Constraining the dark sectors of the Universe with the *Euclid* mission

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University of Zaragoza, June 1, 2026

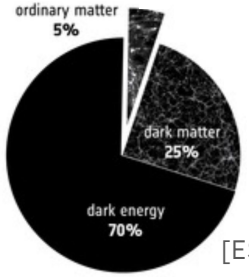
Identification of Dark Matter 2026

Outline

- Introduction
- *Euclid* core science
- Probe combination in *Euclid*
- Going beyond the main probes
- From launch to the first data release
- Conclusions

Introduction

- The **concordance model** in cosmology, LCDM, has been accurately reproducing the **main cosmological observations** for several decades

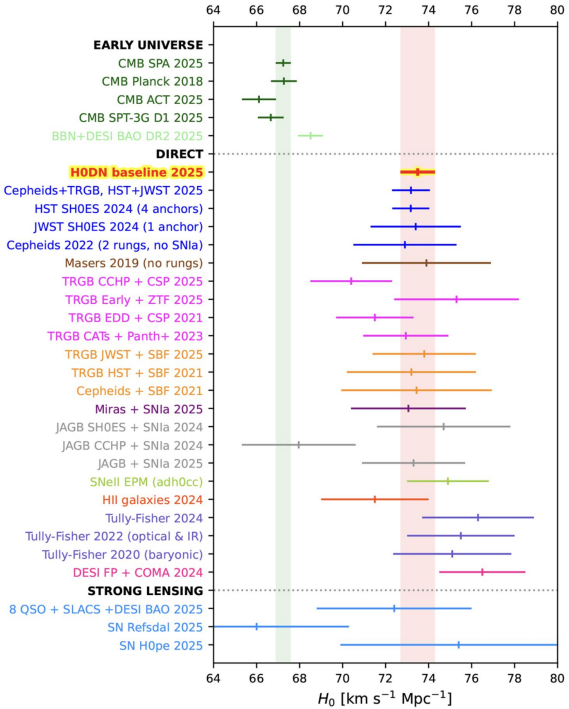


[ESA]

- But:
  - The **nature** of its main components, dark matter and dark energy, remains **unknown**
  - Some **tensions** start to appear
  - The latest data show preference for an **evolving dark energy**

Introduction

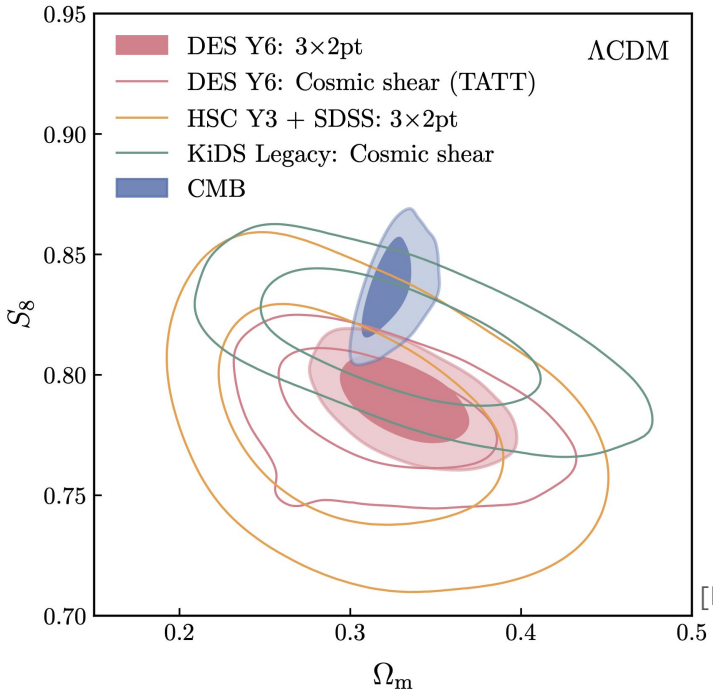
- **Hubble tension**: more than 5 sigma discrepancy between direct measurements and LCDM-derived estimates with high-redshift data



[H0DN Collaboration: Casertano et al. 2026]

