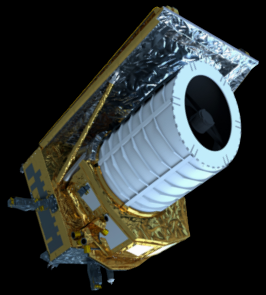
The Euclid mission: status and prospects



Stéphanie ESCOFFIER

Centre de Physique des Particules de Marseille

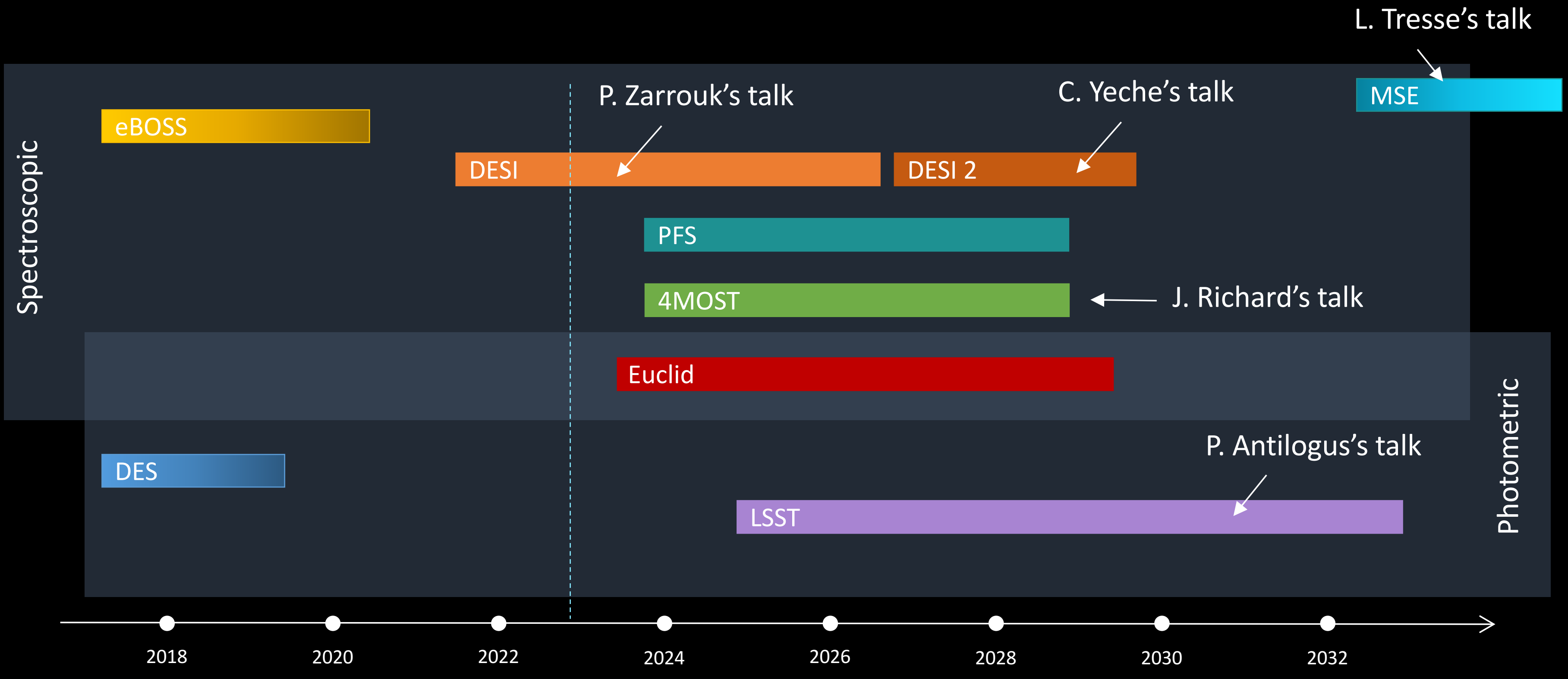
Colloque national Atelier Dark Energy 2022
17-18 novembre 2022

Acknowledgments

- All Euclid material and forecasts shown on behalf of the Euclid Consortium
- Many thanks to all collaborators in Euclid
- As inevitable, a biased review. Apologies in advance to all doing great work that could not make it into this talk

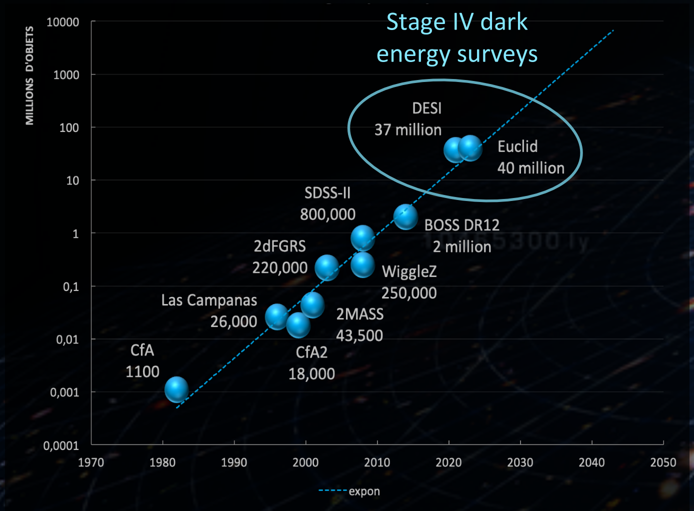
Galaxy redshift surveys

Galaxy surveys



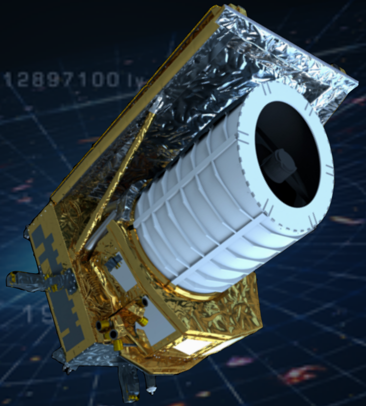
The stage-IV redshift galaxy surveys

Galaxy redshift surveys

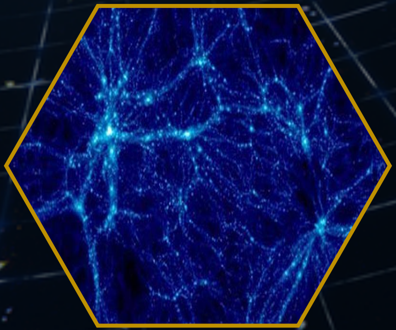


> galaxies number x10 / decade

Euclid is a ESA space mission



Galaxy clustering



NISP Instrument

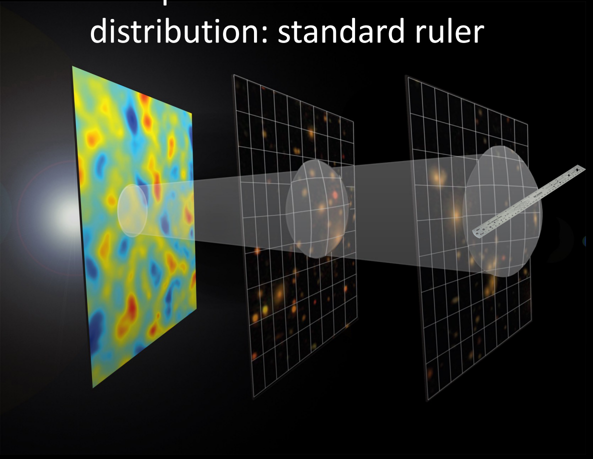
Weak lensing

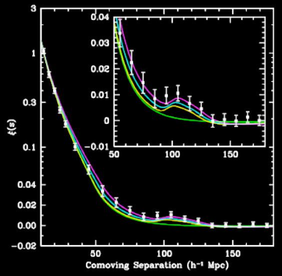
VIS Instrument

Galaxy Clustering probe

Baryon Acoustic Oscillation (BAO)

