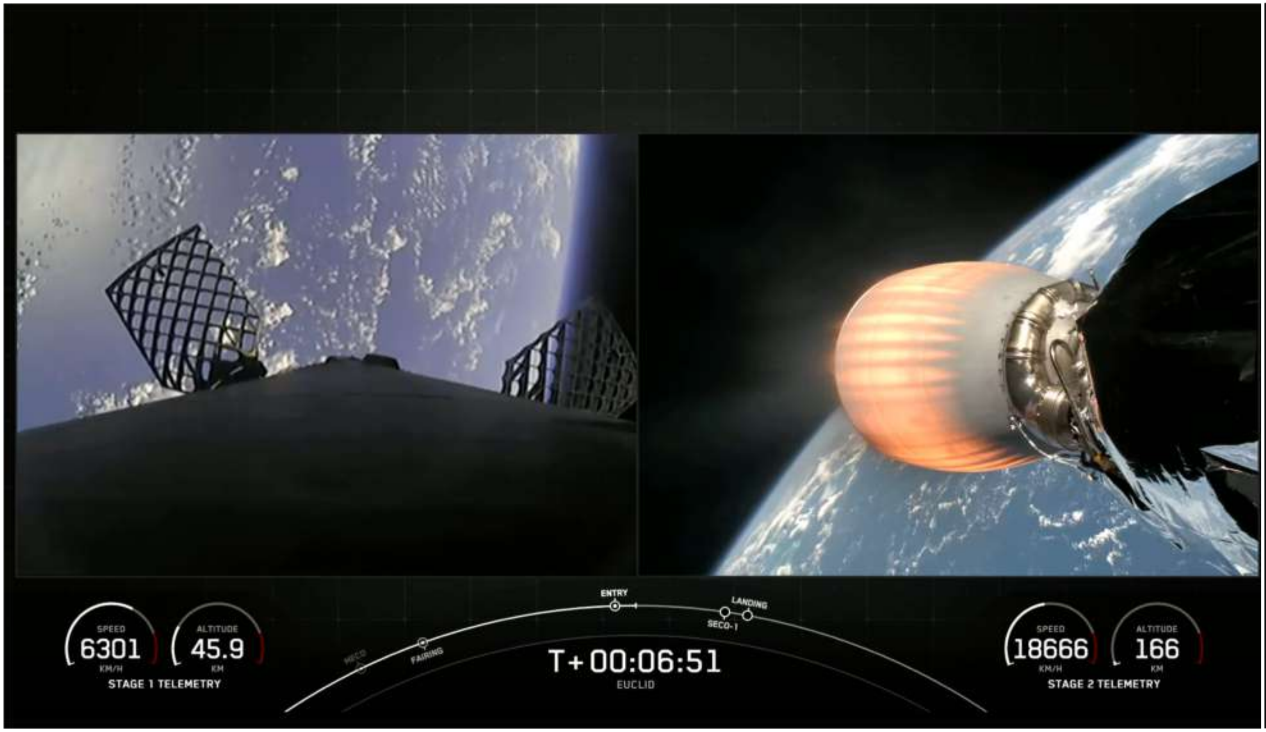
TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

Status of Euclid and perspective of CMB cross-correlations

Workshop “CMB Day 2”
ASI - 17 October 2023

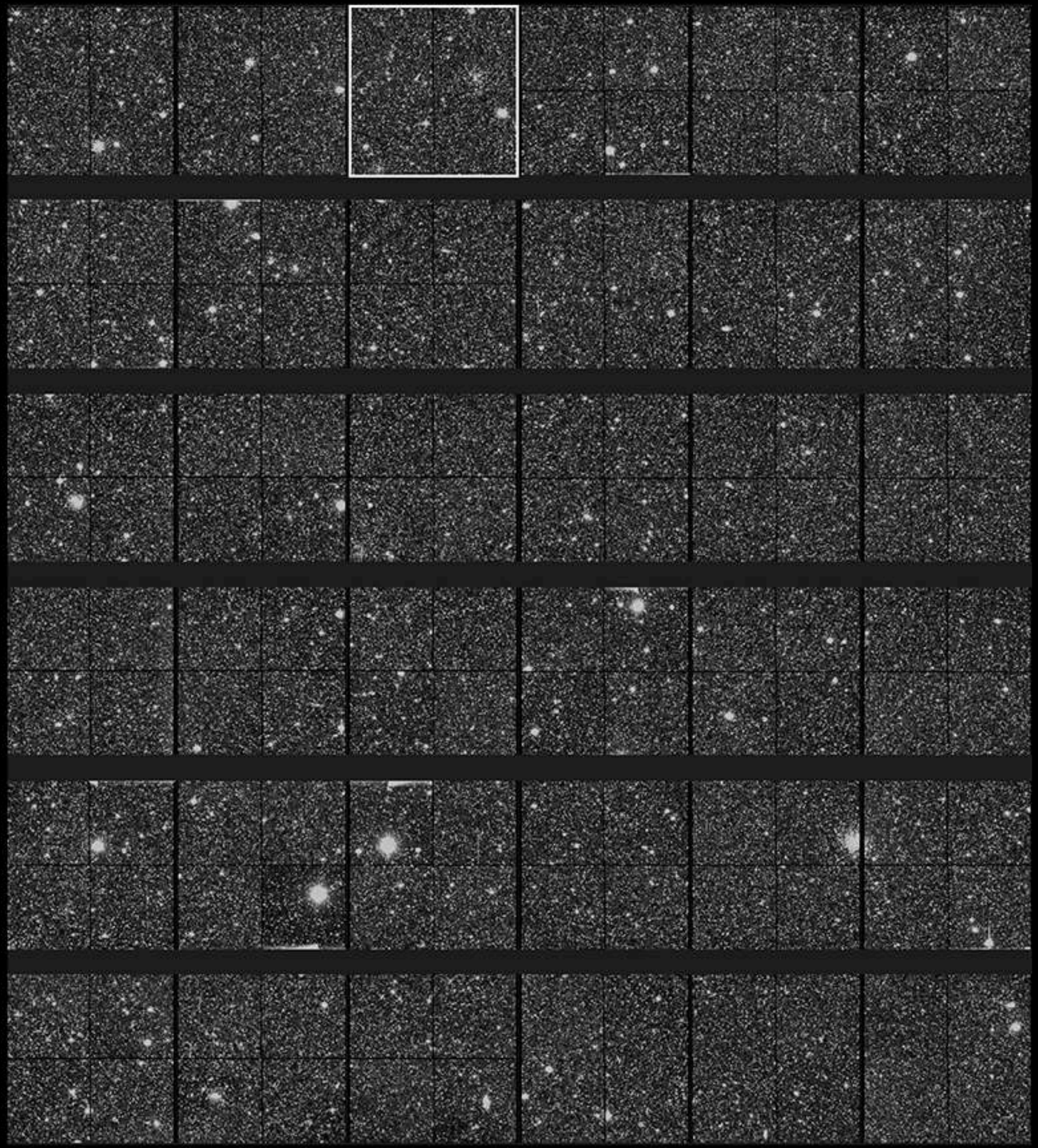
Marina Migliaccio

Successfully launched on a SpaceX Falcon 9 rocket from the Cape Canaveral Space Force Station in Florida.
On July 1st, 2023 at 5.12 PM CEST



- **5 October:** End of commissioning, updated guiding software and PV resumes.
- **19 August:** Commissioning extended, troubleshooting the fine guidance sensor
- **12 August**: Performance Verification starts
- **31 July:** First images released
- **28 July:** Euclid focused and at destination orbit
- **15 – 18 July:** VIS and NISP see first light
- **2 - 4 July:** On the way to L2 - Commissioning starts

