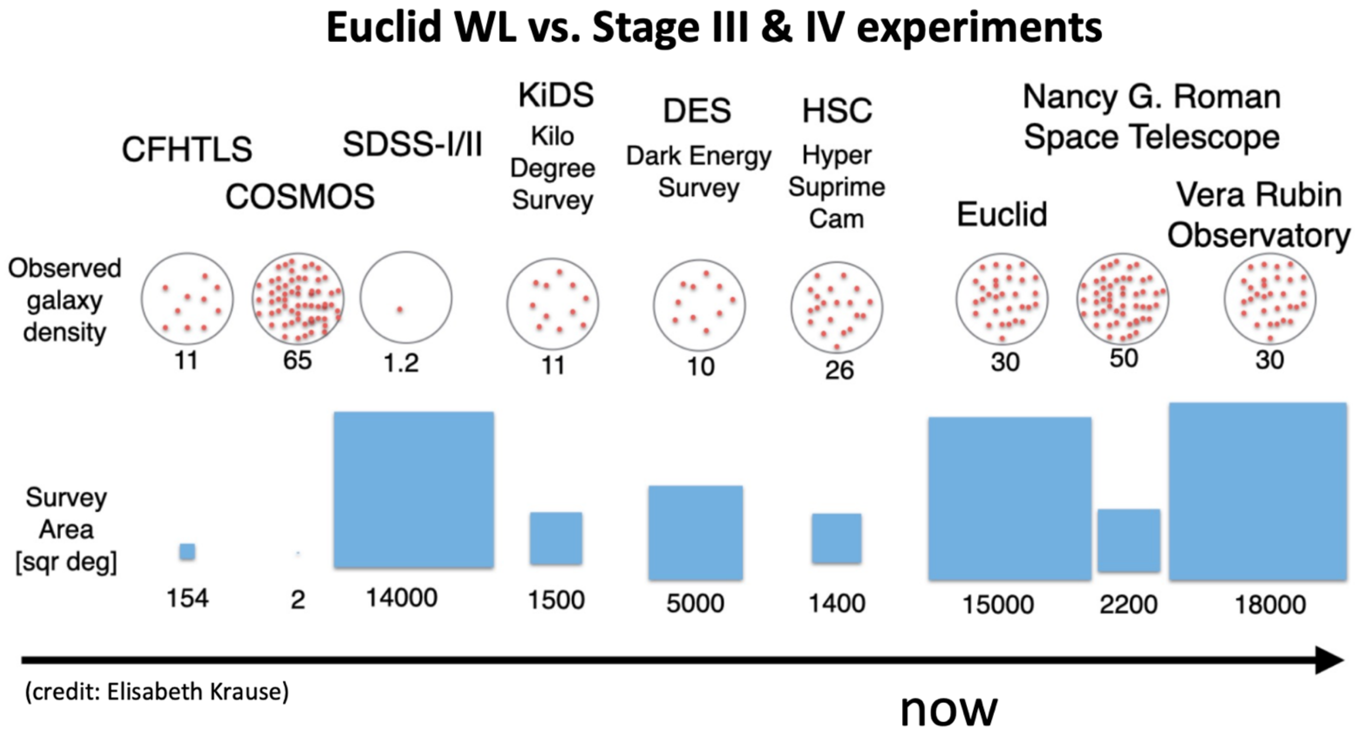
Euclid Wide Survey
- 14 000 deg^2
- 1.5 billion galaxies with photometric redshif and shape measurement (ng = 30 gal/arcmin^2)
- 30 million of galaxies with spectroscopic redshift

Euclid Deep Survey
- Expected galaxy density: ng = 50 gal/arcmin^2
- 3 fields
  - EDF-N : 20 deg^2
  - EDF-S : 23 deg^2
  - EDF-F : 10 deg^2