Introduction

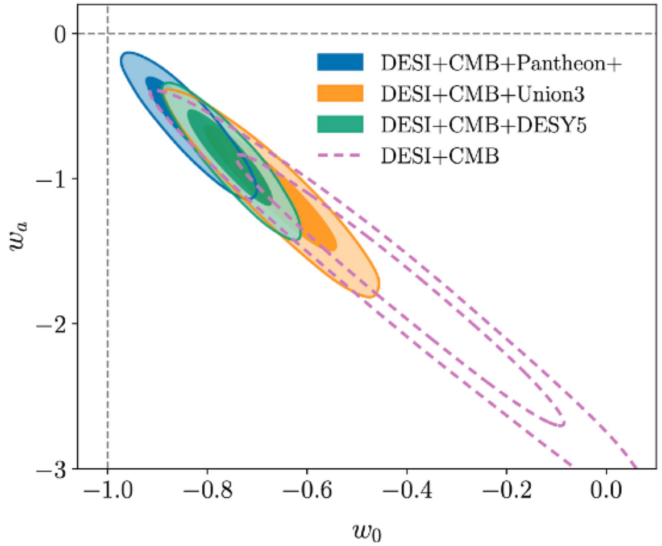
- **S8 tension**: ~2 sigma discrepancy between weak gravitational lensing and cosmic microwave background estimates



[DES Collaboration: Abbott et al. 2026]

Introduction

- **Evolving dark energy**:
  - Phenomenological approach: treat dark energy as a fluid
  - Parameterizing its equation of state parameter as $w(z) = w_0 + w_a \frac{z}{1+z}$
  - 3-4 sigma preference for evolving dark energy with the latest observations:



[DESI Collaboration: Abdul-Karim et al. 2025]

Introduction

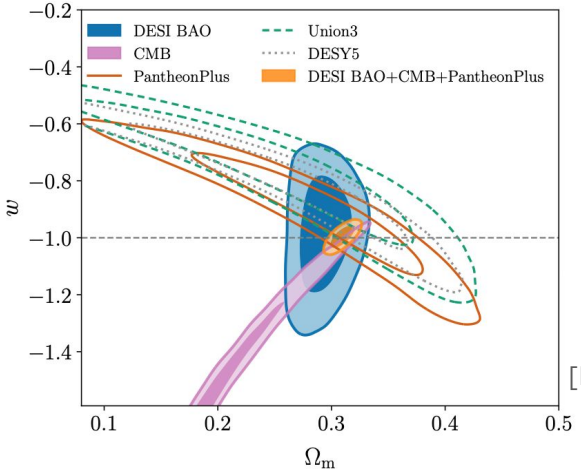
- In the coming years **observational cosmology** will reap the benefits from the **investment in large projects** to better understand the Universe

- *Euclid*:
  - Largest European project with important contributions from Canada, Japan, USA
  - Exquisite measurements to shed new light on the dark components
  - Different cosmological probes are considered


[ESA]

Introduction

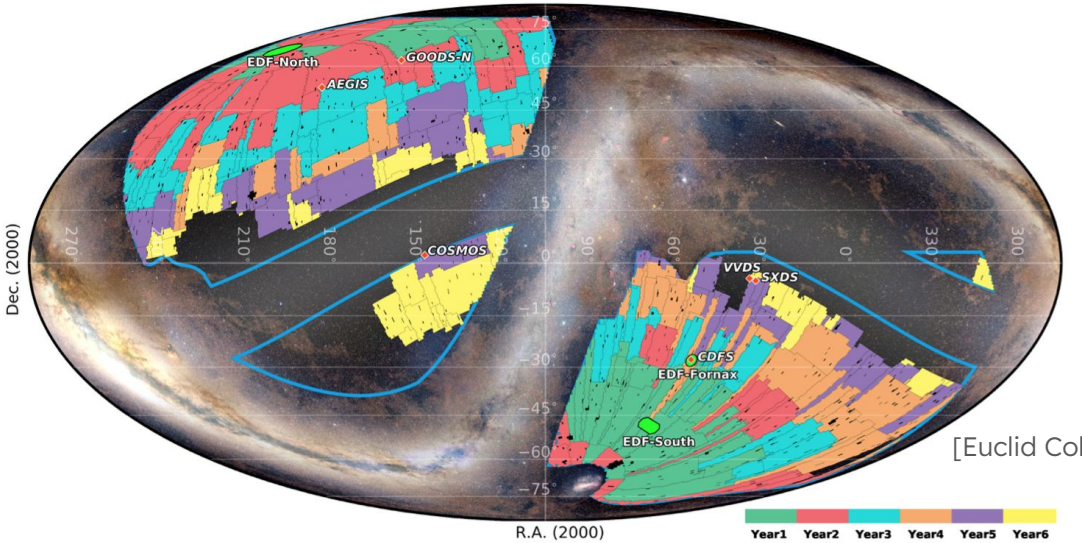
- **Combining** different **probes** is one of the most powerful ways to **constrain a cosmological model**:
  - Sensitive to different aspects of how **gravity** acts in the cosmos
  - Different **degeneracies** and **systematic** effects
- Example:



[DESI Collaboration: Adame et al. 2025]

Introduction

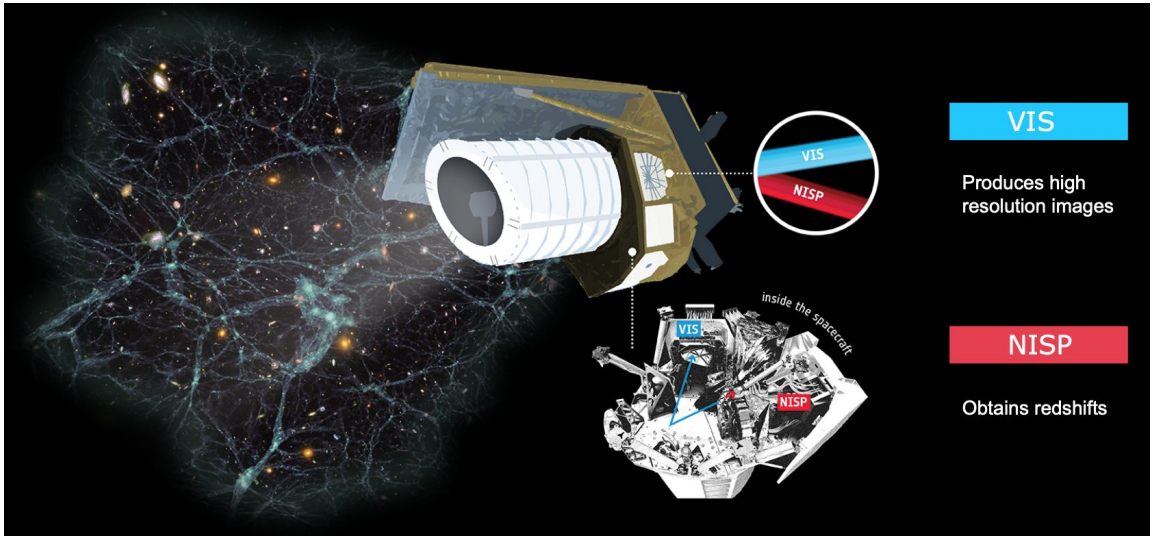
- *Euclid*:
  - **Survey** started on Feb 14th, 2024 – 1st stage-IV weak lensing survey **in operations**
  - It will cover about **14 000 sq deg** of extragalactic sky in **6 years**



[Euclid Collaboration: Mellier et al. 2025]

Introduction

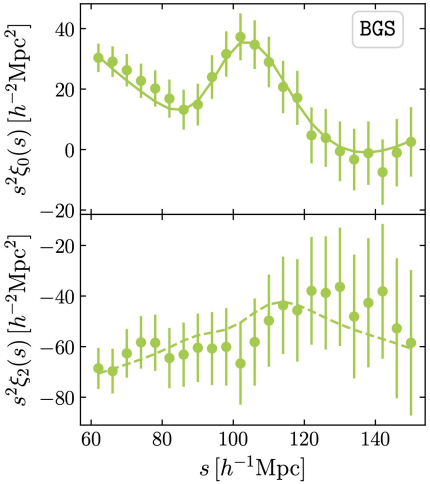
- *Euclid* contains 2 instruments onboard:
  - Visible instrument (VIS) – **imaging**
  - Near Infrared Spectrometer and Photometer (NISP) – **imaging** and **spectroscopy**



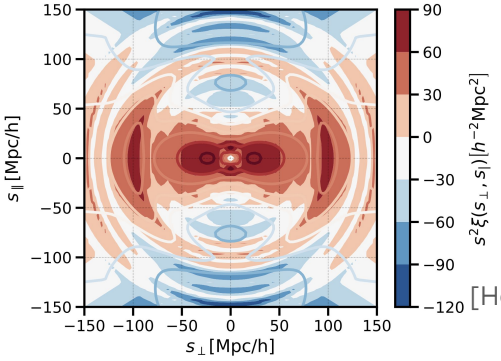
[ESA/ATG]

Euclid core science

- (Spectroscopic) **galaxy clustering** (GC)
- Baryon acoustic oscillations:
  - ➢ Provide a **cosmic ruler**
  - ➢ Sensitive to the **expansion** history and the angular-diameter **distance**
- Redshift-space distortions
  - ➢ Sensitive to the **growth rate** of structures
  - ➢ Tests of modified gravity