EARLY COMMISSIONING TEST IMAGE, VIS INSTRUMENT



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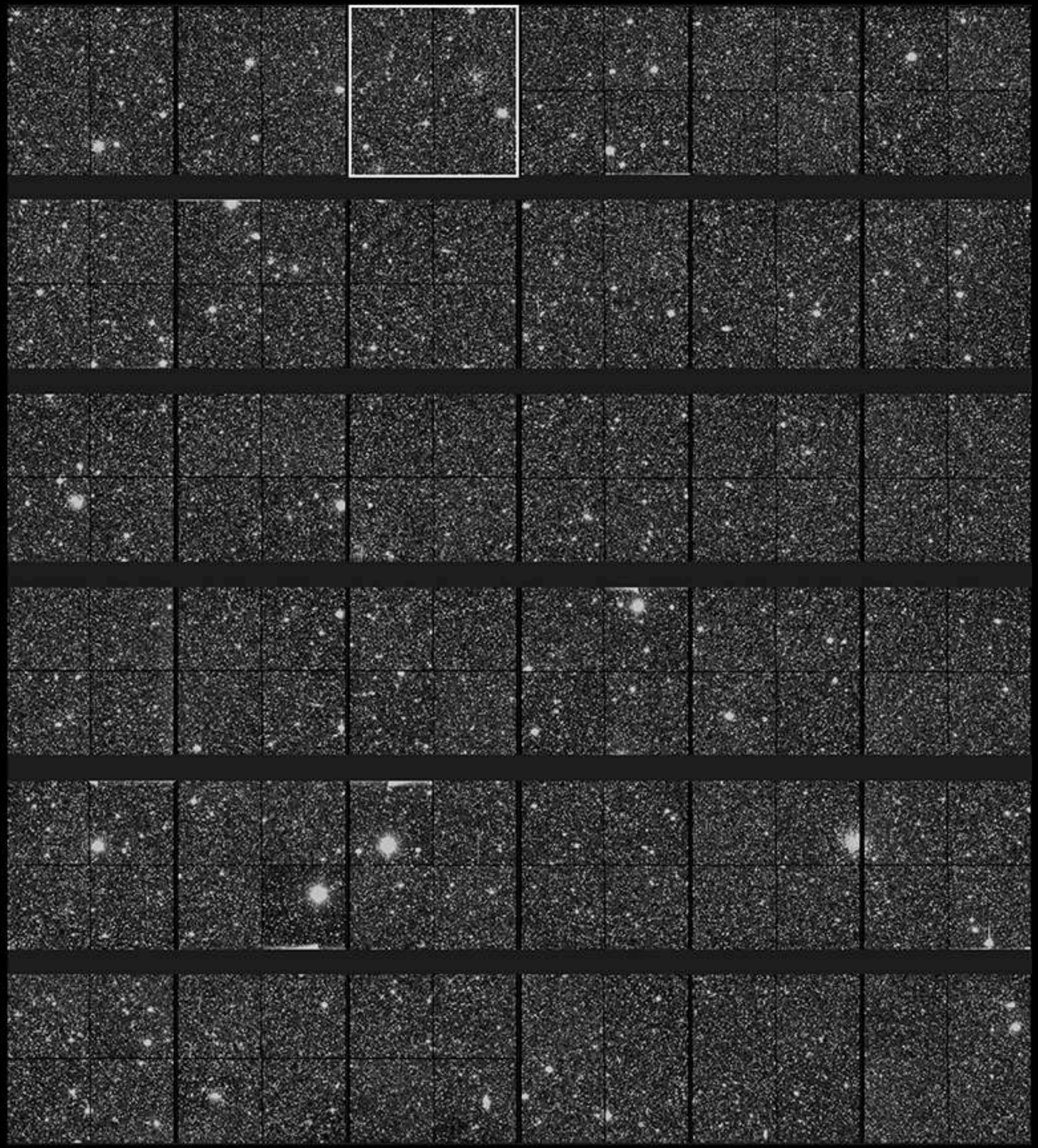