Eulid Wide Survey in context

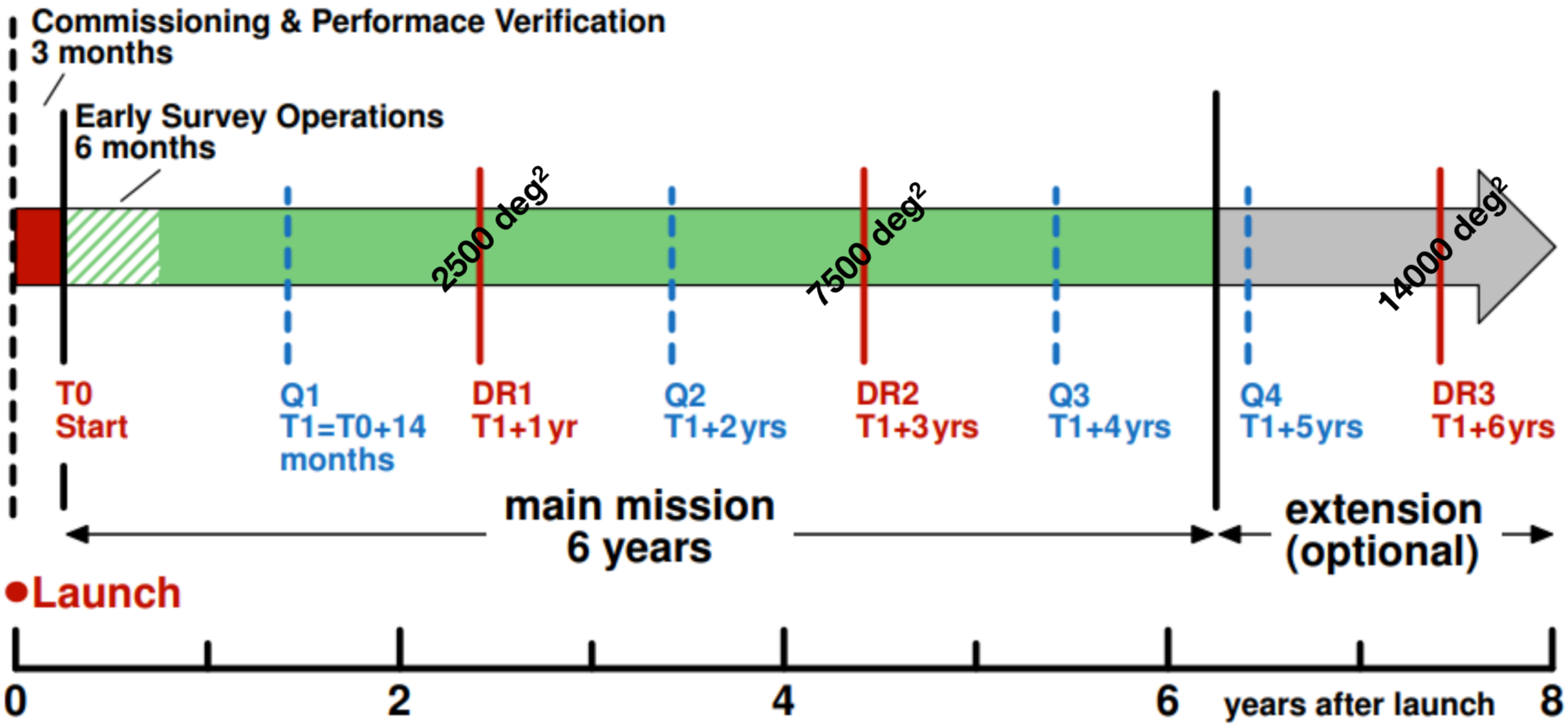






Unprecedented volume coverage with objects up to redshift 2

Euclid Data Releases



First Cosmology results in 2026 and several public releases afterwards that will continue to produce interesting physics results

Cosmological inference

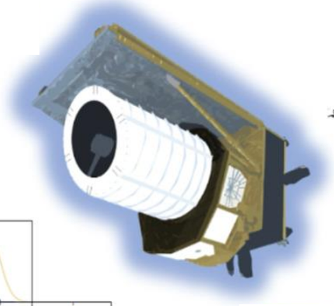
Theoretical Predictions
COMPUTE EUCLID PRIMARY OBSERVABLES ACCORDING TO THE THEORY

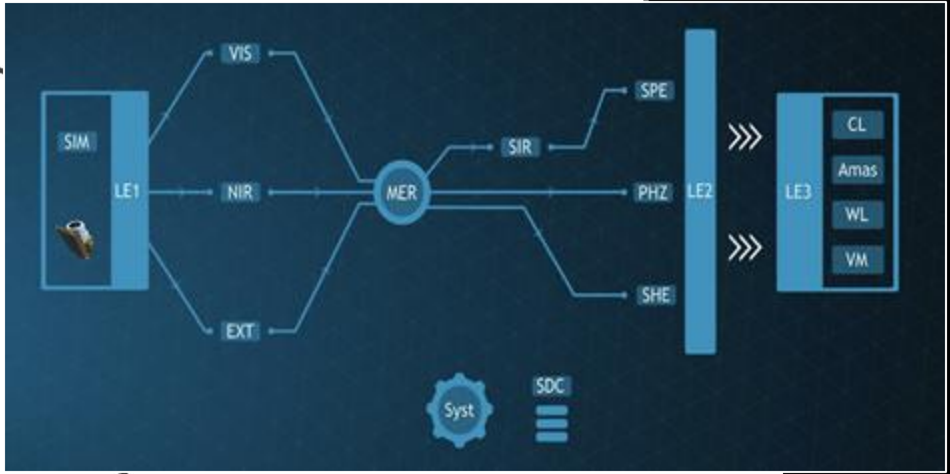
Non-linear cosmology
MODEL NON-LINEAR SCALES FOR POWER SPECTRA

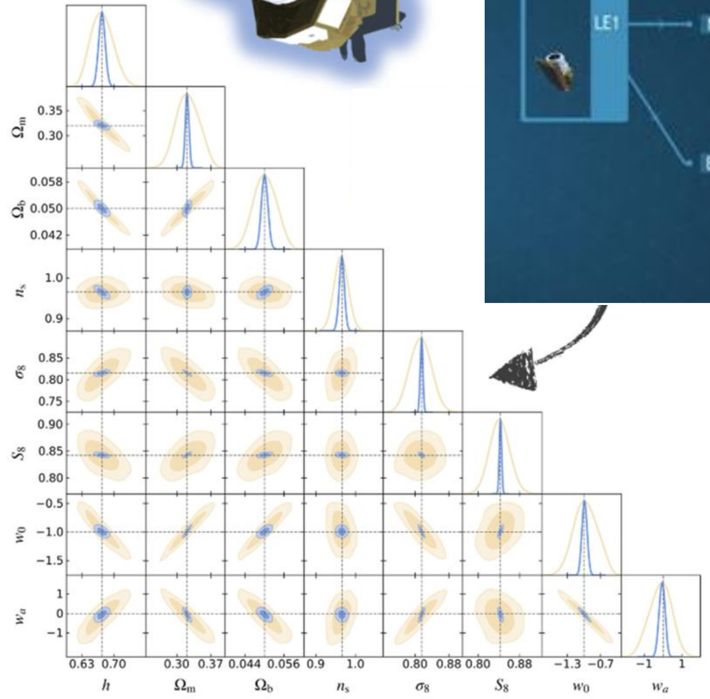
Euclid data as input
DATA VECTORS ARE PROVIDED BY THE EUCLID SCIENCE GROUND SEGMENT