BAO provide a characteristic scale “frozen” in the galaxy distribution: standard ruler





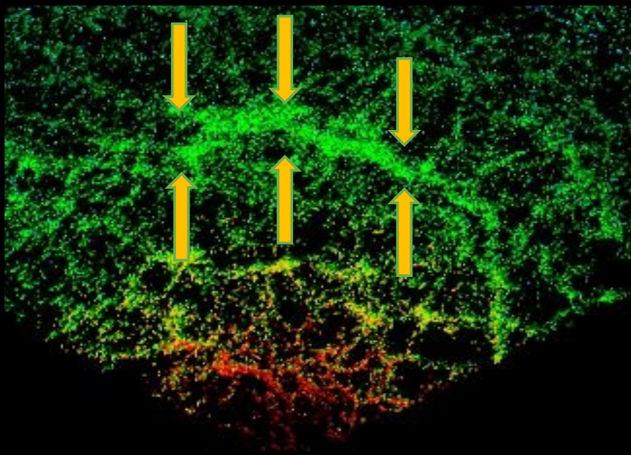
Eisenstein et al. 2005

BAO provide measurement of :

- the expansion rate H(z)
- the angular diameter distance $D_M(z)$

Redshift Space Distortions (RSD)

Gravitational infall of galaxies onto massive forming structures



Related to the linear growth rate of structure f(z):

$$f \equiv \frac{d \ln G}{d \ln a} \approx \Omega_m(z)^{\gamma}$$

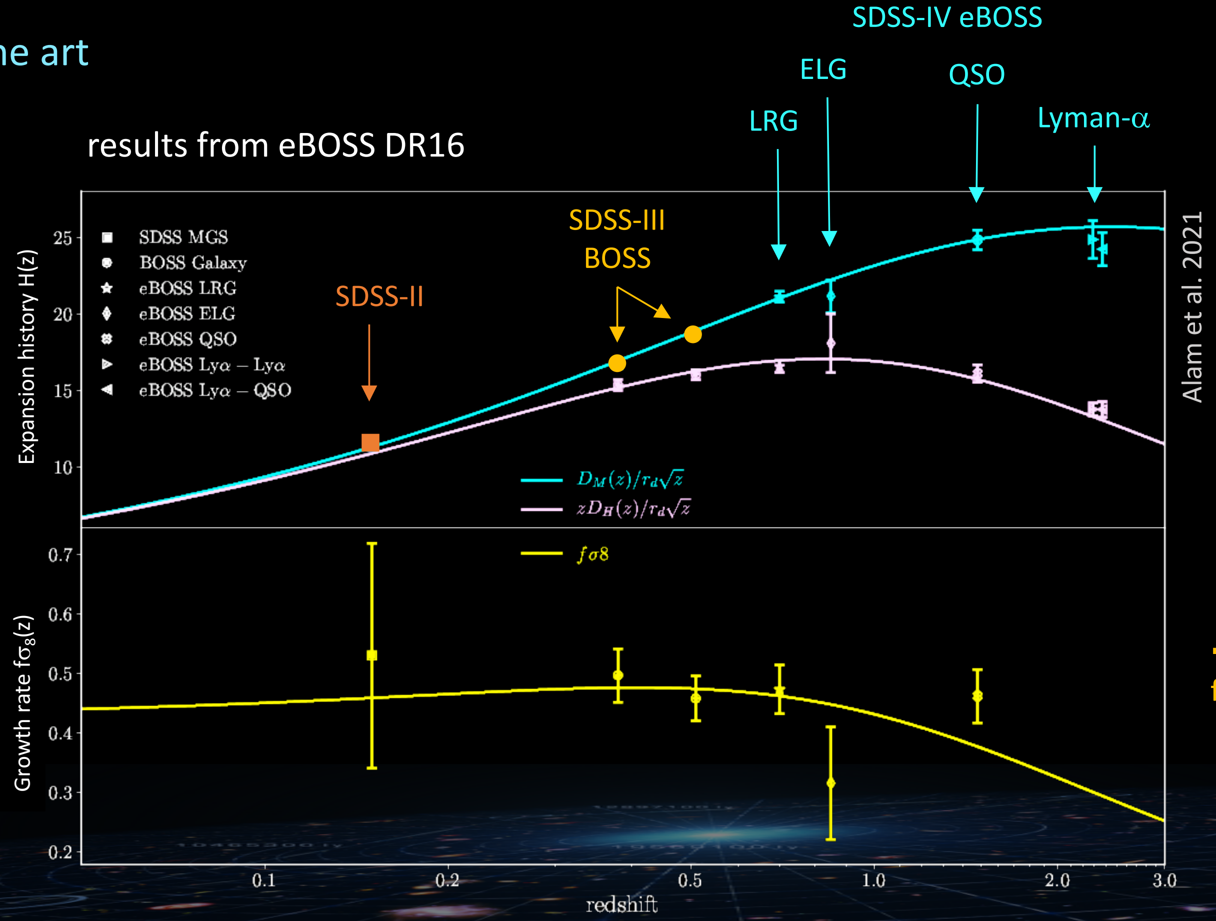
$\gamma = 0.55$ in GR

Powerful tool to constrain possible deviations from GR

Galaxy Clustering probe

State of the art

results from eBOSS DR16



➔ Degeneracy between f(z) and $\sigma_8(z)$

Weak lensing probe

Light propagation through large-scale structure results in a lensed image

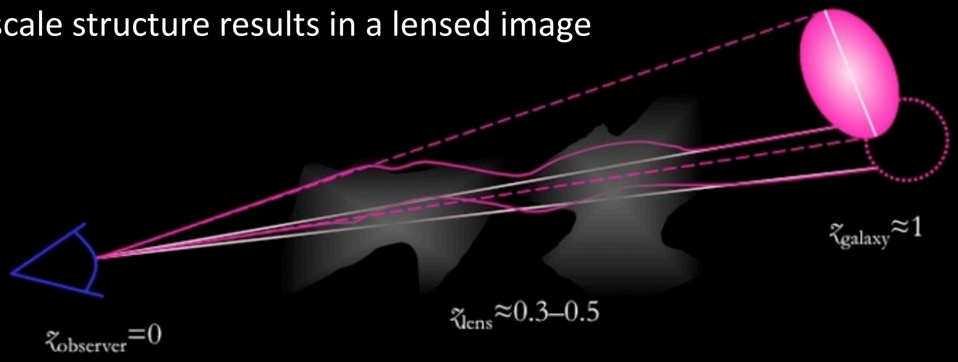
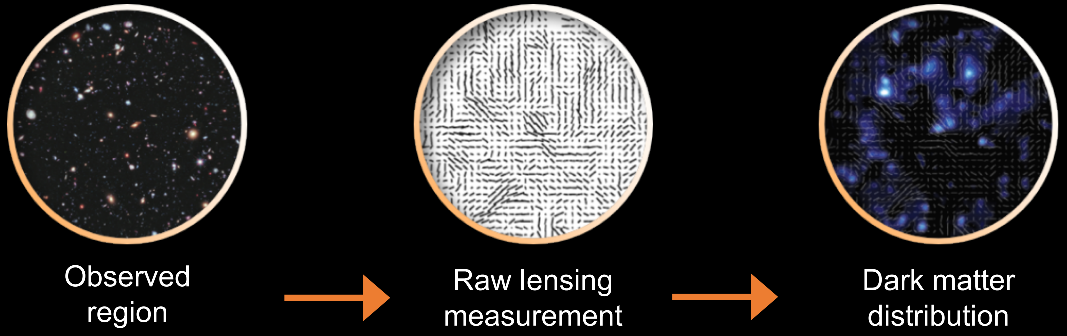


image credit: Jasonn Rhode (JPL)s



Massey et al.
Image Hubble Space Telescope

Weak lensing effect cannot be measured from any individual galaxy.
Must be measured statistically over many galaxies.