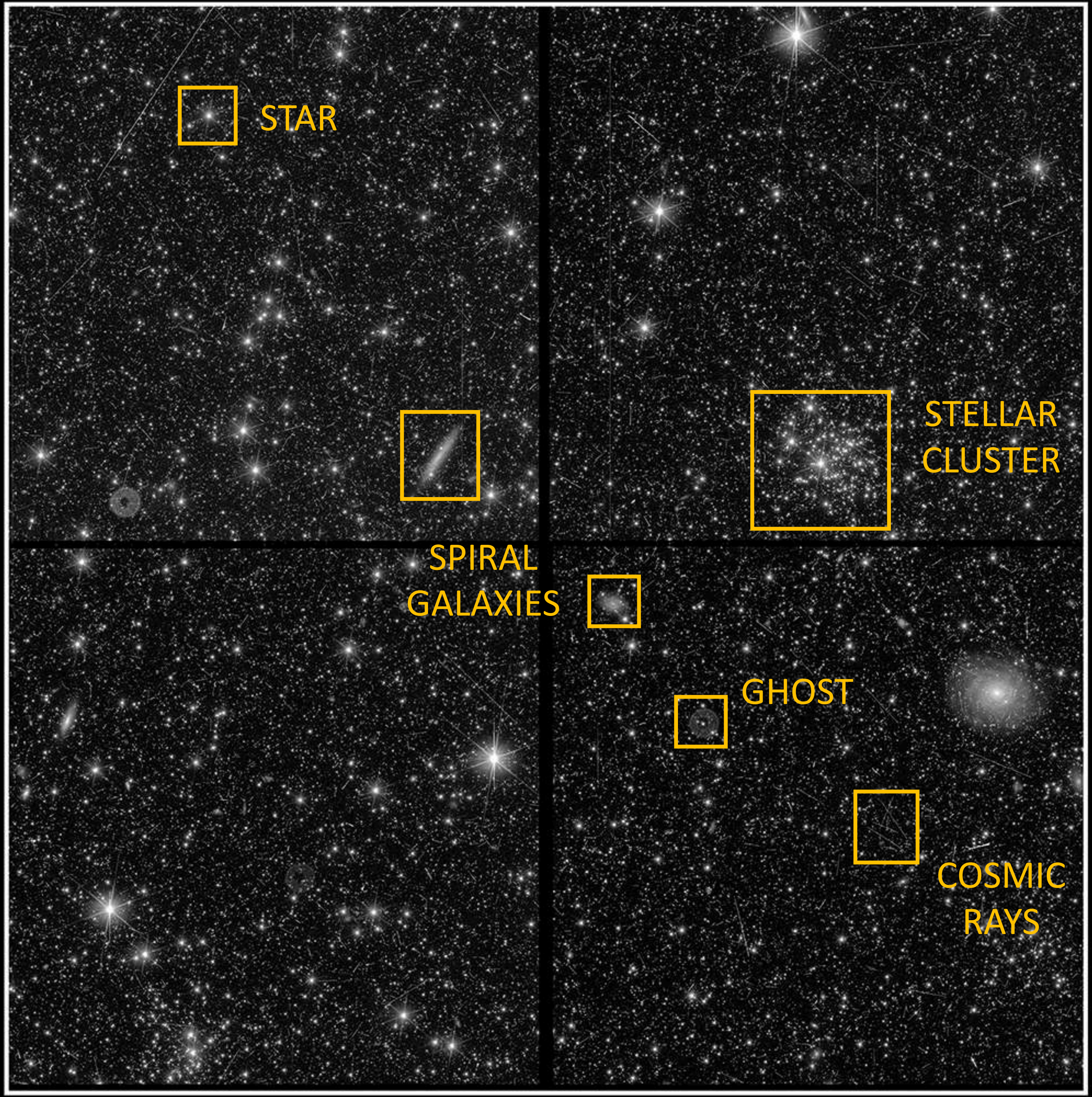
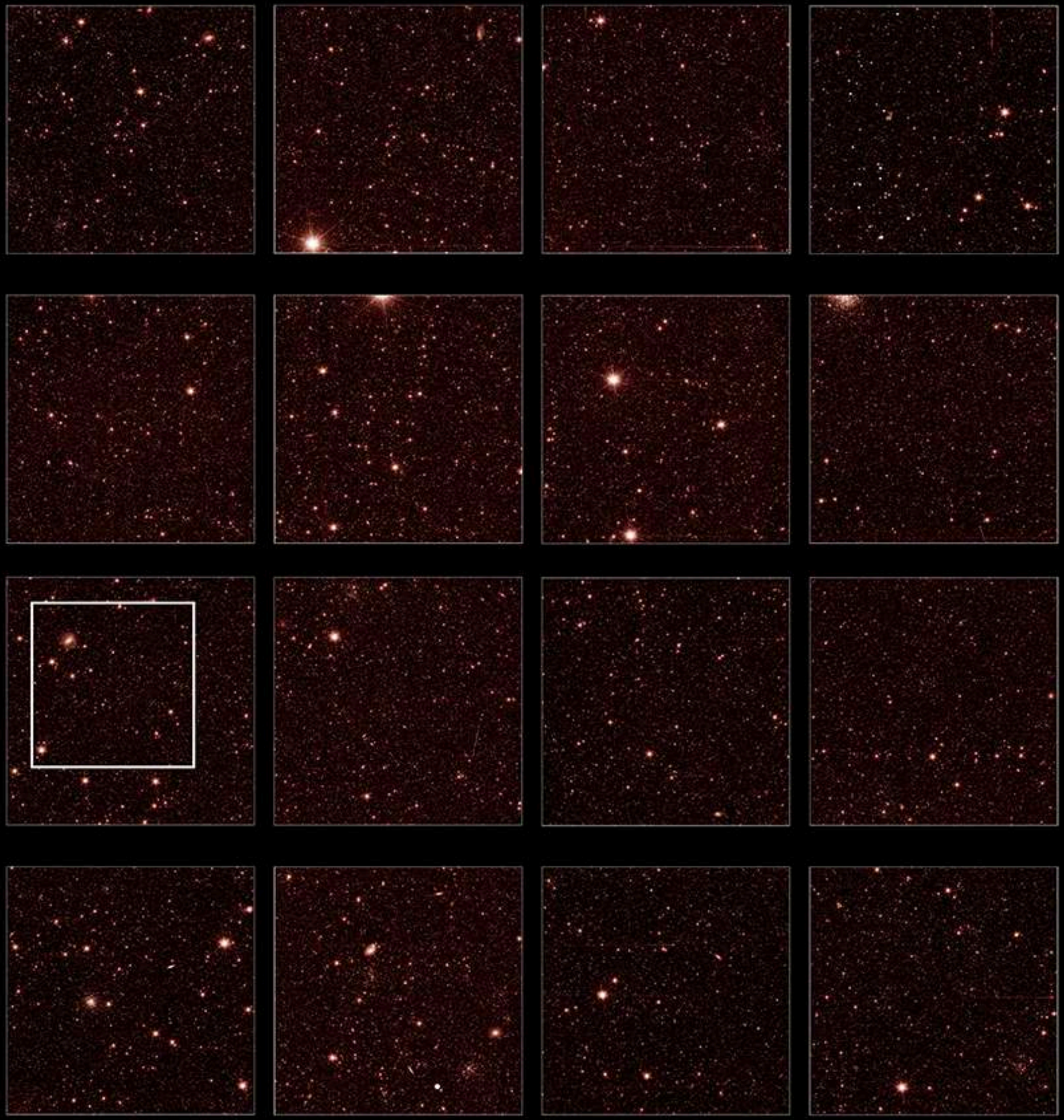
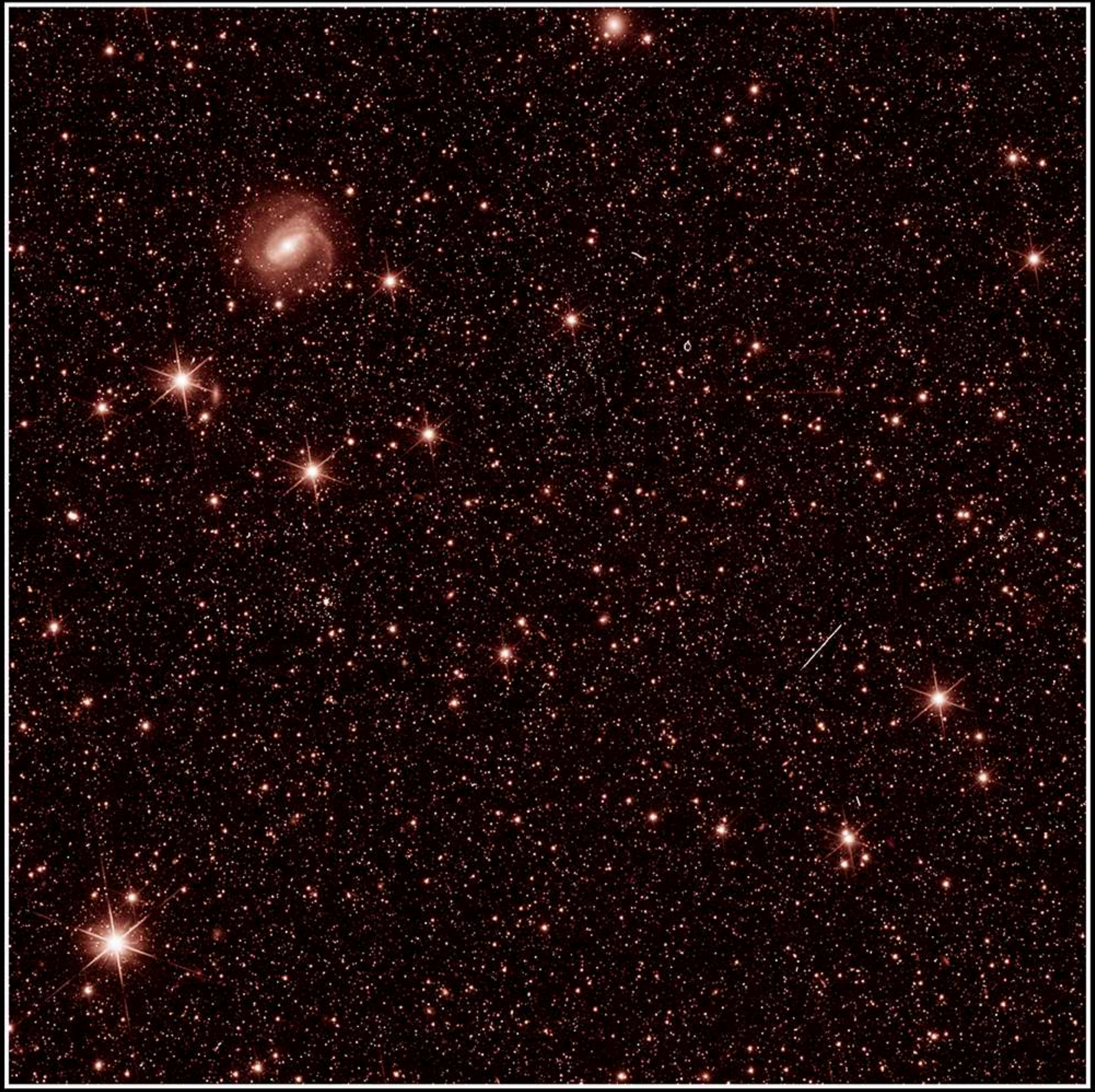