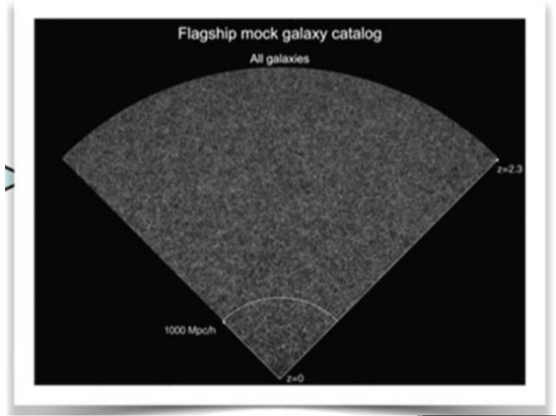
Likelihood computation
WE COMPARE THEORY AGAINST DATA DOING A STATISTICAL ANALYSIS

Cosmological parameters
PRODUCE THE BAYESIAN STATISTICAL ANALYSIS TO OBTAIN CONSTRAINTS ON COSMOLOGICAL PARAMETERS









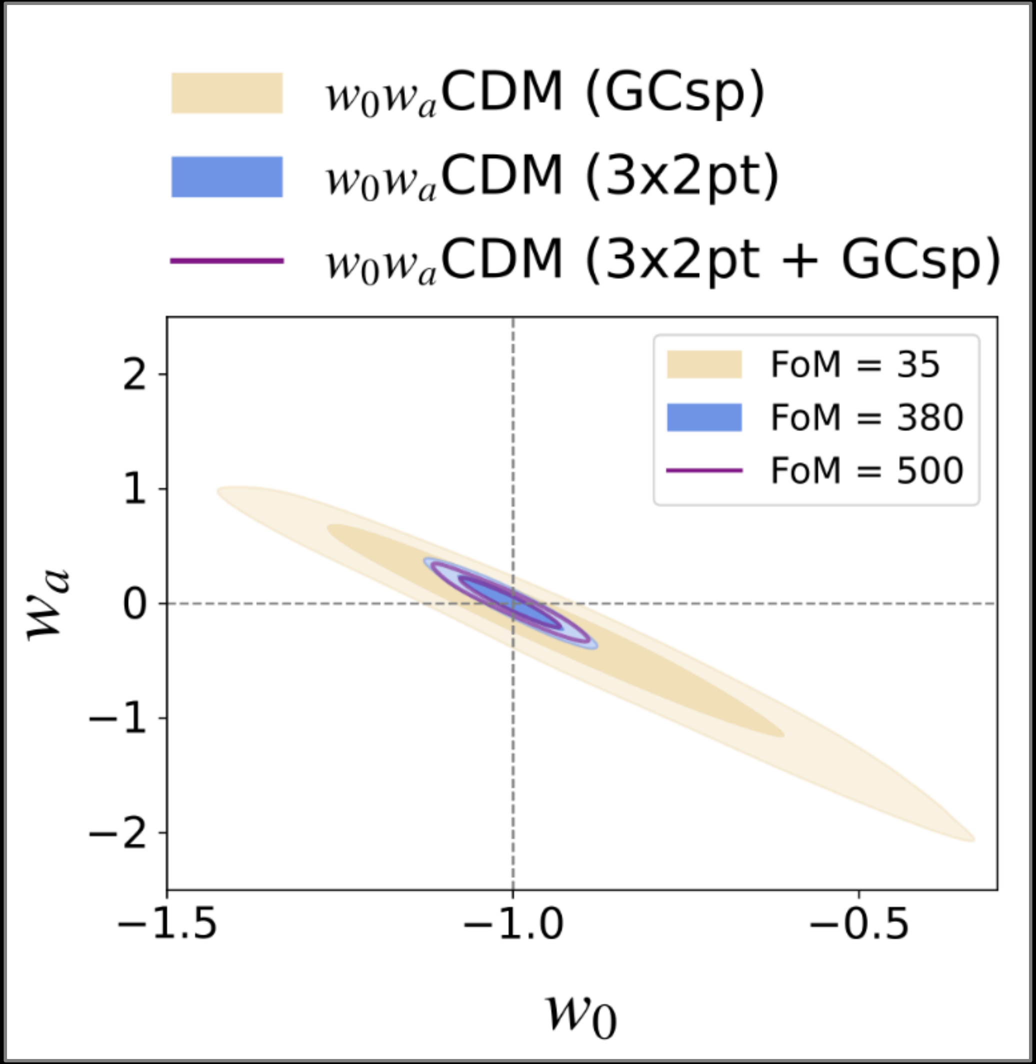
Castander et al. 2024

Euclid: the physics of cosmic acceleration

The dark energy equation of state $w \neq -1$ indicates a departure from the cosmological constant, requiring a dynamical dark energy scenario.

Parameterised evolution of $w(z)$:

$$w(z) = w_0 + w_a \frac{z}{1+z}$$

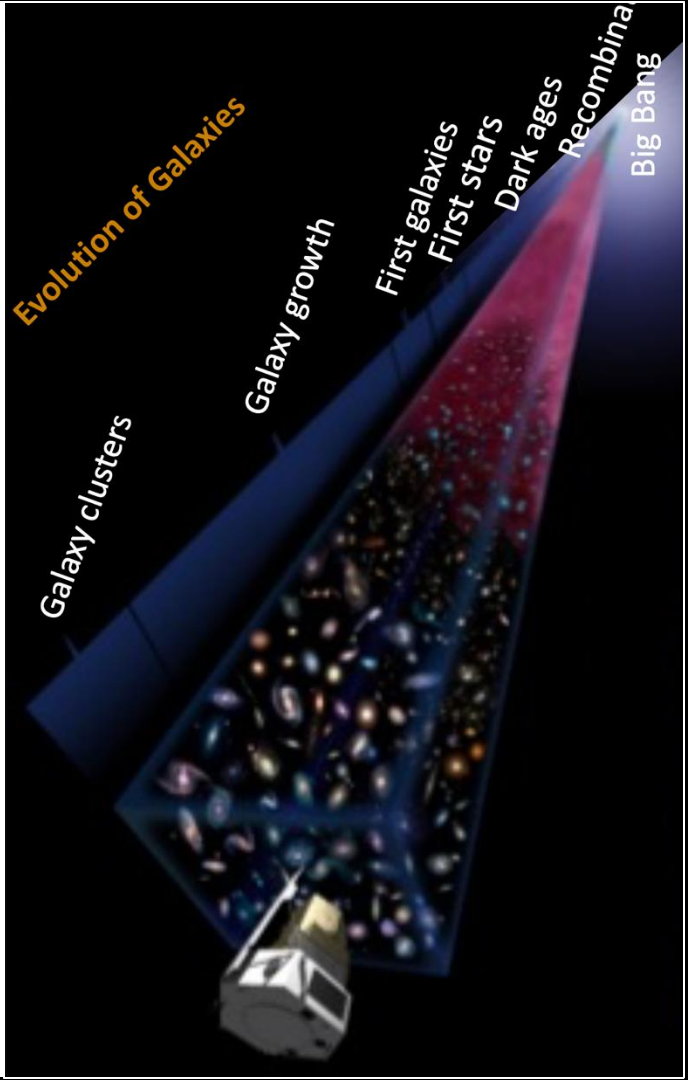


Euclid Forecast (Mellier et al 2024)

Euclid Additional Science

- 10^5 **galaxy clusters**
- **Cosmic Voids**
- **Cross-correlations with CMB** temperature and lensing
- 10^5 **strong gravitational lenses**
- Transients in Deep fields
  - ~50 **Super-luminous SNe** / year (Inserra+17)
- Galaxy formation and evolution
  - Census of **AGN** at $1 < z < 3$
  - Galaxy **morphologies** at $z > 1$
  - **Lyman break galaxies** at $z > 7$
  - High-z **quasars**
- Milky Way
  - Census of **brown dwarf** stars
  - **Satellites & environs**

x10 in number of sources compared to previous surveys in most cases



Outlook

Euclid launched successfully from Cape Canaveral on July 1st 2023 with Space-X Falcon9: very efficient orbit insertion into L2, >10 yrs lifetime expected

Unique optical quality telescope: a terapixel machine. Early issues (guiding system, stray light and ice deposition) solved. X-ray flares are handled successfully on a regular basis

Currently surveying 10 deg^2 per day: goal is to map one third of the sky (14000 deg^2) and unveil the nature of DM and DE by measuring weak gravitational lensing and galaxy clustering to exquisite precision and unmatched accuracy (probe combination)

Immense potential for legacy science: Early Release Observations provide a glimpse of the unprecedented information content of even a single Euclid snapshot.

Results will provide high precision results on the equation of state of dark energy and other cosmological parameters.
First data release after one year of operations (2500 deg^2, mid 2026)