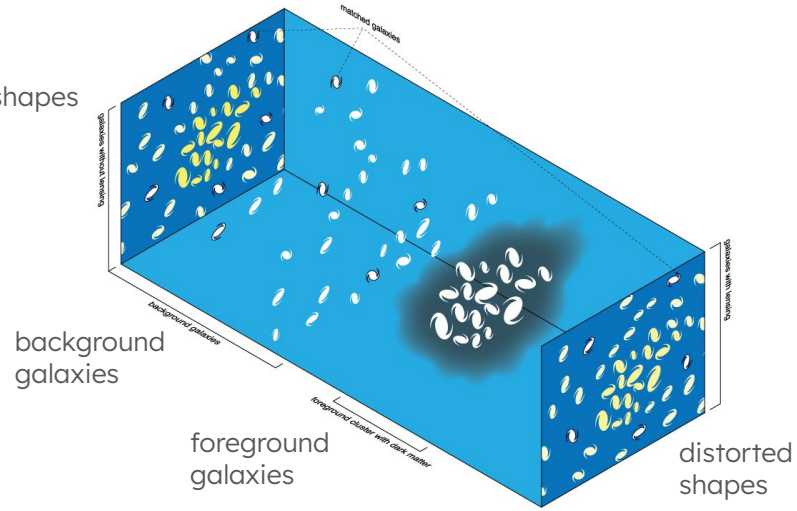
[DESI Collaboration: Abdul-Karim et al. 2025]



[Hou et al. 2021]

Euclid core science

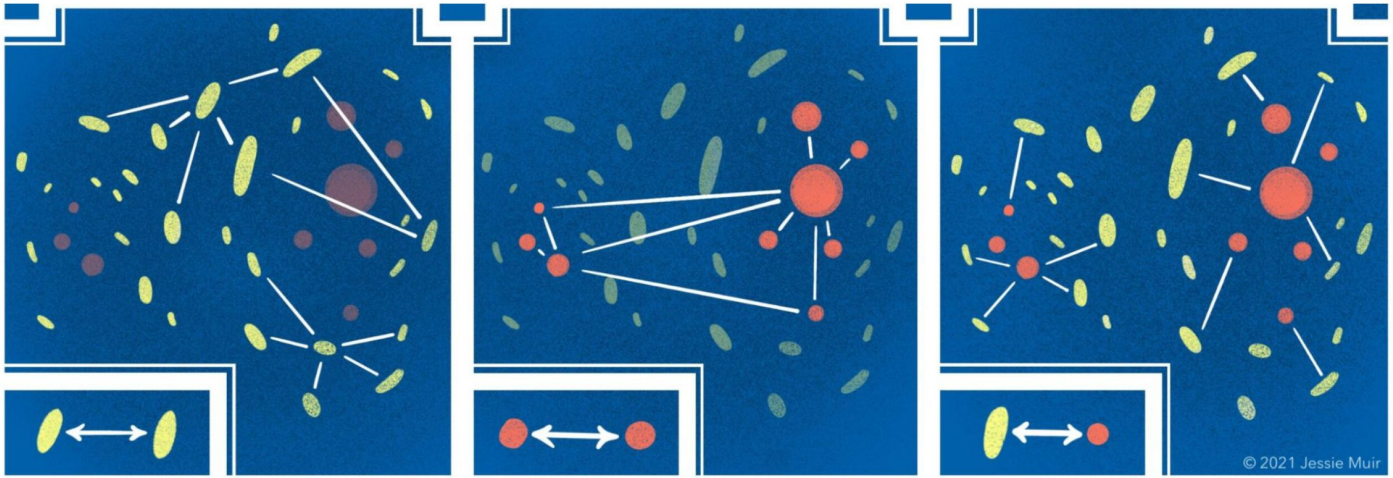
- (Photometric) **weak lensing** (WL):
  - Information about **mass distribution** imprinted on galaxy images
  - Sensitive to **matter density**, initial conditions, and **growth of structures**



[M. Sachs]

Euclid core science

- Combined **3x2pt** analysis from **photometric** data:

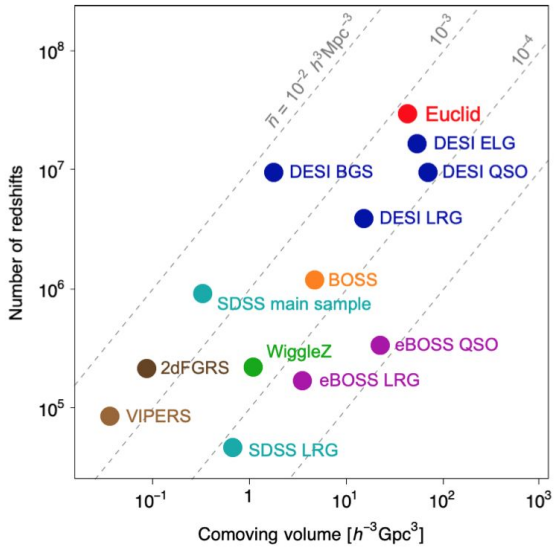


[J. Muir]