Euclid: unveiling gravity and dark energy

Combination between GC and WL

In General Relativity, $\varphi = \phi$

$$ds^2 = -(1 + 2\Psi)dt^2 + (1 - 2\Phi)a^2 dx^2$$

Φ

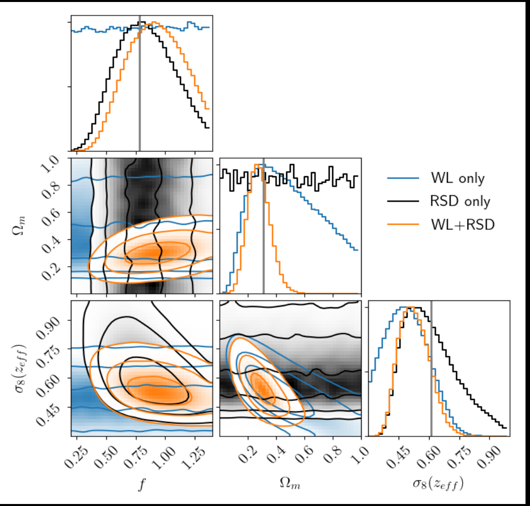
Matter gravitational potential

Light gravitational potential

Galaxy Clustering measures Ψ
➔ measures $f\sigma_8$ and $b\sigma_8$

Ψ

Galaxy lensing measures $\Psi+\Phi$
➔ measures b and σ_8



Jullo et al. 2017

Weak Lensing and Galaxy Clustering are very complementary:

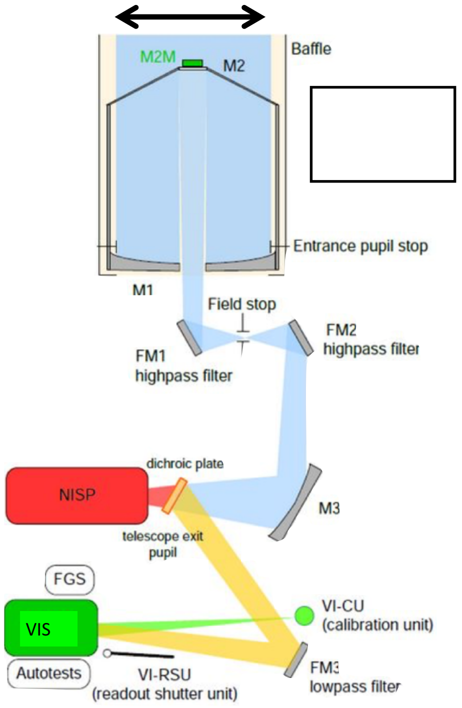
- g-g lensing and galaxy clustering of same foreground galaxies allows breaking degeneracies between cosmological parameters and galaxy bias
- One can also defined combined observables (e.g. E_G)

$$E_G = \left[\frac{\nabla^2(\Psi - \Phi)}{3H_0^2 a^{-1} f\delta}\right]$$

Zhang et al 2007

The Euclid mission

Euclid payload: two instruments for two probes



Overview of the PLM sub-systems – Courtesy Airbus Defence and Space.

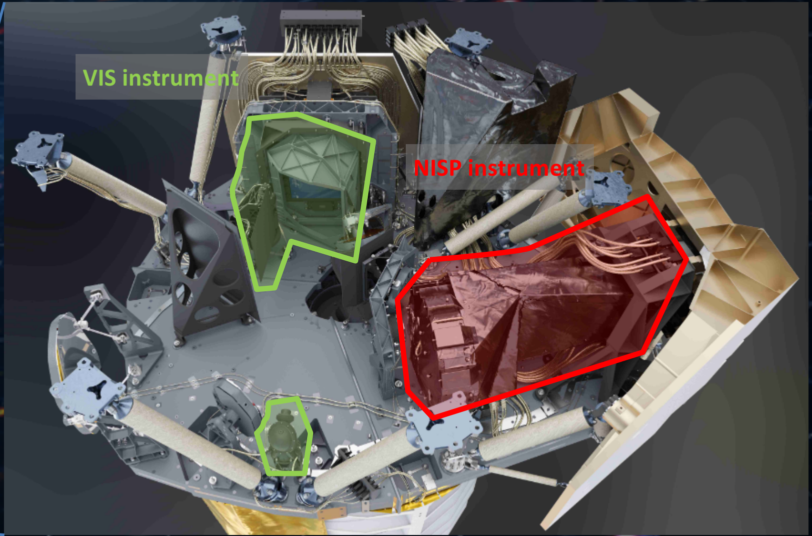
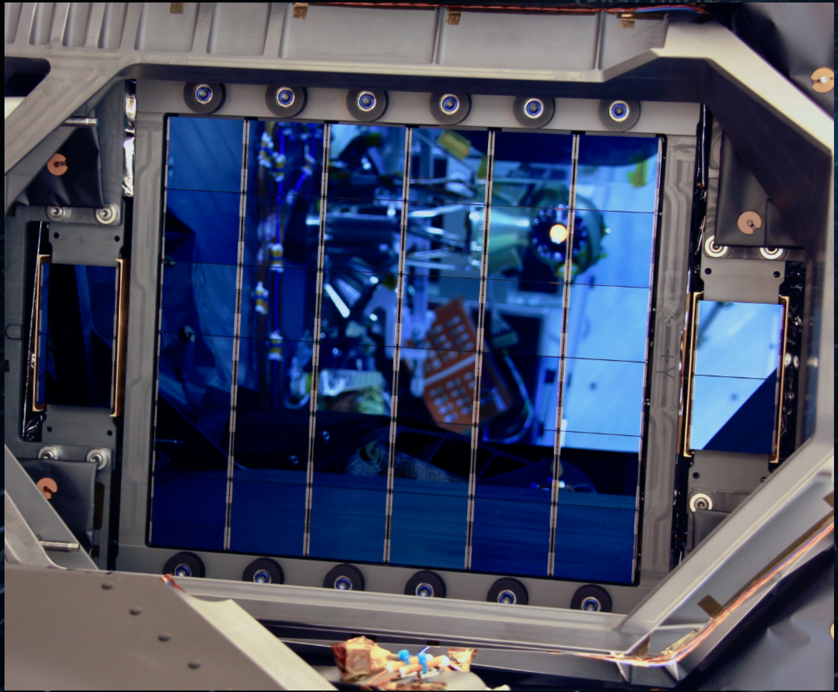