EARLY COMMISSIONING TEST IMAGE, NISP INSTRUMENT





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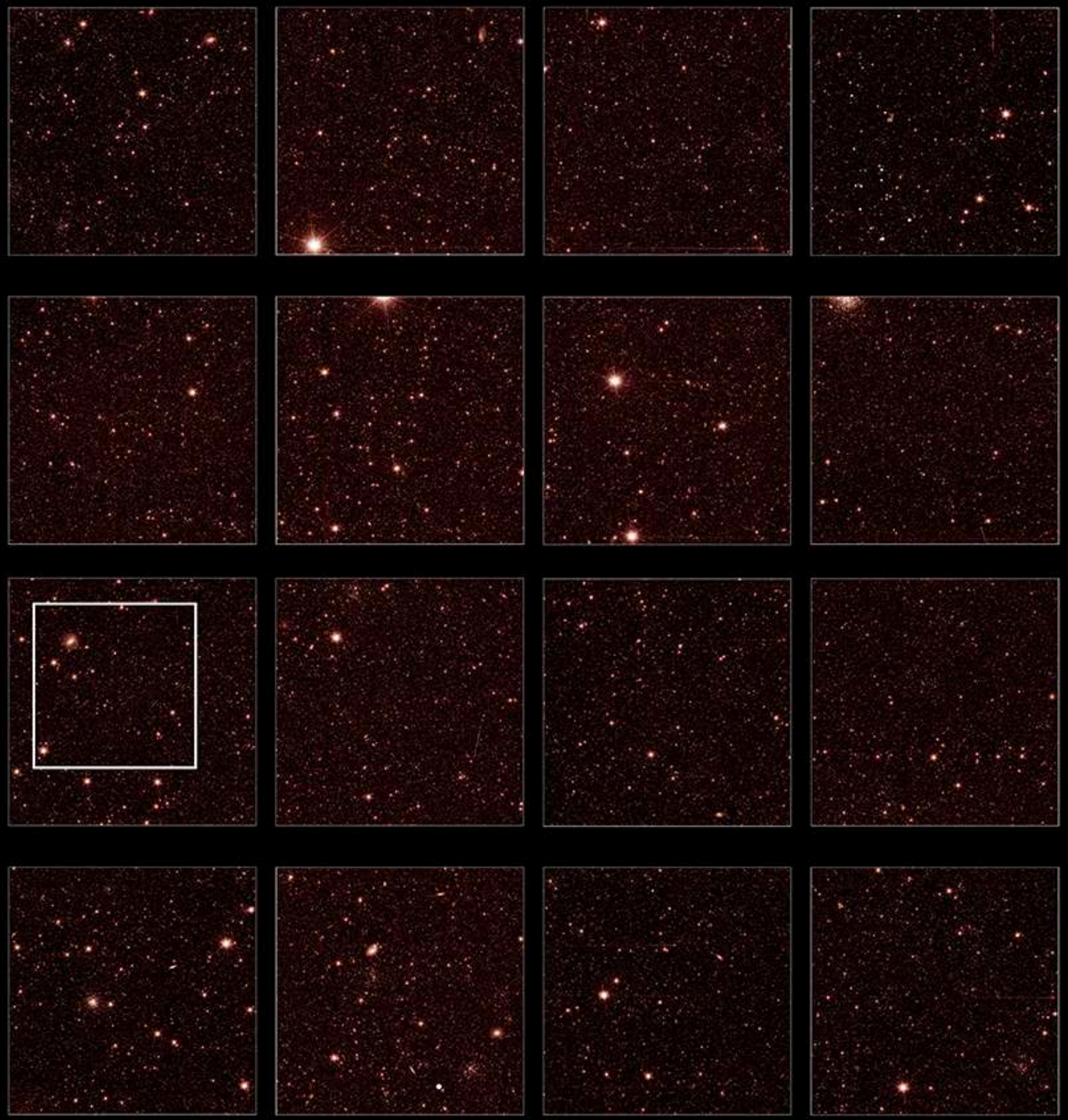
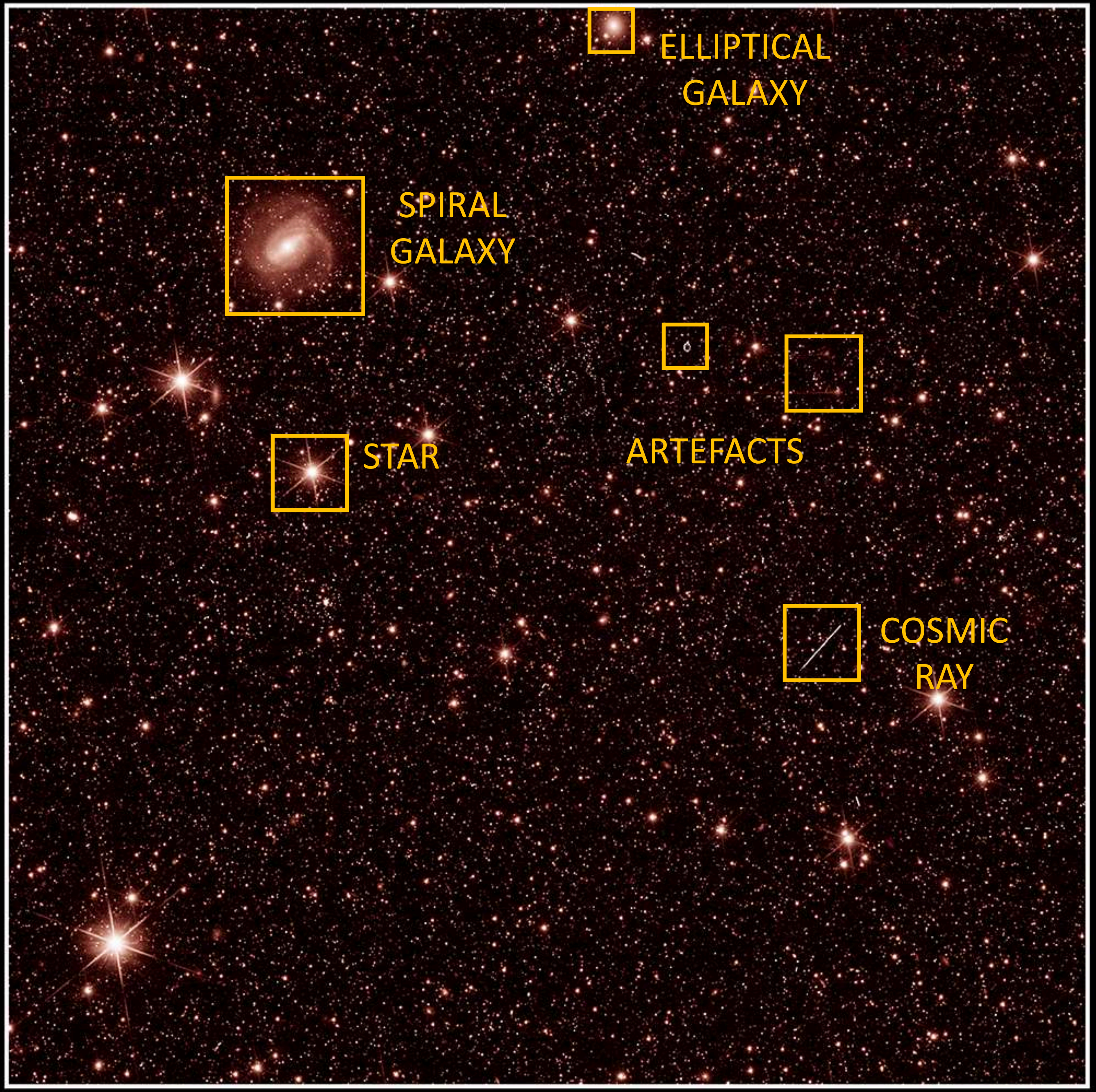
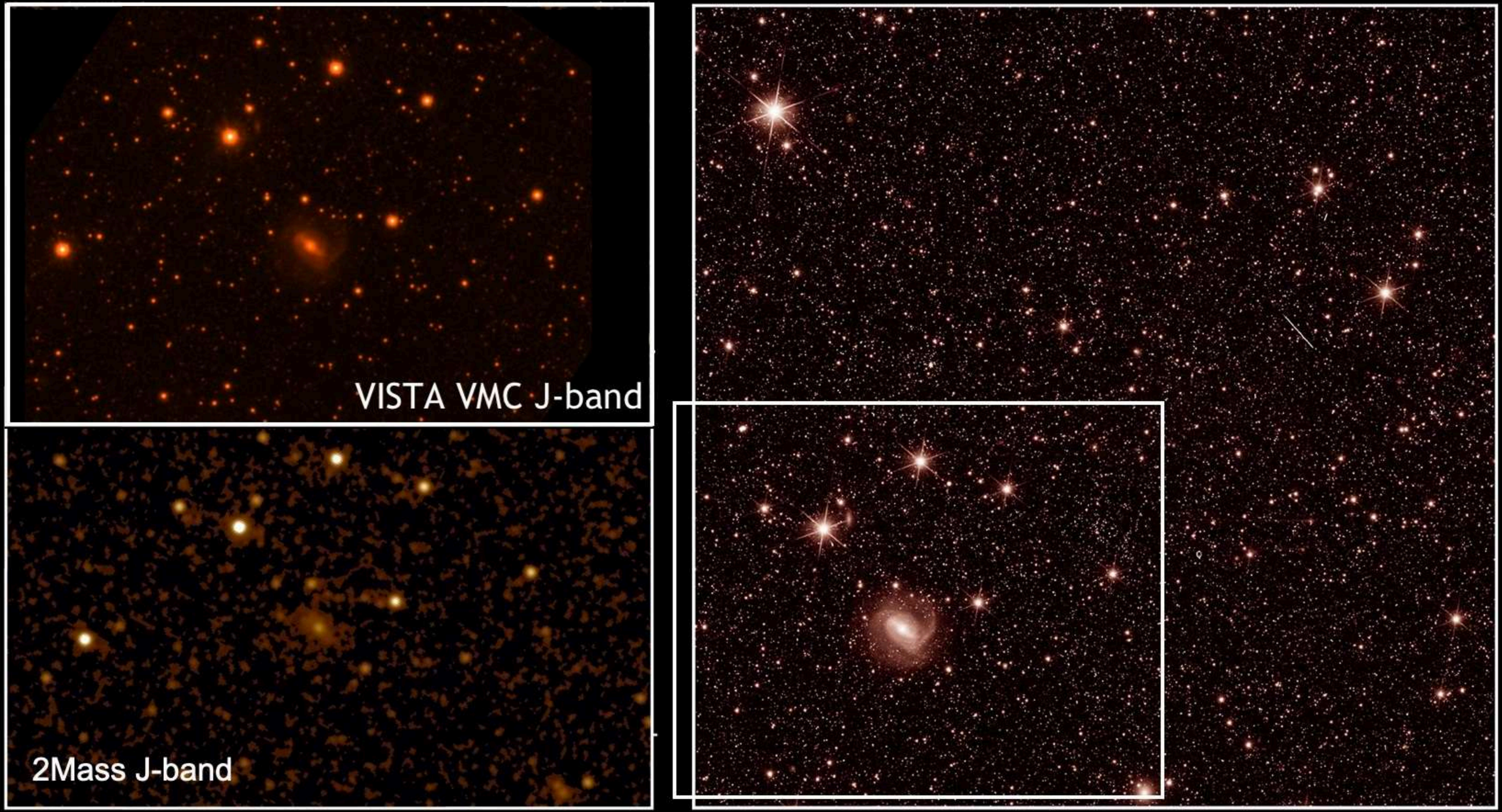





VISTA VMC J-band
2Mass J-band

- Medium Class ESA Mission
- Visible to near-infrared (with spectroscopy) space telescope operating in L2
- Image billions of galaxies out to a distance of 10 billion light years (z~2) across 36% of the sky
- Primary Probes: Galaxy Clustering and Cosmic Shear to trace the expansion history and the growth rate of cosmic structures with unprecedented precision
- Other probes: Clusters, Voids, CMBX, Strong Lensing, and more

Euclid consortium

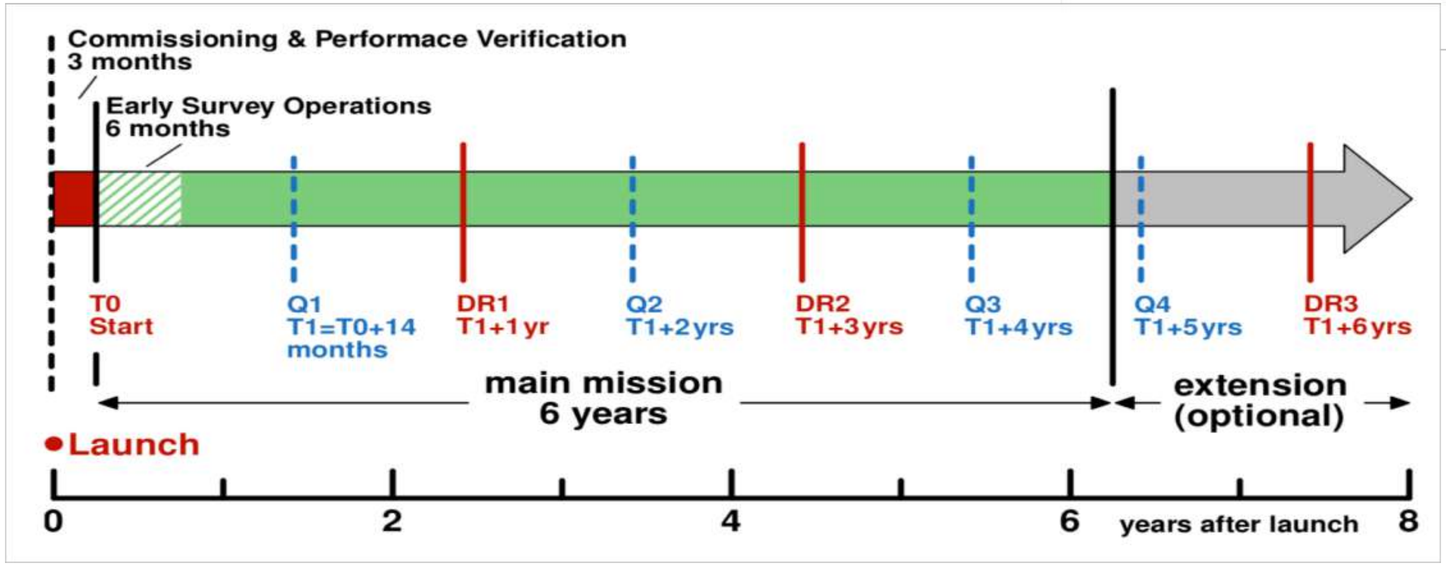
ESA science requirements: Tight constraints on deviations from ΛCDM, neutrino masses, initial conditions.
Euclid red book (2011) arXiv: 1110.3193

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν/eV	f_{NL}	w_p	w_a	FoM
Euclid Primary	0.010	0.027	5.5	0.015	0.150	430
Euclid All	0.009	0.020	2.0	0.013	0.048	1540
Euclid+Planck	0.007	0.019	2.0	0.007	0.035	4020
Current	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>50**	**>300**