WL | Photometric galaxy clustering | Galaxy-galaxy lensing

Probe combination in *Euclid*

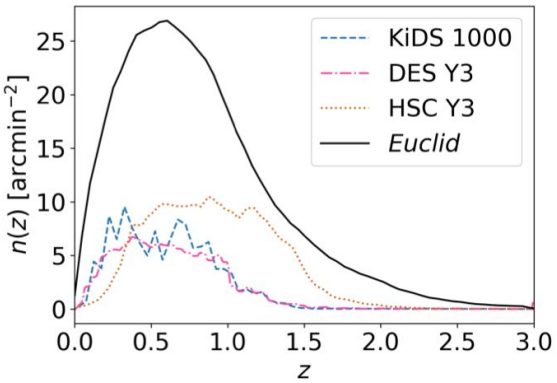
- How does *Euclid* compare to previous surveys?
  - ➢ Spectroscopic galaxy clustering:
    - More than 10^7 galaxies at high redshift (0.9-1.8)

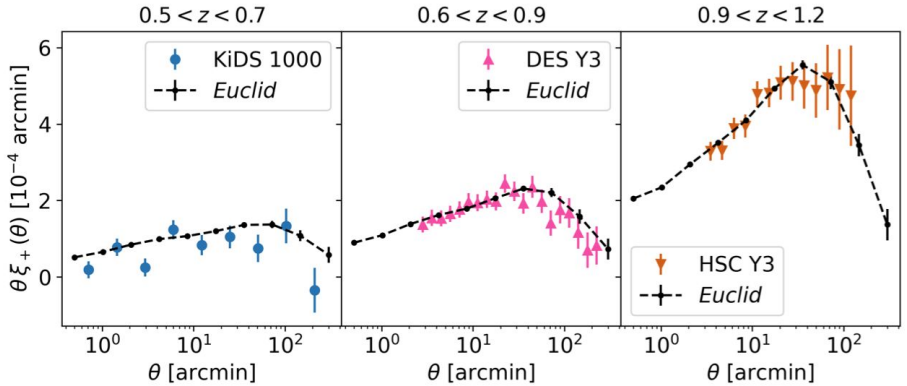


[Euclid Collaboration: Mellier et al. 2025]

Probe combination in *Euclid*

- How does *Euclid* compare to previous surveys?
  - ➢ Weak lensing:
    - More than 10^9 shapes of galaxies up to high redshift

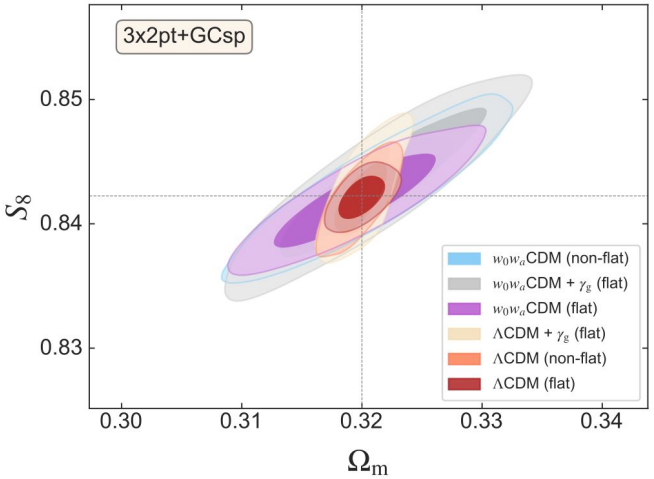


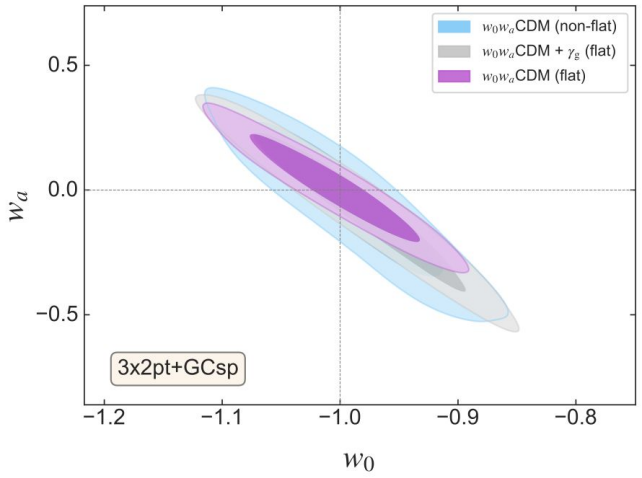


[Euclid Collaboration: Mellier et al. 2025]