Photo: courtesy ESA/TAS

VIS Instrument:
FM delivery in March 2020



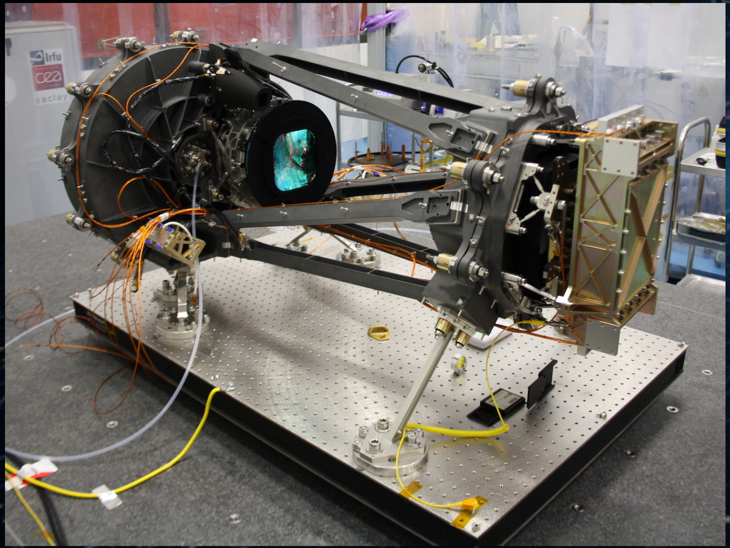
Focal Plane

Focal plane instrument, no optics;
limiting magnitude: mAB=24.5 extended sources at 10σ
spectral range λ: 550–900nm
focal plane: 6x6 CCDs (e2v, 12x12µm2 pixels, 4096x4096 pixels)
plate scale: 0.1 arcsec/pix
FOV: FoV=0.787x0.709 deg2
focal length: f=24.5 m
Datarate: ≤ 520 Gb/day

Partners

cea IAS UCL MULLARD SPACE SCIENCE LABORATORY

NISP Instrument:
FM delivery in May 2020



Focal Plane

Based on Teledyne H2RG detectors 2048 x 2048 pixels
Pixel sizel : 18 µm
Spectral band: 0,9 µm – 2 µm
Focal plane cooled to 90K

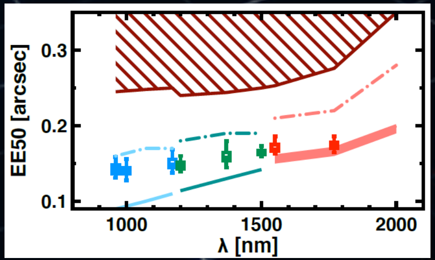
The focal plane contains 16 H2RG, or about 64 million pixels!

Partners

LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE · CPPM CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE · iP2i · cea

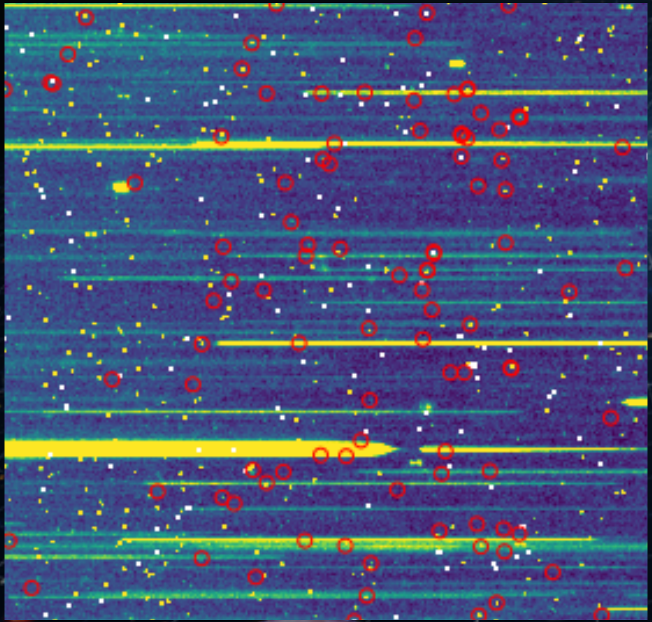
+ Italy, Spain, Germany, Norway, Denmark, Belgium, NASA (detectors)

PSF verification



The infrared camera, the largest ever launched into space, will provide measurements of unprecedented accuracy.

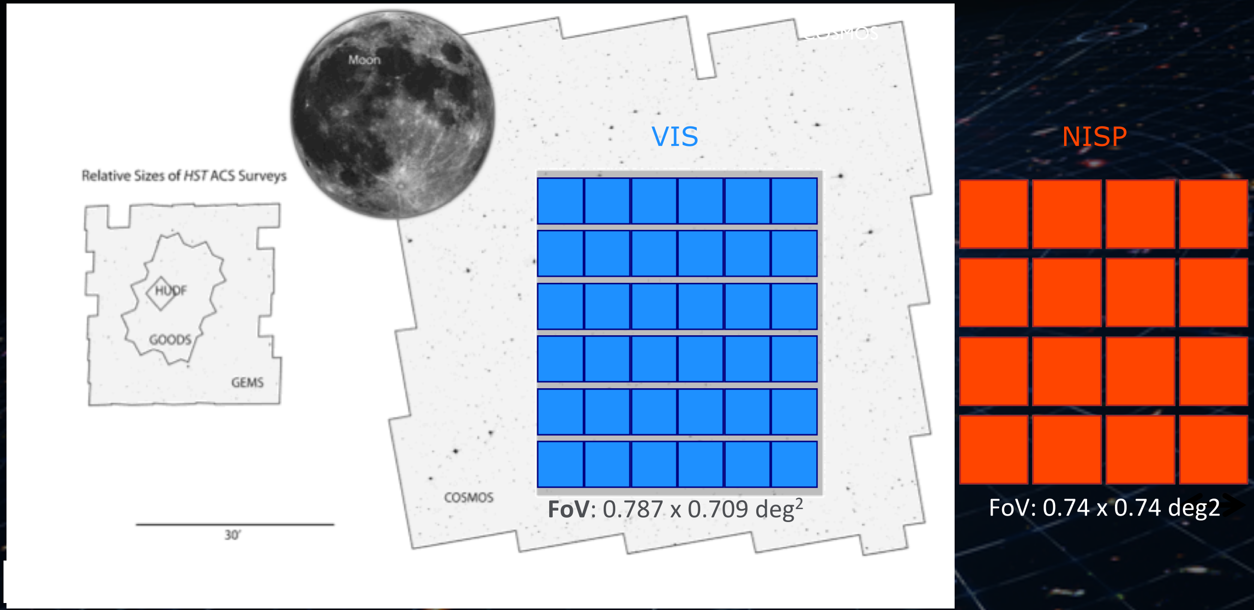
Euclid data are complex: slitless spectroscopy



Euclid NISP-S simulated exposure, with H_α lines marked

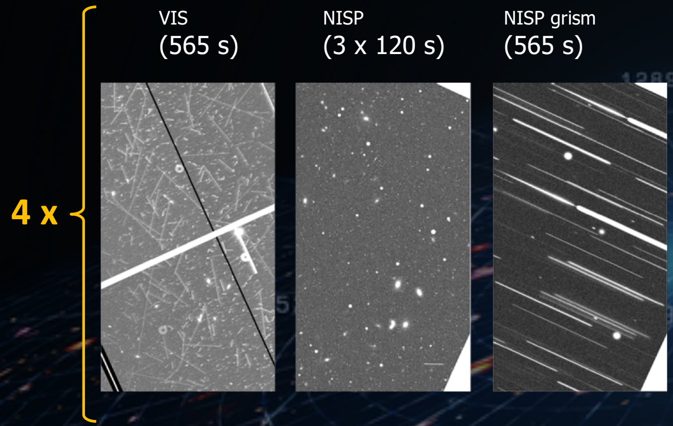
Slitless mode critically different from traditional redshift surveys with MOS (eBOSS, DESI, 4MOST, ..)