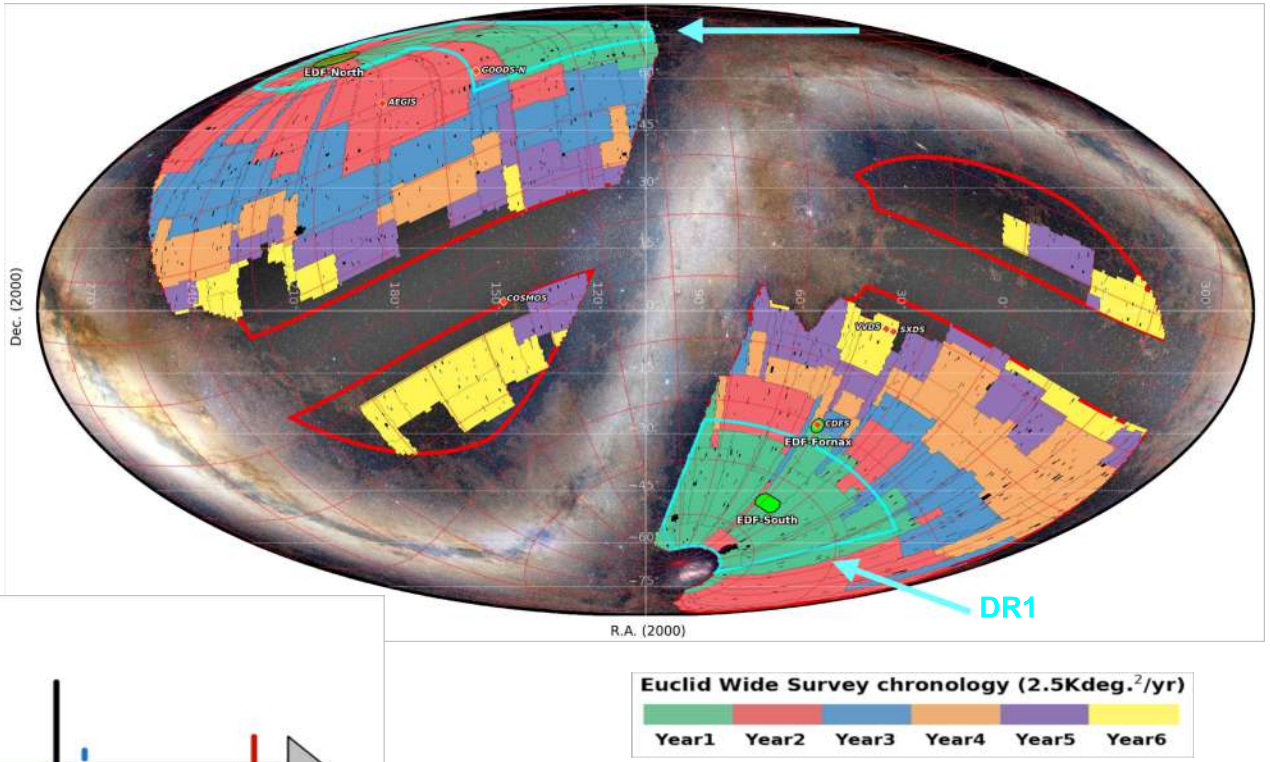
BUT will do much more..

More than 30 Euclid Preparation Papers already published and many more soon to come

Timeline of Euclid



2023 2025 2029 2030



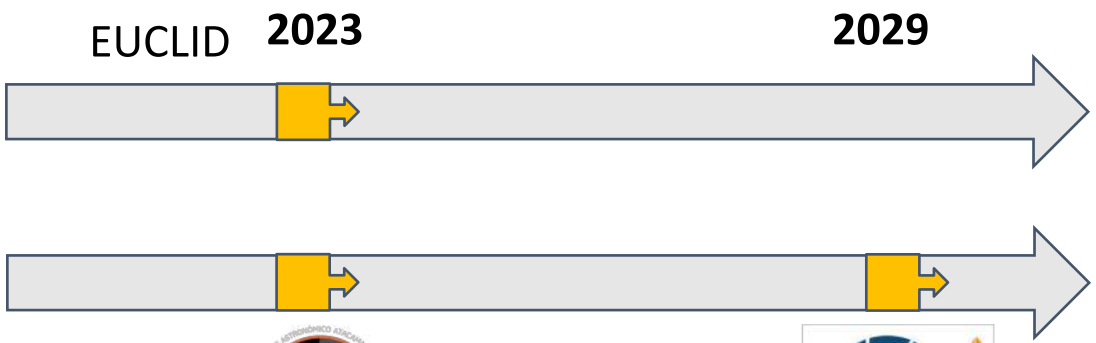
Euclid Wide Survey

Timeline of CMB Probes

Upcoming CMB experiments will be targeting:

- Polarization
- Secondary Anisotropies

EUCLID



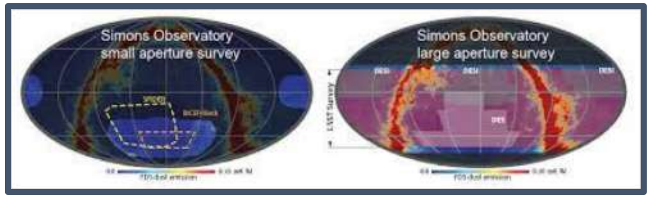
PLANCK

SPT

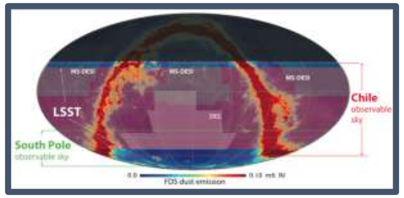
ACT

Simons Observatory

LiteBIRD



CMB-S4
Next Generation CMB Experiment



For the cross-correlation with Euclid:
maps of the northern sky only from space experiments!

Euclid and CMB joint analyses

COMBINATION and CORRELATION of the upcoming Euclid data with CMB measurements will provide the largest lever arm of epochs, ranging from recombination to structure formation and the late-time accelerated expansion of the Universe.

- Maximise the return of information in constraining the cosmological parameters.

$$\{C_\ell^{TT}, C_\ell^{TE}, C_\ell^{EE}\} \quad + \quad \{C_\ell^{TG}, C_\ell^{\kappa\kappa}, C_\ell^{\kappa G}, C_\ell^{\kappa\gamma}, C_\ell^{GG}, C_\ell^{\gamma\gamma}, C_\ell^{\gamma G}\}$$

- Cross-Correlations originate from CMB secondary anisotropies
  - photons interact with structures gravitationally (Lensing, late-time ISW effect) or by scattering (SZ effect).

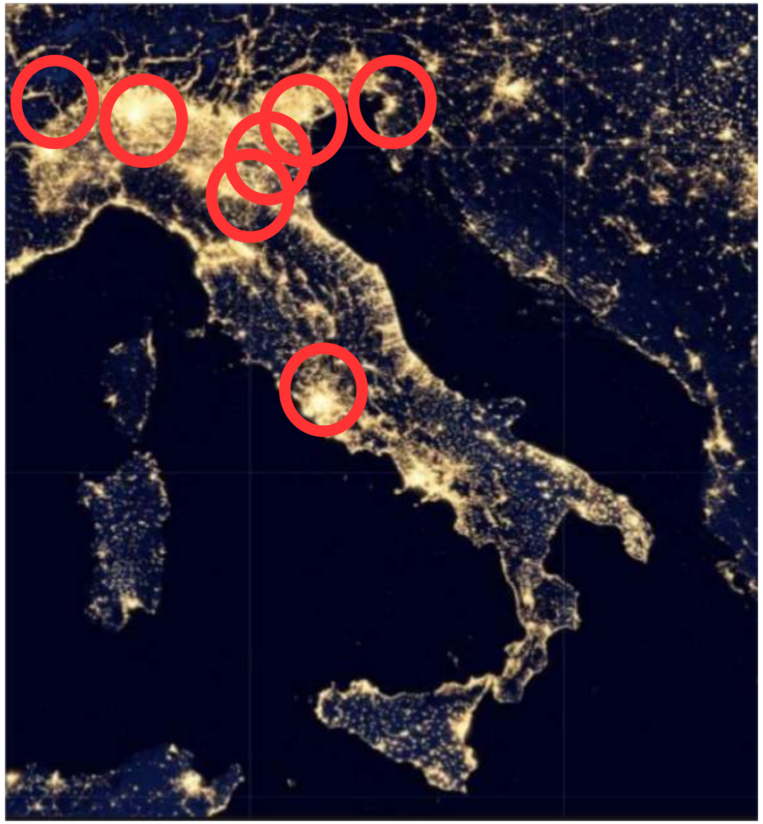
- Cross-correlation science is transitioning from detection regime to powerful cosmological probe.
  - Break degeneracies between cosmological and astrophysical parameters.
  - Control uncorrected systematic effects in the data.
  - Build novel estimators for cosmology and astrophysics.