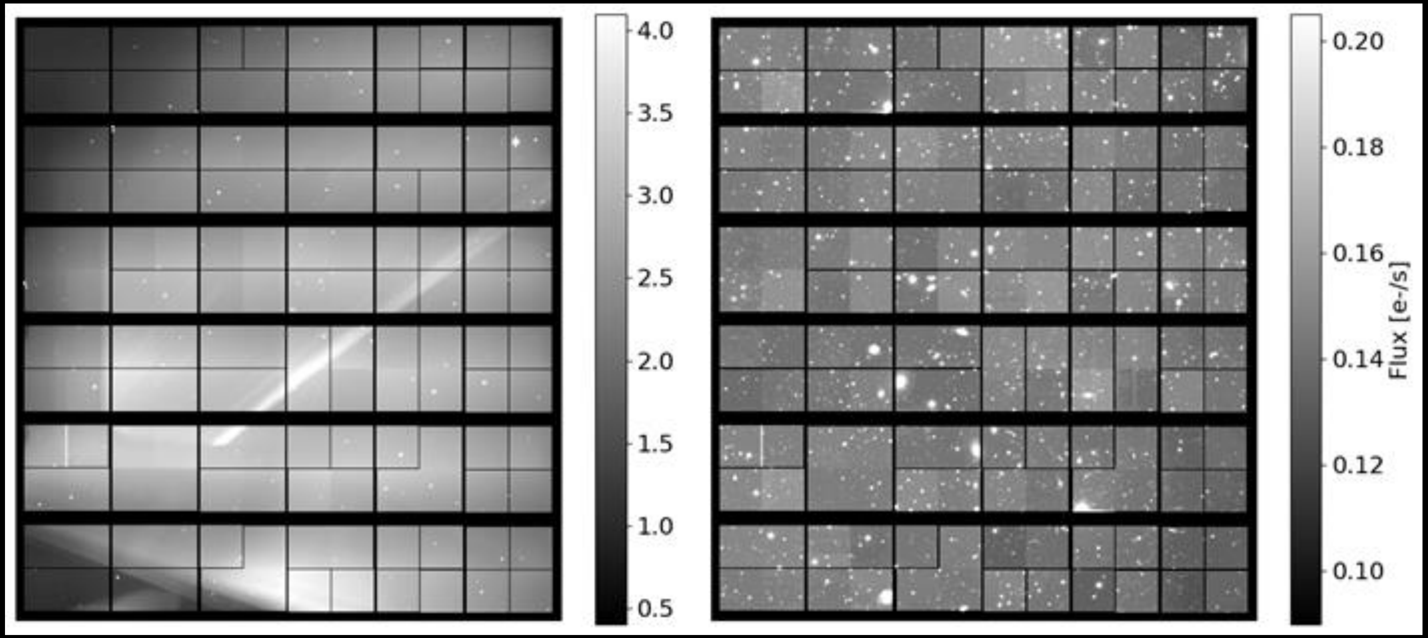
Euclid consortium

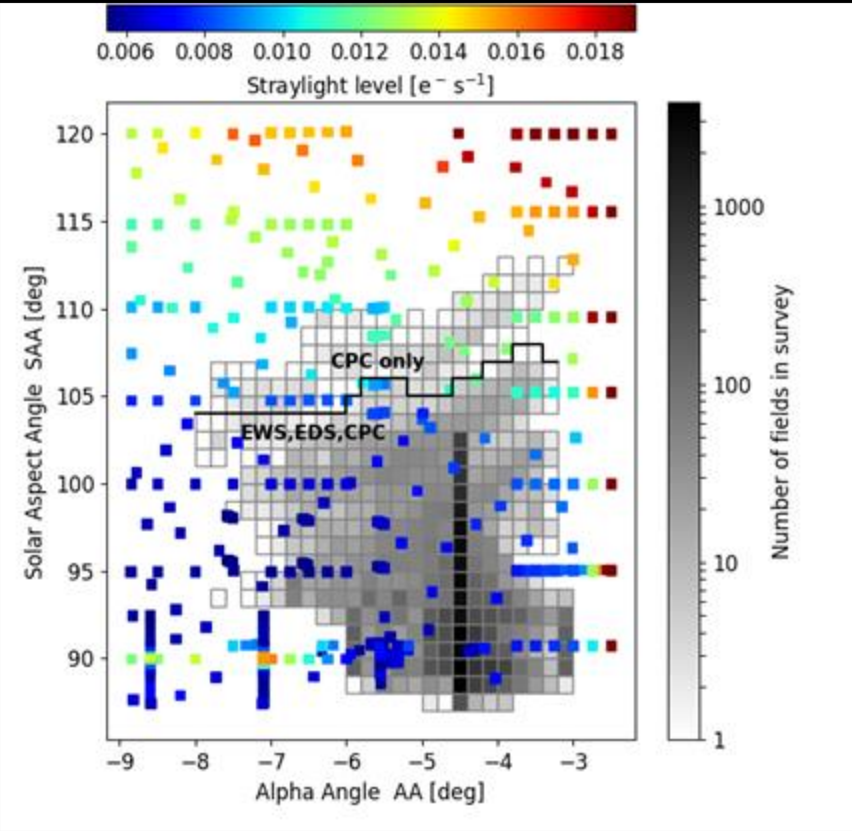
Euclid
consortium

EXTRA SLIDES

Internal straylight

Mellier et al 2024





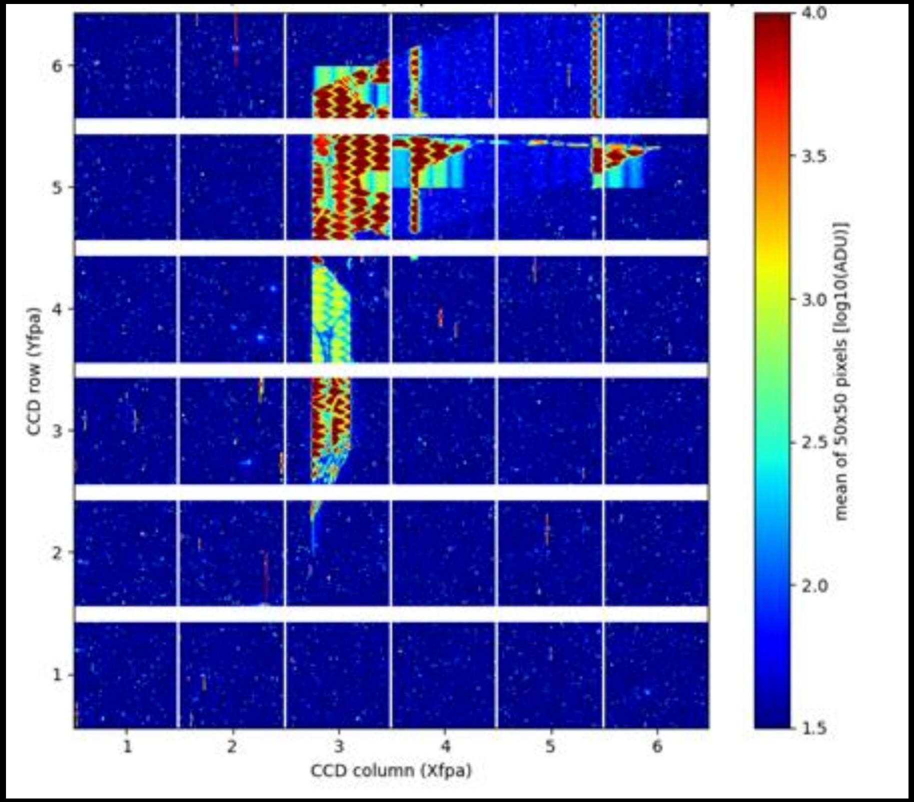
Left: Sunlight hitting a thruster nozzle reaches VIS detectors. NISP is unaffected.