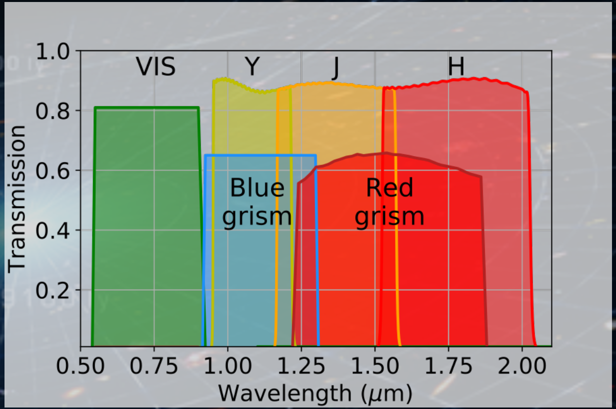
Euclid: dual wide-field imager



	VIS	NISP
Pixel size	0.1”	0.3”
Dispersion	-	R~380, 13.4 A/pixel

A panchromatic view



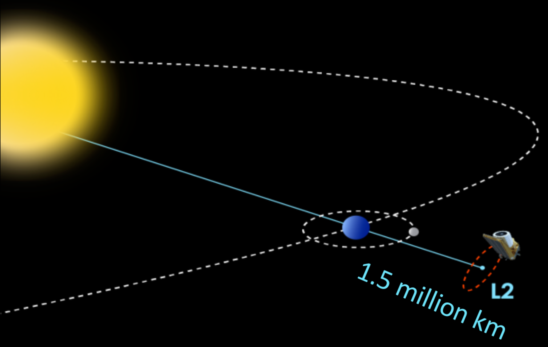


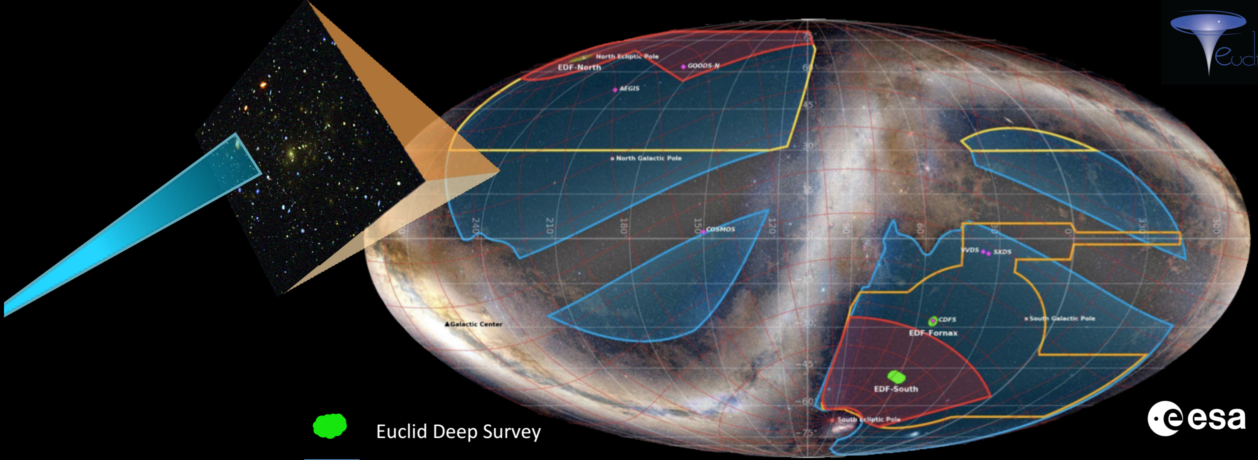
*Blue grism is exposed on Deep fields only

	VIS	Y	J	H	Grism
Wide	24.5	24	24	24	2 10^{-16} erg/s/cm^2
Deep	26.5	26	26	26	2 10^{-17} erg/s/cm^2

(slide by Ben Granett)

The Euclid survey





Euclid Deep Survey

Euclid Wide survey (15 kdeg²)

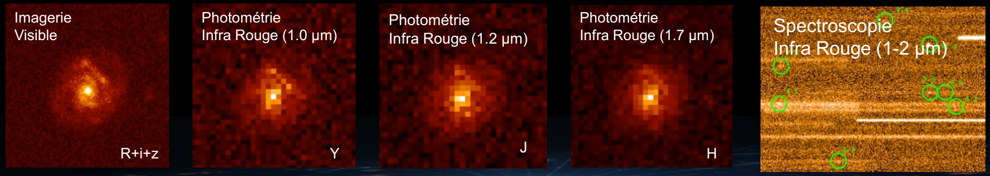
Euclid DR1 area (2.5 kdeg²)

UNIONS (N 4.8 kdeg²) + DES (S 4.5 deg²)

From J.-C. Cuillandre and the ECSURV team

Mirror diameter: 1.2 m
Field of view: 0.5 deg².
15000 deg² survey
Visible & infrared

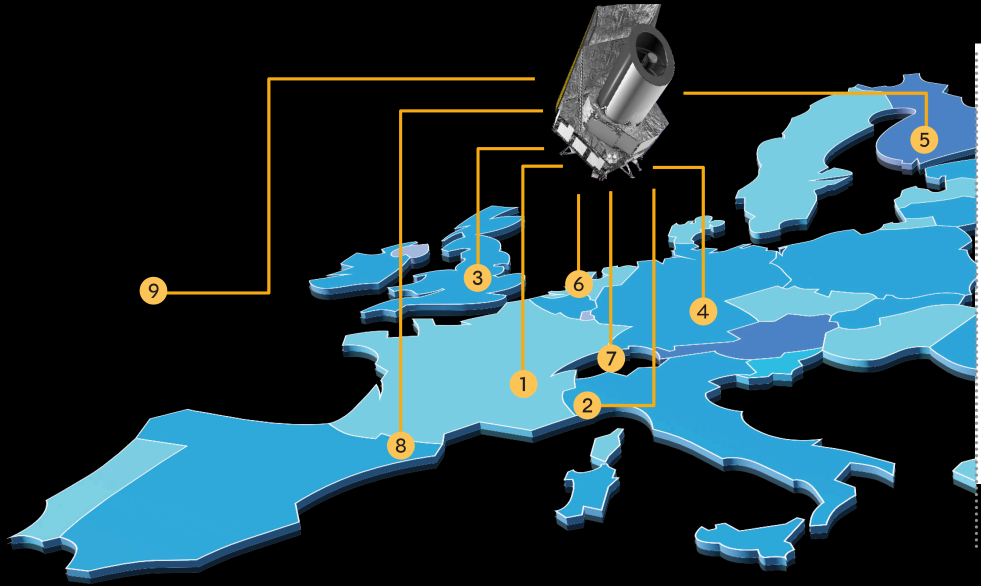
A 15 000 deg² survey consisting of :
30 000 observed fields of 0,5 deg² each on the sky
10 000 calibration fields