CMBX Science Working Group

Leads: C. Baccigalupi, G. Fabbian, S. Ilic (deputy)

Deep involvement of the Italian CMB community

with leadership roles in several Key Projects



Activities

Aosta: CMB-N-Body & Ray Tracing, Simulations, Analysis

Bologna: CMB-N-Body Simulations, Analysis, Estimators & Likelihood, Theory

Ferrara: Estimators & Likelihood

Milano: CMB-N-Body & Ray Tracing Simulations, Analysis

Padova: Estimators, Analysis, Theory

Rome: Estimators & Likelihood, Simulations, Analysis

Trieste: Analysis of CMB-N-Body Simulations

Euclid preparation

XV. Forecasting cosmological constraints for the *Euclid* and CMB joint analysis

A&A, 657, A91 (2022)

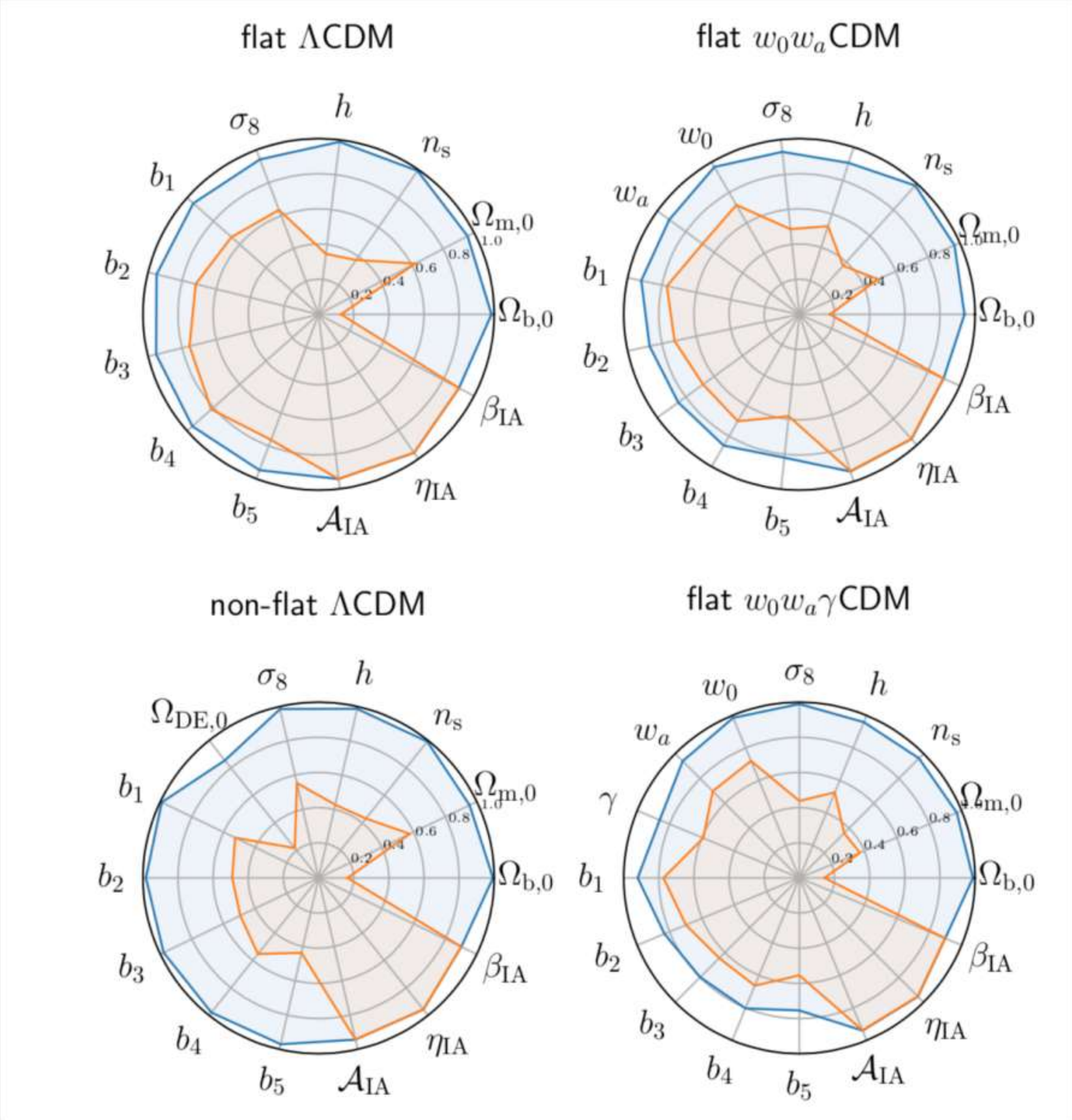


Fig. 6. Ratio of predicted 1σ uncertainties (see end of Sect. 5.2) showing how constraints are tightened after adding CMB lensing (blue) or all CMB probes (orange) when compared to the *Euclid*-only constraints (black outer rim), assuming a pessimistic *Euclid* scenario and SO-like CMB data, for four selected cosmological models (*from top to bottom, left to right*: flat ΛCDM; flat w_0 w_aCDM; non-flat ΛCDM; and flat w_0 w_a γCDM).

Euclid preparation

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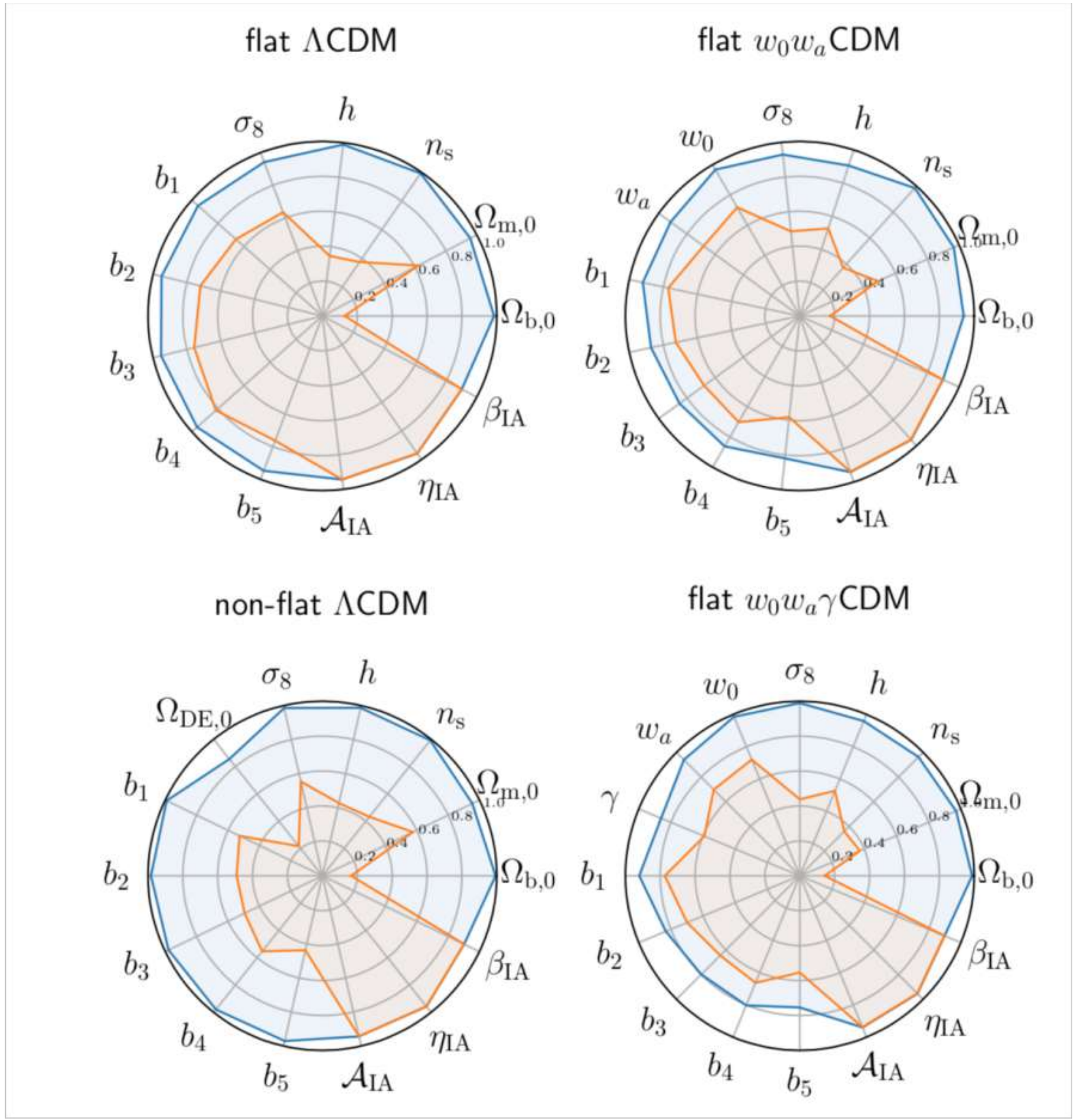


A new Key Project paper in preparation on CMBX Extended Forecasts

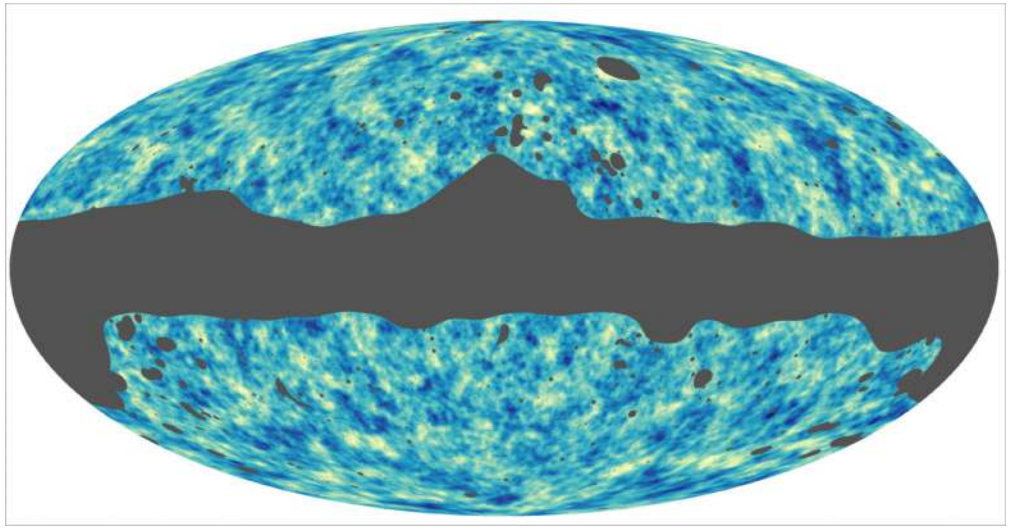
- **Non-standard cosmologies**
- **Characterization of Euclid Probes**

Fig. 6. Ratio of predicted 1σ uncertainties (see end of Sect. 5.2) showing how constraints are tightened after adding CMB lensing (blue) or all CMB probes (orange) when compared to the *Euclid*-only constraints (black outer rim), assuming a pessimistic *Euclid* scenario and SO-like CMB data, for four selected cosmological models (*from top to bottom, left to right*: flat ΛCDM; flat w_0 w_aCDM; non-flat ΛCDM; and flat w_0 w_a γCDM).