Probe combination in *Euclid*

- Very **precise constraints** on the nature of **dark matter** and **dark energy**





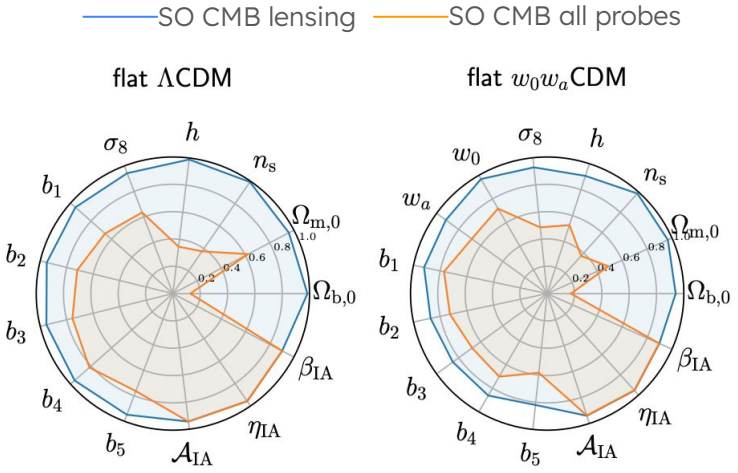
[Euclid Collaboration: Cañas-Herrera et al. 2025]

- More precise on dark energy than combined current constraints with *Euclid* main probes **alone**

Going beyond the main probes

- Several **other cosmological probes** can be combined to extract even more information:
  - Cross-correlations with the cosmic microwave background
  - Galaxy clusters
  - Voids

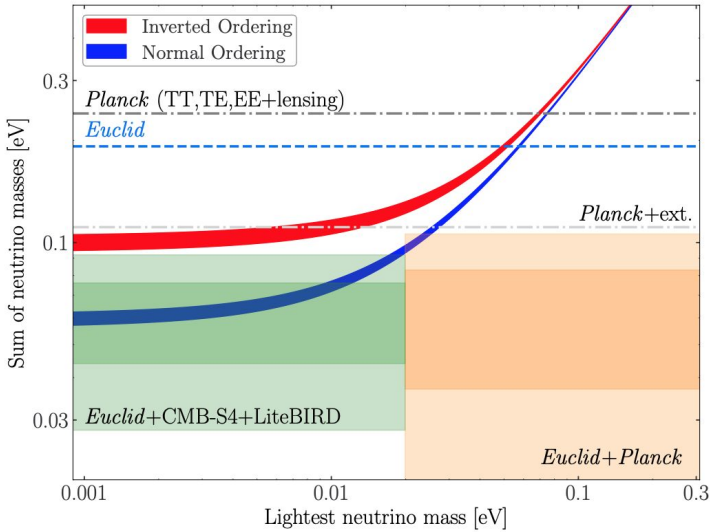
- Also combinations with **higher-order statistics**
  - 2pt + 3pt statistics
  - Simulation-based inference
  - Field-level inference



[Euclid Collaboration: Ilic et al. 2022]

Going beyond the main probes

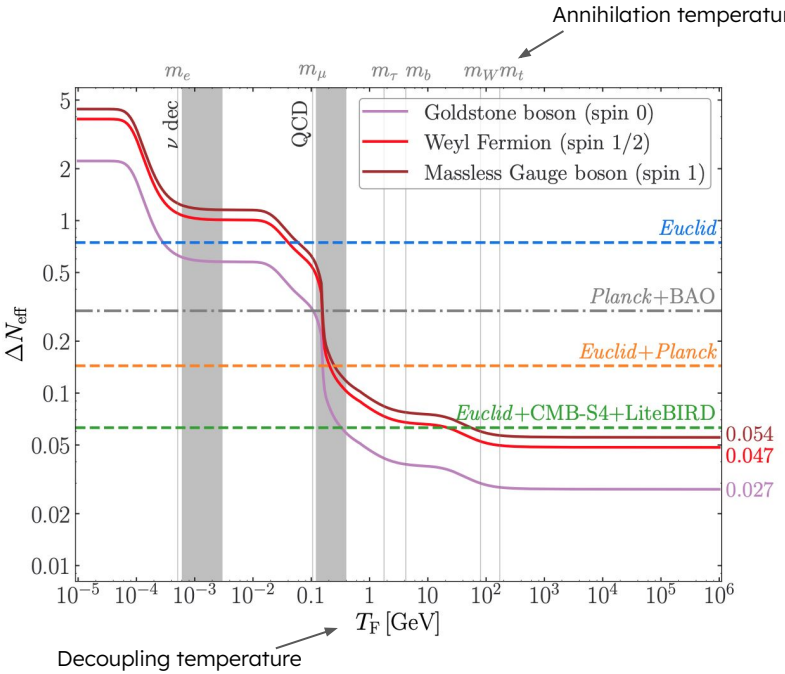
- Thanks to probe combination, *Euclid* will also help us test **neutrinos** and other particles beyond the standard model:
  - If the true sum of neutrino masses is 0.06 eV (normal ordering), *Euclid* + future CMB data can rule out inverted ordering at 2.5 sigma