2 billion galaxies observed in visible and infrared photometry

50 million infrared spectra between $0.9 < z < 2$

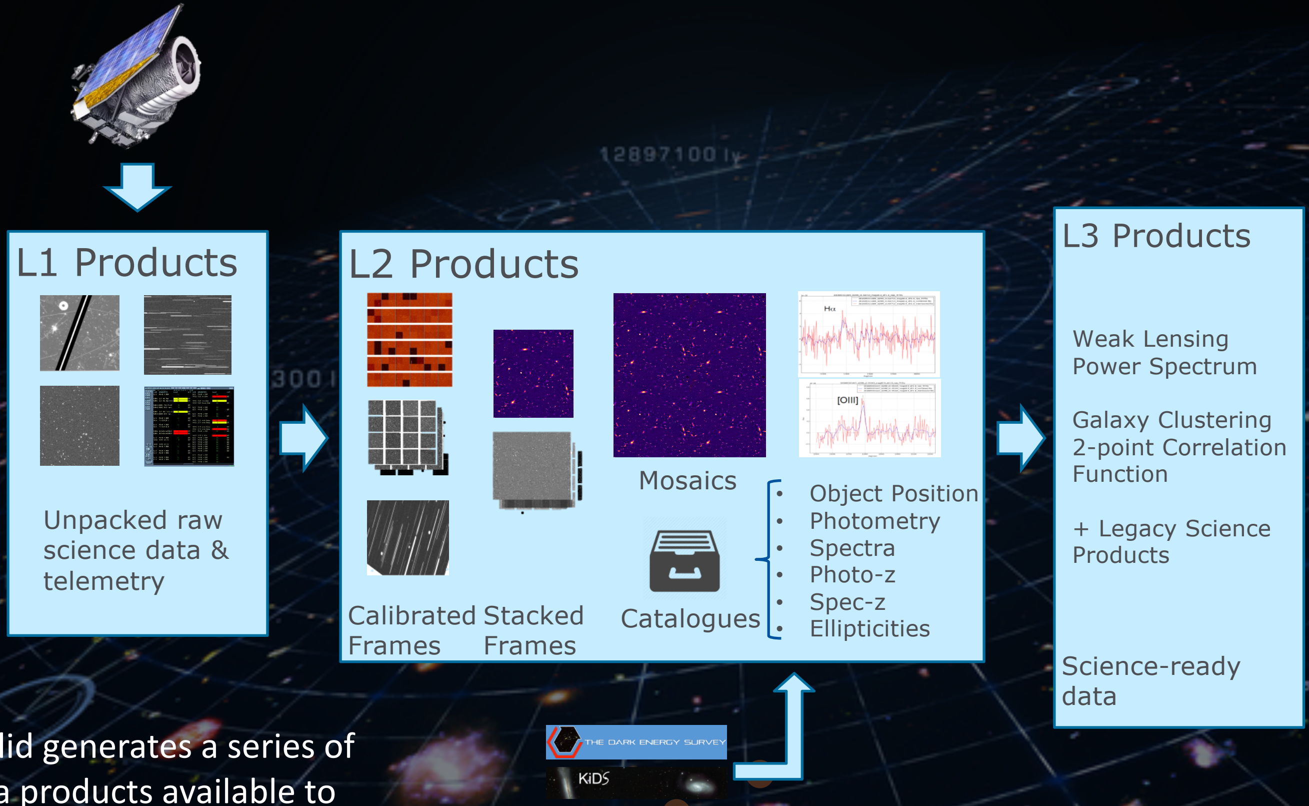
The Scientific Ground Segment (SGS)



1. Centre de Calcul de l'IN2P3 - Lyon - France
2. Astronomical Observatory of Trieste - Italie
3. Institute for Astronomy - Edimbourg - Royaume-Uni
4. Max-Planck-Institute for Extraterrestrial Physics - Münich - Allemagne
5. University of Helsinski - Finlande
6. Donald Smits Centrum voor Informatie Technologie - Gröningen - Pays-Bas
7. Département d'astronomie de l'université de Genève - Suisse
8. Port d'Informació Científica - Barcelone - Espagne
9. IPAC, Caltech , Pasadena - Californie - USA

More than 170 million gigabytes of data!
30% will be processed in the Science Data Center (SDC) France: CC-IN2P3

The Euclid Data Products



Data from external surveys

Euclid generates a series of data products available to the community via the Euclid Archive System (EAS).

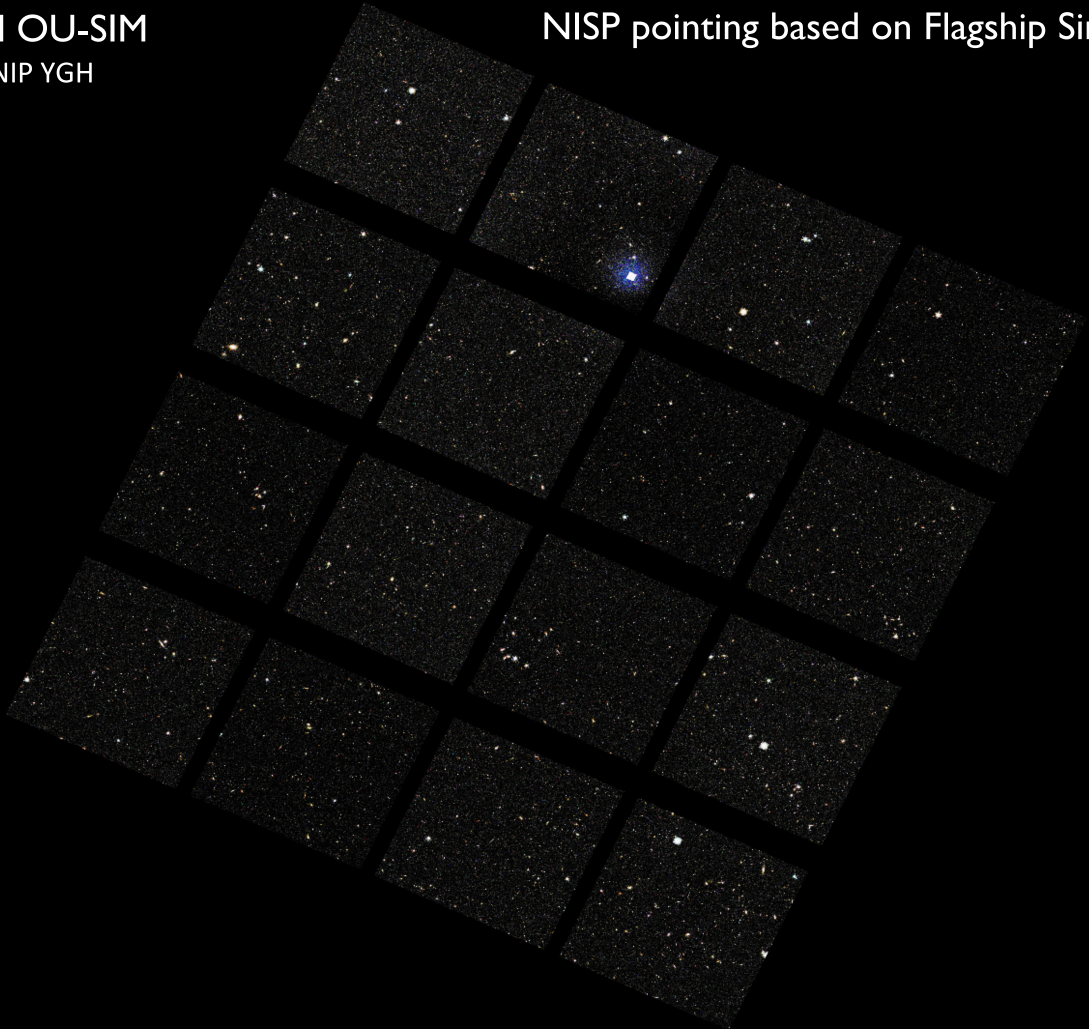
Shapes and Photo-z for 1.5 billion galaxies