Middle: Straylight is largely avoided by orienting Euclid so that nozzle is in shadow

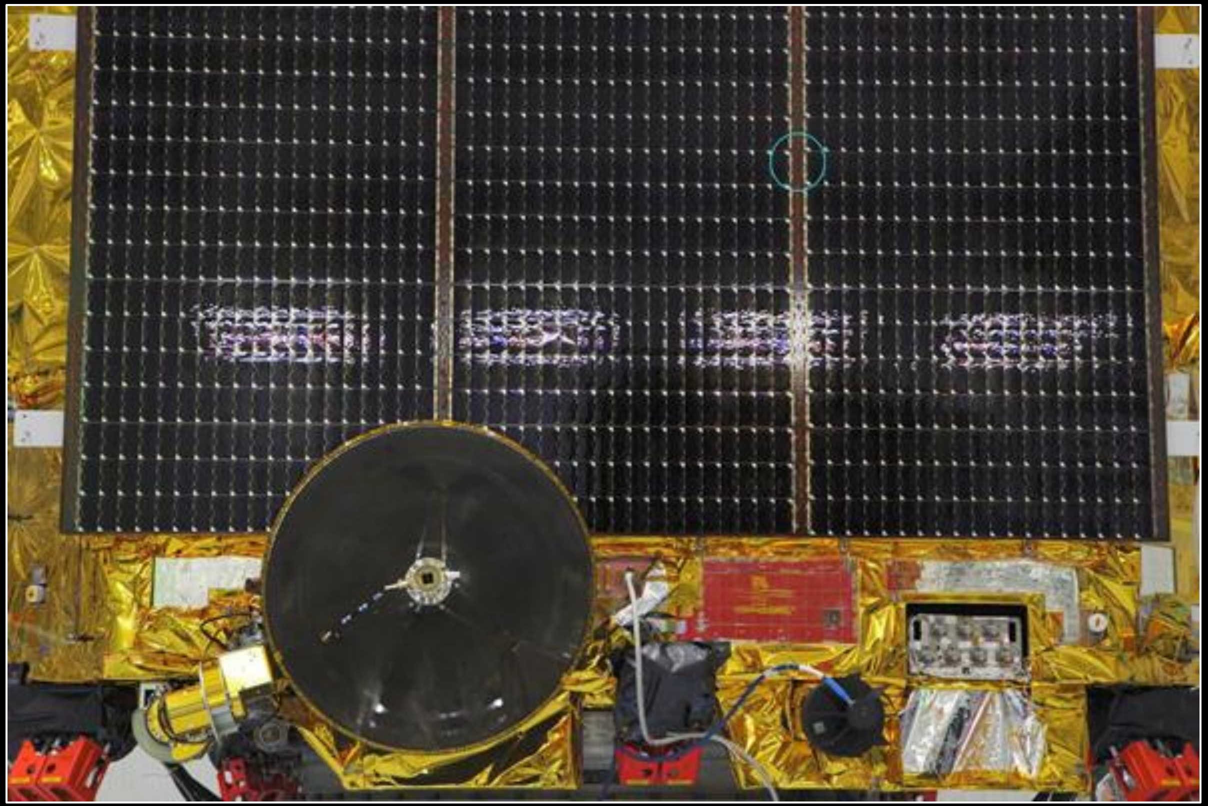
Right: The survey was fine-tuned to select low-straylight conditions, only.

X-ray contamination

X-rays from Solar flares penetrate sunshield and reach VIS. Average area loss during Solar maximum: 3-4%



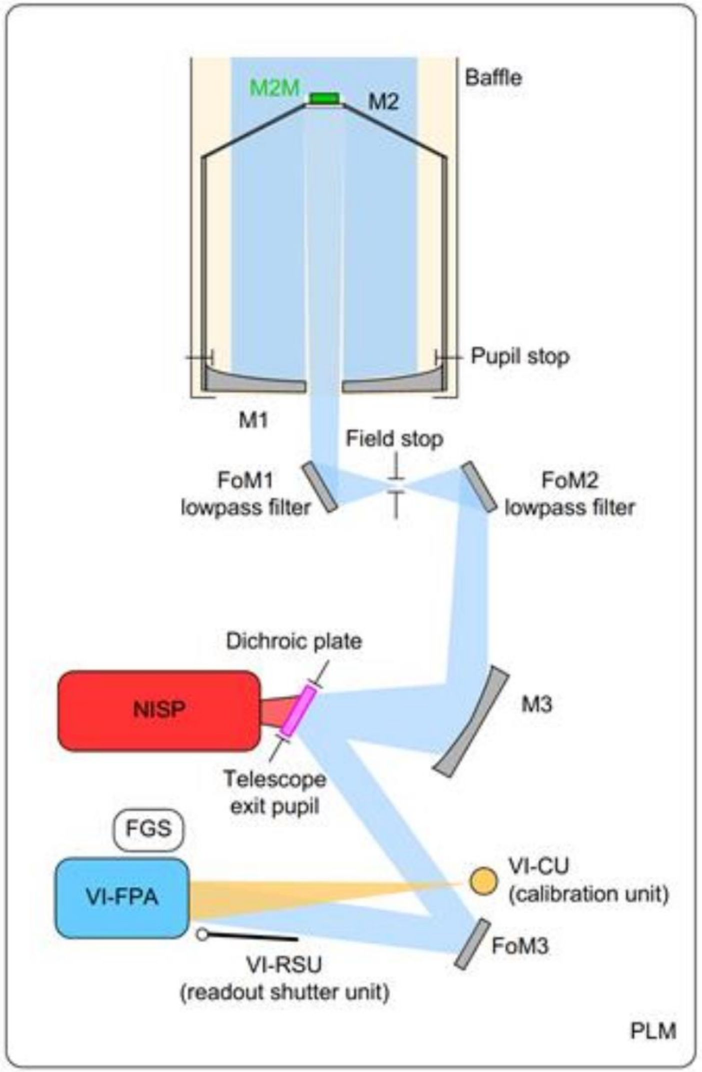
VIS image taken during an X-class flare. Weak flares cause isolated cosmics. Strong flares result in contiguous area loss.