Euclid and CMB cross-correlation analyses

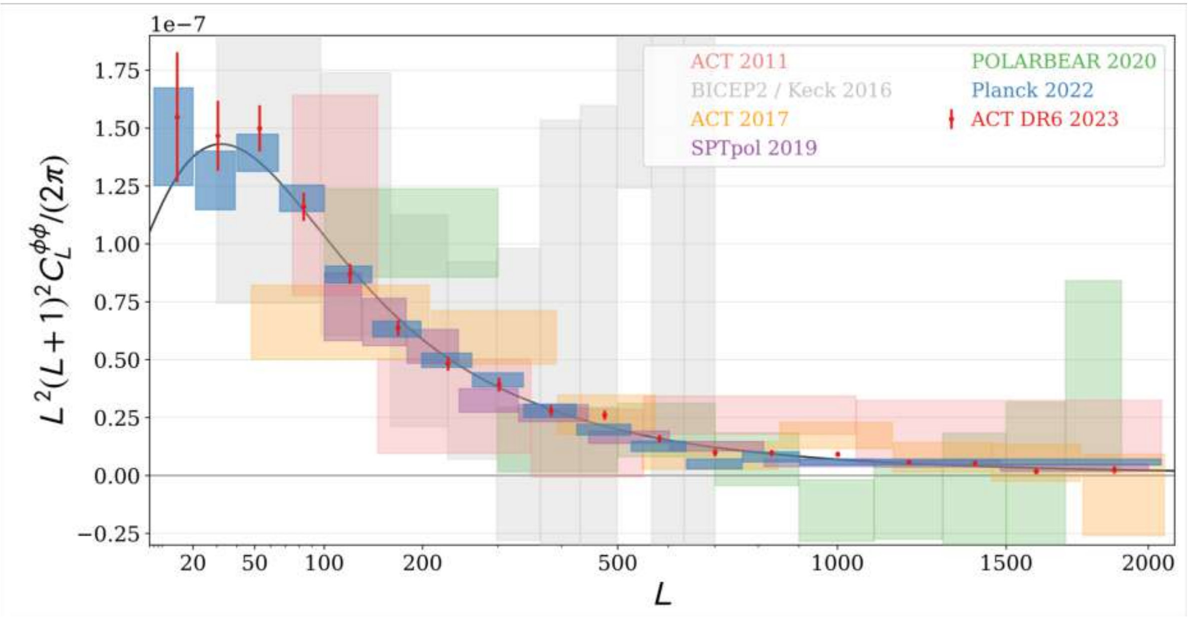
CMB Lensing

- Unbiased tracer of the mass distribution in the Universe integrated along the line of sight.
- In the future complementary reconstructions from temperature and polarization CMB data.

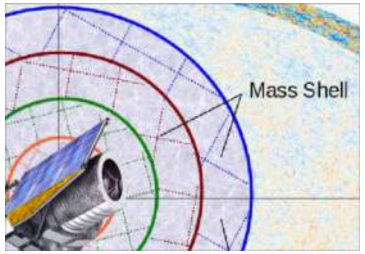


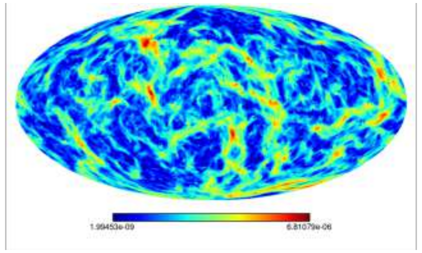
CMB Lensing x Galaxy Clustering

- now detected from radio frequencies to γ-rays.
- κG can be measured with S/N > 100 with Euclid x SO
- powerful confirmation of GR on cosmological scales
- breaks degeneracy with galaxy bias
- constraints on late-time expansion and clustering of matter



CMBX-sims End-to-end Pipeline (left to right)





Lightcone production

Map-making, projection on full-sky

- kCMB + ISWRS maps
- WL (fixed z_source)
- WL (Euclid spec. n(z))

CMB Lensing [LensPix or lens2Hat]

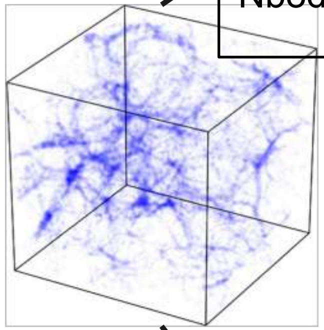
- lensed CMB T,E,B field

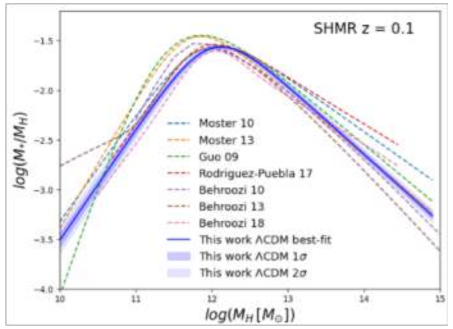
Lensing Estimation [planckLens]

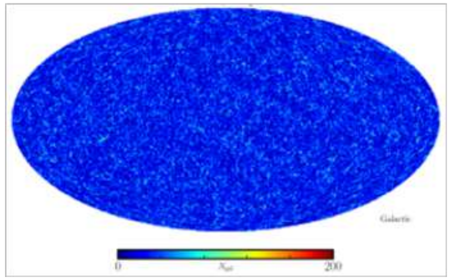
- reconstructed lensing potential

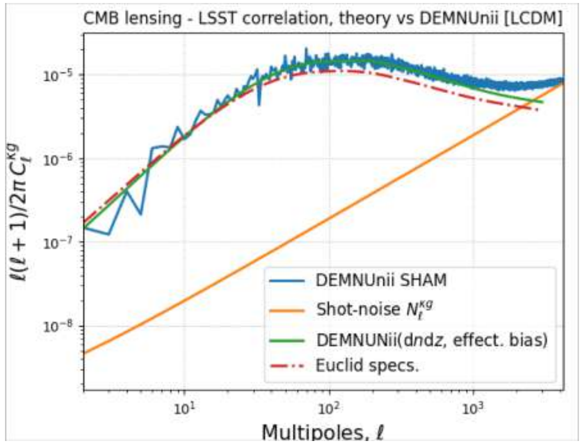
Cross-correlation

Nbody sim









Objects detection [SUBFIND]

Galaxy population [SHAM]

Map-making, projection on full-sky

- Projected galaxy Maps

Euclid and CMB cross-correlation analyses

Late-time Integrated Sachs-Wolfe Effect

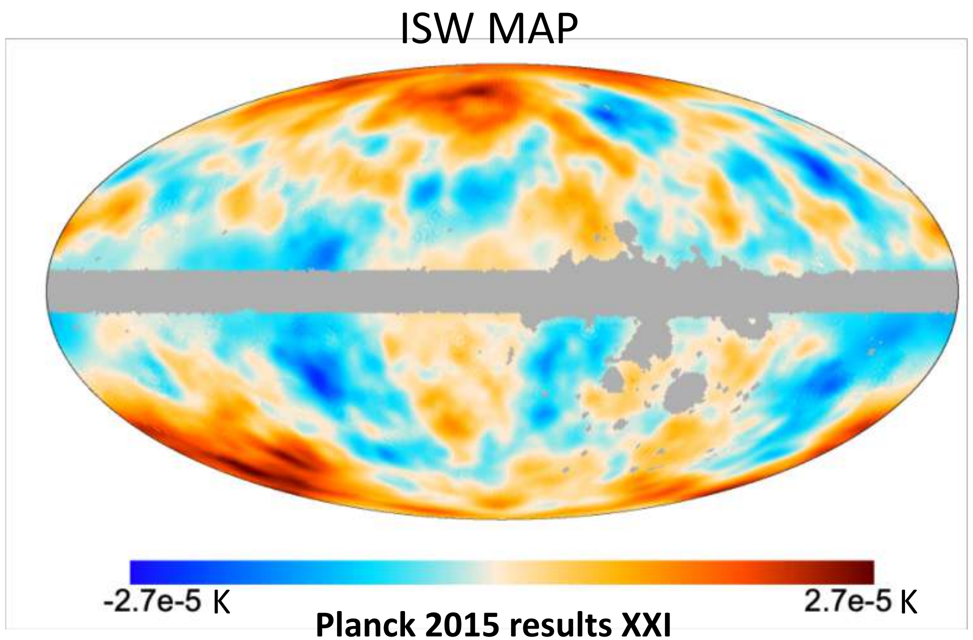
Time-varying gravitational potentials along the photon path induce CMB temperature anisotropies.