Spectroscopic Redshift for 40 million galaxies

Euclid OU-SIM

Field X1:NIP YGH

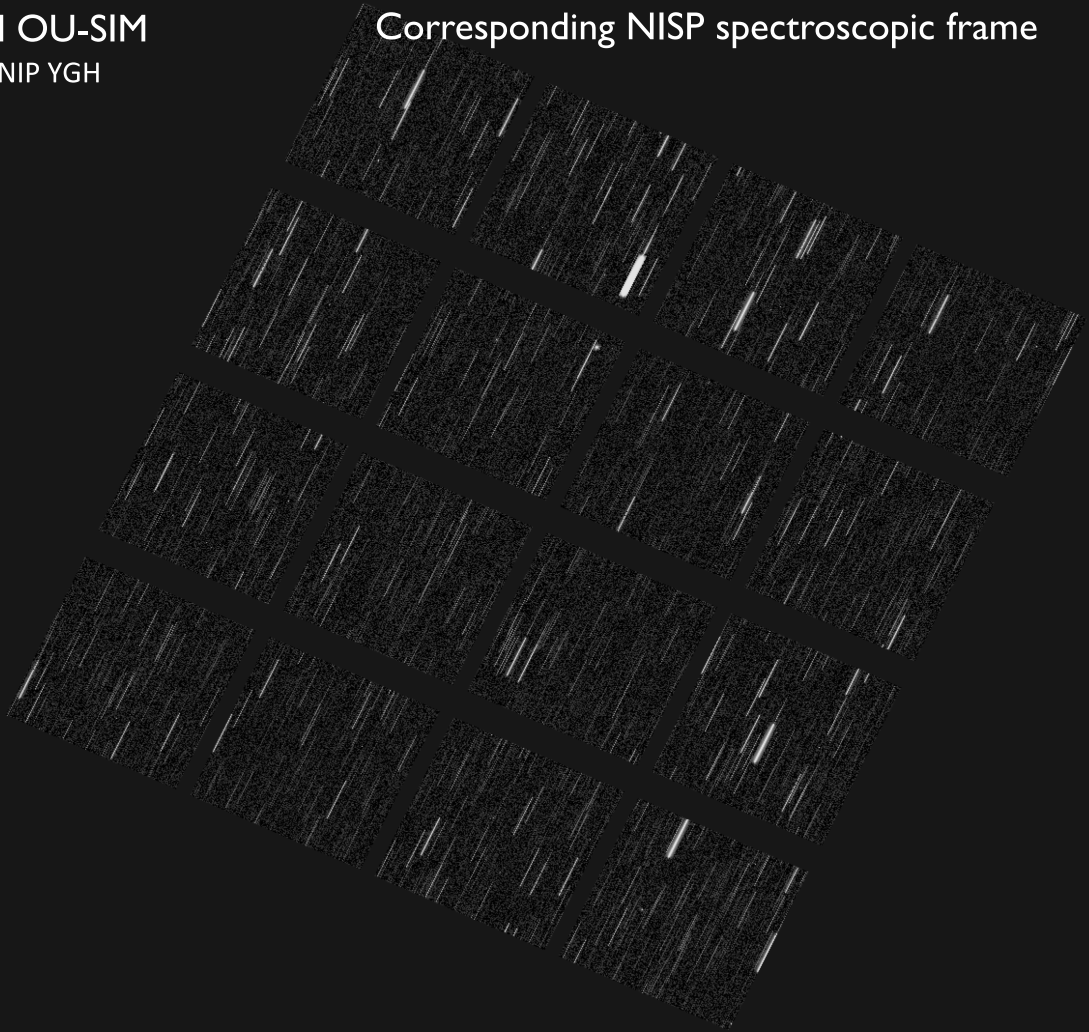
NISP pointing based on Flagship Simulation



Euclid OU-SIM

Field X1: NIP YGH

Corresponding NISP spectroscopic frame



Euclid is ready !