[Euclid Collaboration: Archidiacono et al. 2025]

Going beyond the main probes

- Thanks to probe combination, *Euclid* will also help us test neutrinos and **other particles** beyond the standard model:
  - Adding *Euclid* improves the current limit on the presence of new light particles by more than a factor 2



[Euclid Collaboration: Archidiacono et al. 2025]

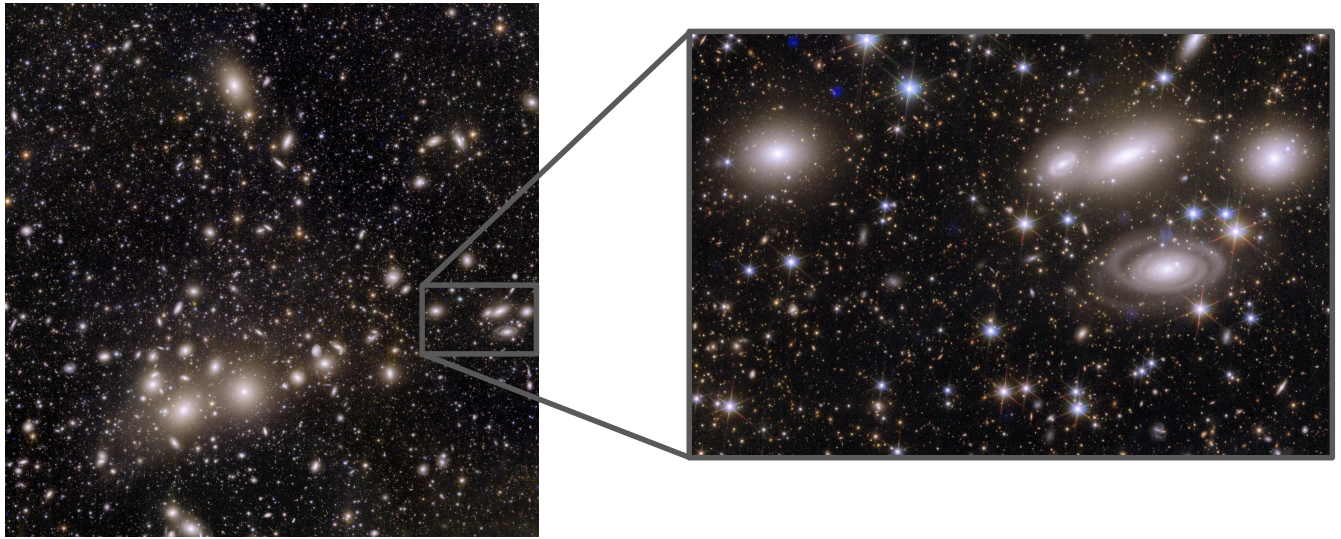
From launch to the first data release

- **Launch** 1st of Jul 2023:
  - Cape Canaveral, Florida, USA with a Space X Falcon 9
  - Destination: 2nd Lagrange point

[Space X; ESA]

From launch to the first data release

- **Early Release Observations** Nov 2023 & May 2024:
  - 24h of observations of allocated targets
  - 10 images – first scientific results



[Perseus cluster – ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi]