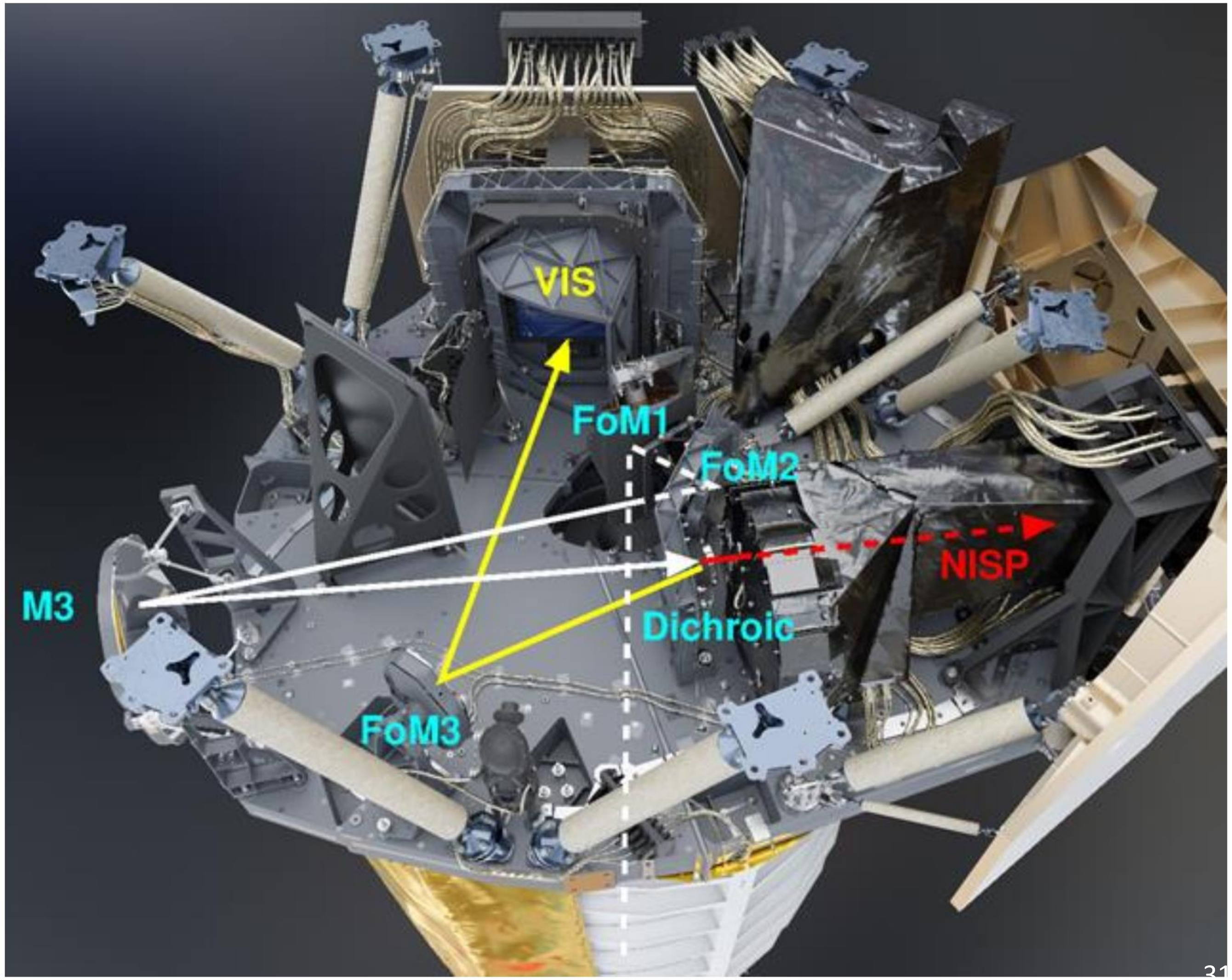


X-rays enter through the major gaps between solar cells.