→ the ISW effect can only be measured by cross-correlating CMB temperature anisotropies with LSS tracers

TG (ISW) can be measured with S/N ≃ 4 with Planck

reaching S/N ≃ 4.6 with LiteBIRD including polarization data

- Dark energy parameters
- Modified gravity models
- Primordial Non-Gaussianity



Planck 2015 results XXI

Optimal extraction of the iSW signal with Euclid:

- large number of galaxies
- wide coverage in sky area and redshift
- high-degree of correlation
- tomographic information

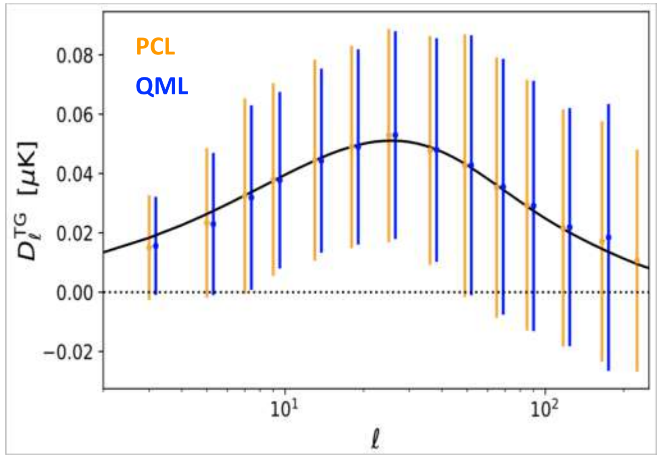
Euclid and CMB cross-correlation analyses

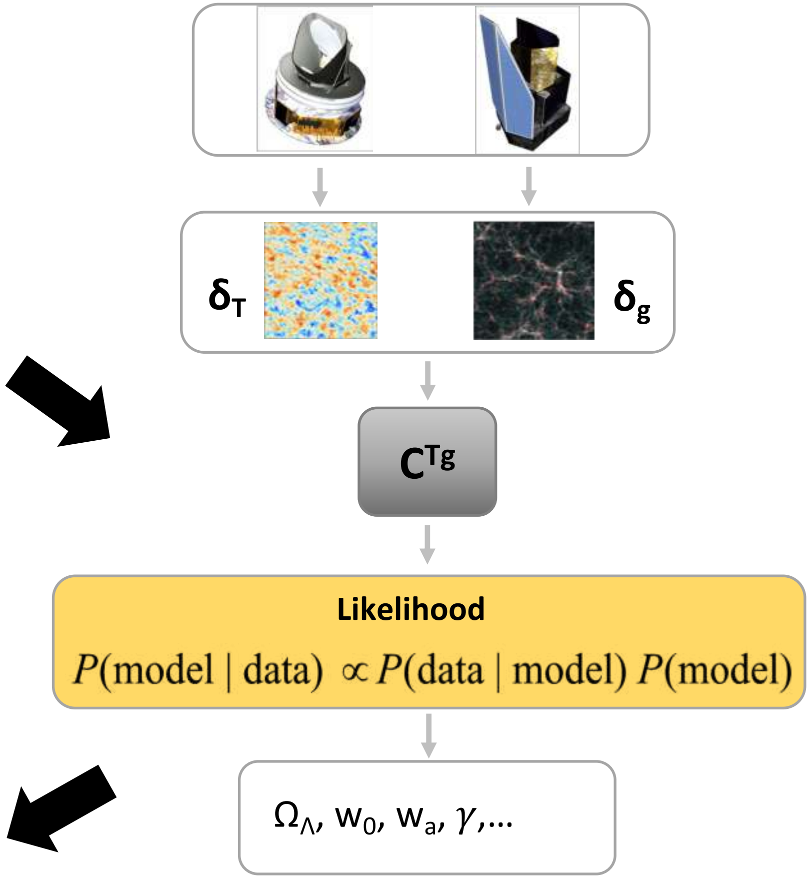
Late-time Integrated Sachs-Wolfe Effect

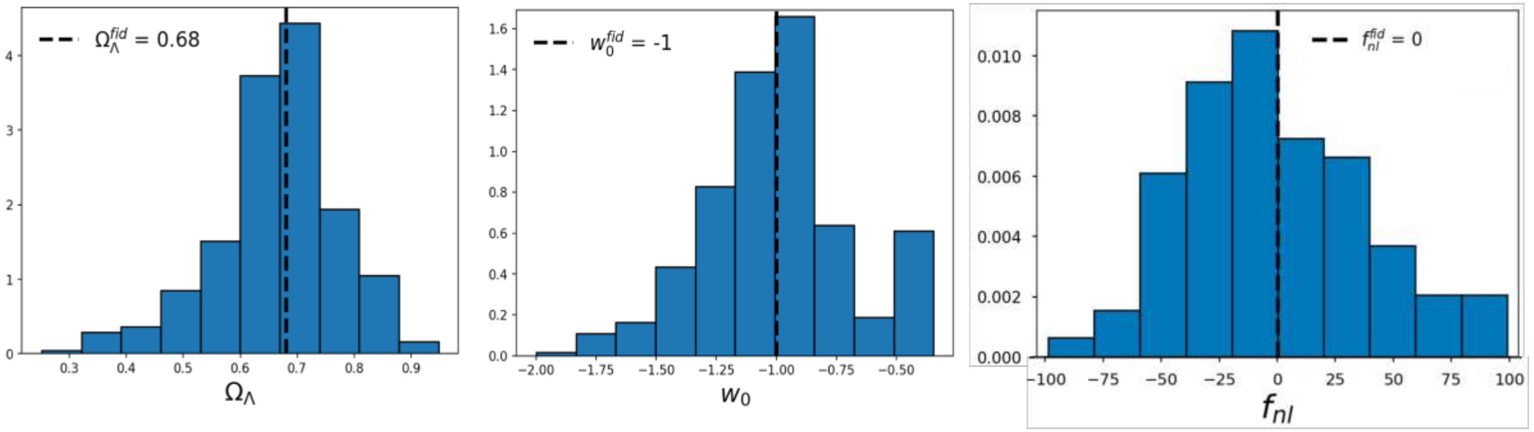
Key Project
Development of an end-to-end analysis pipeline

- Theoretical predictions
- Simulations
- Estimators
- Likelihood
- Cosmological parameters

+ Needlet based estimator
Cross-correlation functions



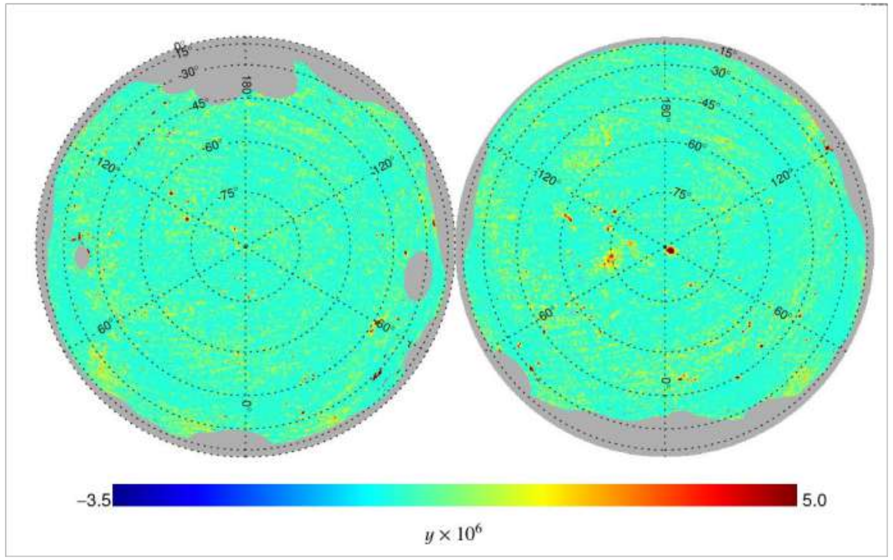




Euclid and CMB cross-correlation analyses

Thermal and Kinetic Sunyaev Zel'Dovich Effect

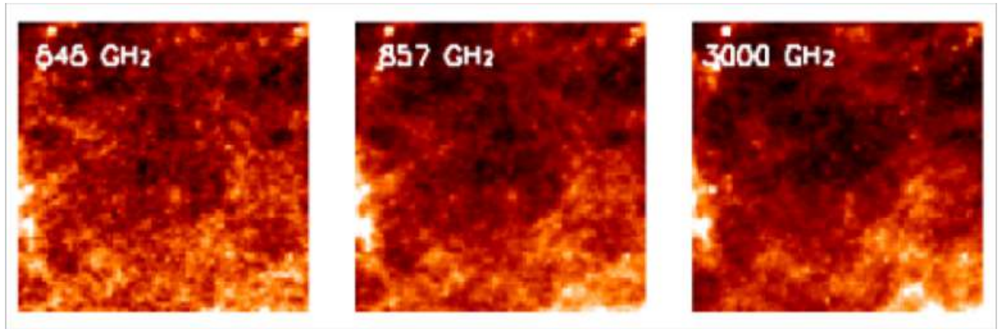
- Mapping gas profiles
- Hot gas tomography



Planck 2015

Cosmic Infrared Background

- Star formation at high redshift



Planck 2013

Euclid is flying!

Will probe the dark sector with unprecedented accuracy.

Combination of the primary probes is crucial to reach the expected scientific targets.

Synergy with external probes will be key to fully exploit the dataset to come.

CMB CAN PLAY AN IMPORTANT ROLE: NEED TO BE READY.

With ideas, theoretical developments, numerical simulations, data analysis pipelines, structured support of the activities, MoU with CMB experiments, …