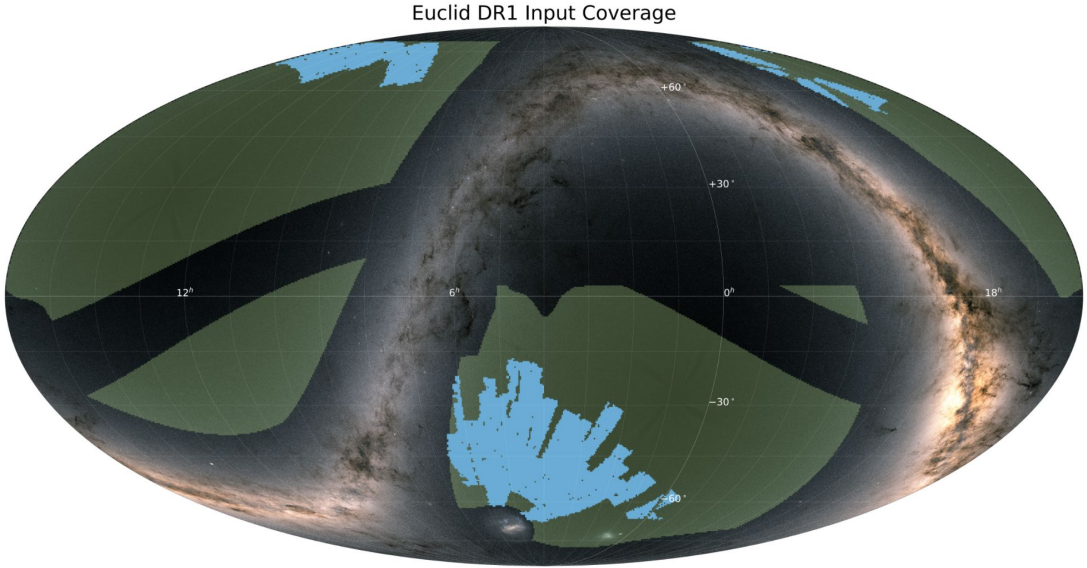
From launch to the first data release

- **Quick data release 1** (Q1) 19th Mar 2025:
  - First glimpse of *Euclid*'s cosmological survey ~63 sq deg
  - 50+ scientific papers so far
  - Non-cosmological science for the moment (e.g., Milky Way, galaxy morphology, proto-clusters)

[Euclid Deep Field South x70 – ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre, E. Bertin, G. Anselmi]

From launch to the first data release

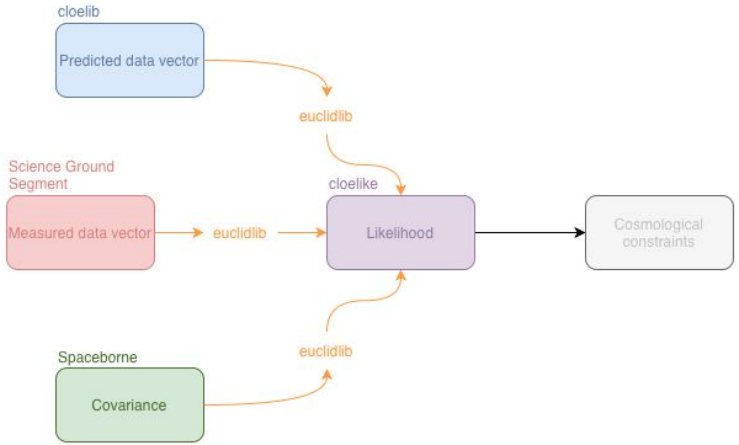
- Towards **Data Release 1** (DR1) Oct 2026:
  - First *Euclid*'s cosmological results with ~1900 sq deg
  - Currently performing data validation



[H. Aussel/ESA/Euclid/Euclid Consortium/NASA; ESA/Gaia/DPAC. Acknowledgement: A. Moitinho]

From launch to the first data release

- Stress-testing the **inference pipeline** and discussing **modelling** and **analysis choices**:
  - Within the Consortium key projects, in particular the Joint Cosmology (C. Carbone, M. Crocce, I. Tutusaus)



euclidlib (G. Cañas-Herrera et al.)
Spaceborne (D. Sciotti et al.)

  - https://github.com/cloe-org (Maintainers: M. Bonici, G. Cañas-Herrera, P. Carrilho, S. Casas, C. Moretti, A. Pezzotta – arXiv:2605.23839, arXiv:2605.23841)

Conclusions

- Some tensions start to appear within LCDM and the nature of the dark components remains unknown
- *Euclid* will provide exquisite measurements to perform galaxy clustering and weak lensing analyses that will shed light on the dark sectors of the Universe
- Probe combination is key to get the most amount of information from the data – spectroscopic GC and photometric 3x2pt
- Additional cosmological probes are also being considered to extract more information
- Data validation, stress-testing of the inference pipeline, and modelling discussions are ongoing
- Stay tuned for the cosmology results with *Euclid* DR1!