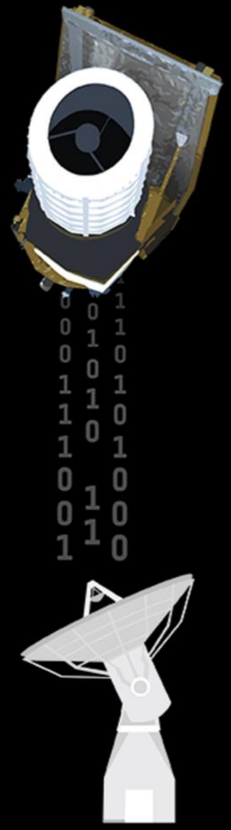
Credit: J.-C. Cuillandre

Payload module, instruments and path





Data Transfer



Credit: ESA/ATG

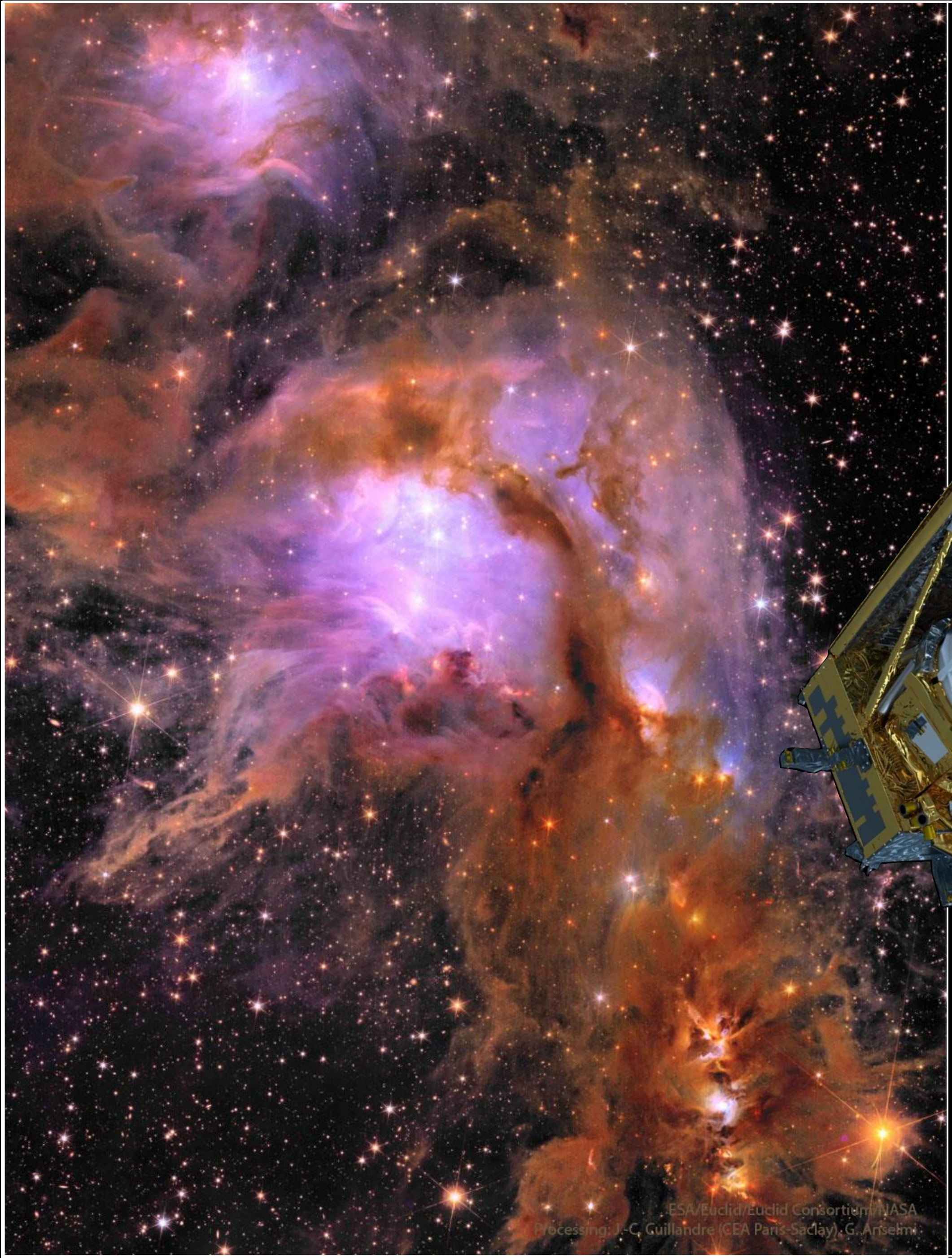
- Collecting 30 Petabytes of unprocessed data
- Communications from L2, to ESOC (Germany), to ESAC (Madrid), once per day
- Distribution along 9 dedicated data centres

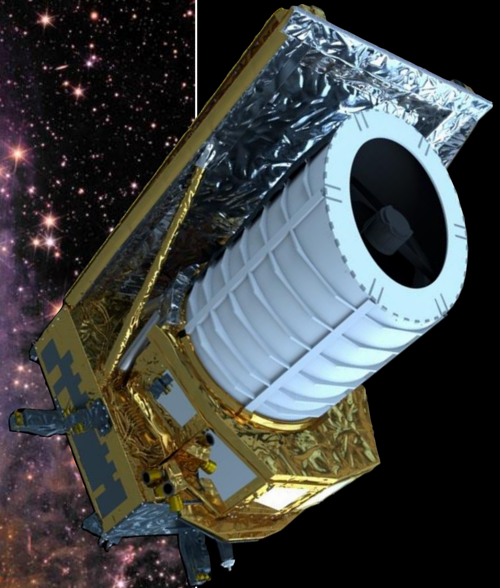
Euclid Top Level Science Requirements

Dark Energy	Test of Gravity
• Measure the cosmic **expansion history** to **better than 10%** in redshift bins 0.9 < z < 1.8. • Look for **deviations from** $w_0 = -1$, indicating dynamical Dark energy. • Euclid primary probes to give FoM_{DE} **> 400** (**1-sigma errors on** w_0 **and** w_a **of 0.02 and 0.1 respectively**)	• Measure the growth rate to better than 0.02 in redshift bins between 0.9 < z < 1.8. • Measure the **growth index, γ, with a precision better than 0.02.** • Separately constrain the two relativistic potentials. ψ and φ· • Test the cosmological principle.
Dark Matter	**Initial conditions**
• Detect Dark matter halos on a mass scale $10^8 < M/M_\odot < 10^{15}$. • Measure the Dark matter mass profiles on cluster and galactic scales. • Measure the **sum of neutrino masses with an accuracy of 0.03 eV.**	• Constraint σ_8 **and** n_s **to a 1-sigma accuracy of 0.01.** • For extended models, improve constraints on spectral indices compared to Planck alone by a factor ~2. • Measure **non-Gaussianity:** $\Delta f_{NL} = \pm 2$.

- *DE equation of state:* $P/\rho = w$ *with* $w(a) = w_p + w_a(a_p - a)$
- *Growth rate of structure formation:* $f \sim \Omega^{\gamma}$;
- *FoM=1/(*$\Delta w_a \times \Delta w_p$*) > 400* → *~2% precision on* w_p

Euclid Redbook 2011


ESA/Euclid/Euclid Consortium/NASA
Processing: J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi



THE END