July 2022 @ Thales-AleniaSpace premises in Turin

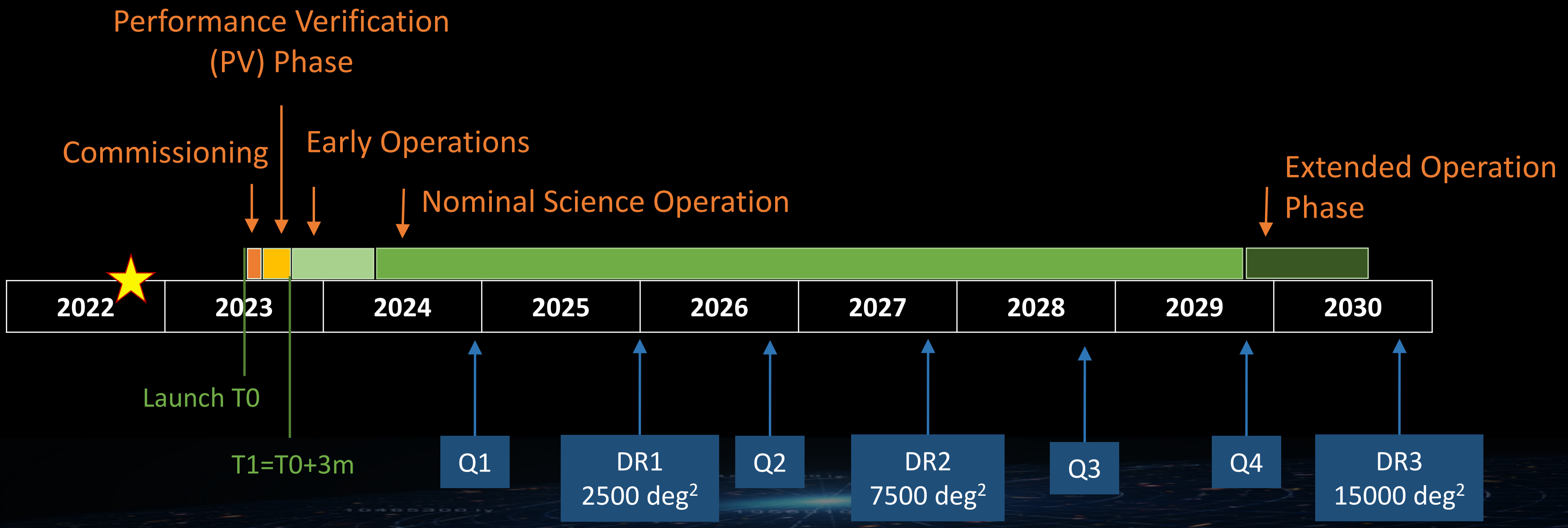
Flight model fully assembled

November 2022 @ Thales-AleniaSpace in Cannes

Test the thermal conditions inside the vacuum chamber in Thales's clean room

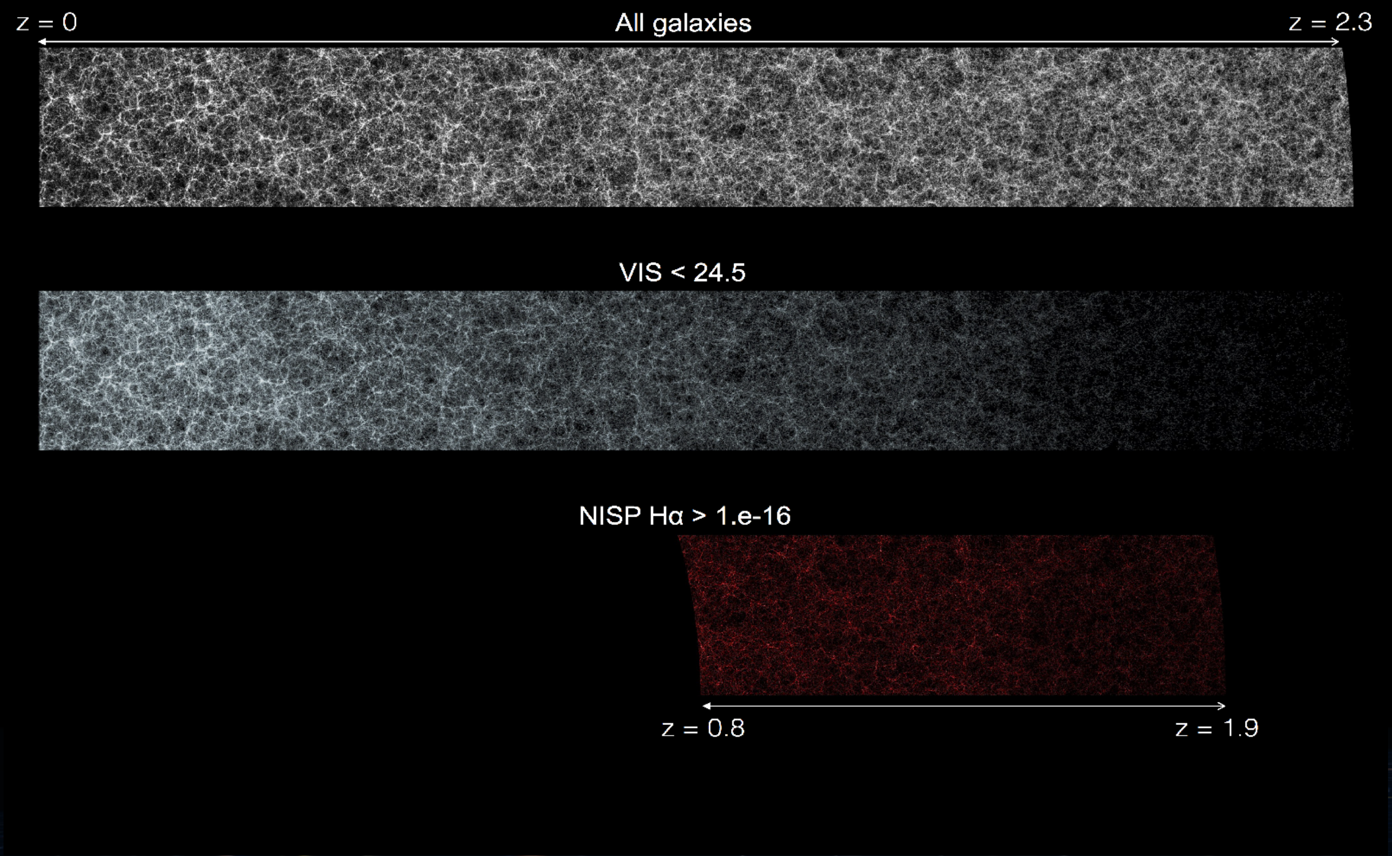
Euclid: Timeline

- The launch was scheduled for 2023 with Soyuz: agreement broken with the Russian Agency in the spring 2022
- The official launcher became Ariane 6.2, but need 2 successful launches (2024-2025)
- ESA agreement to launch Euclid with a Space X Falcon 9 in July 2023



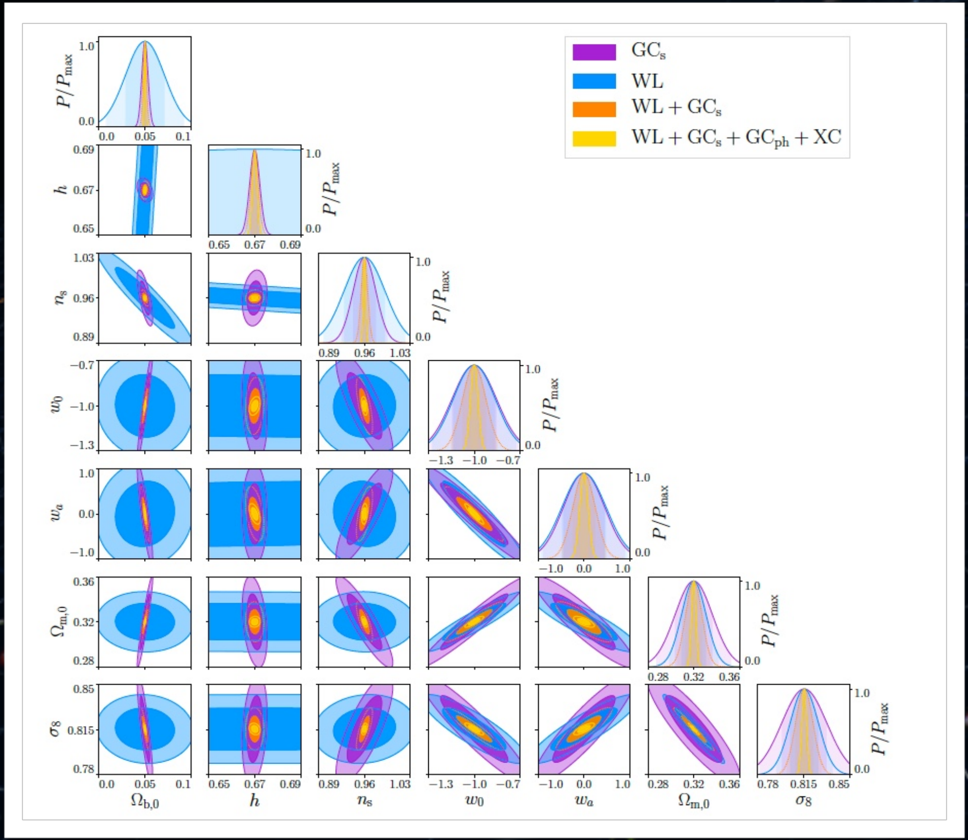
Science with Euclid: some selected topics

Euclid Flagship simulation: mock galaxy catalog



Forecasts of scientific performances

REFERENCE PAPER: A. Blanchard & Euclid Consortium, 2020



Forecasts of scientific performances

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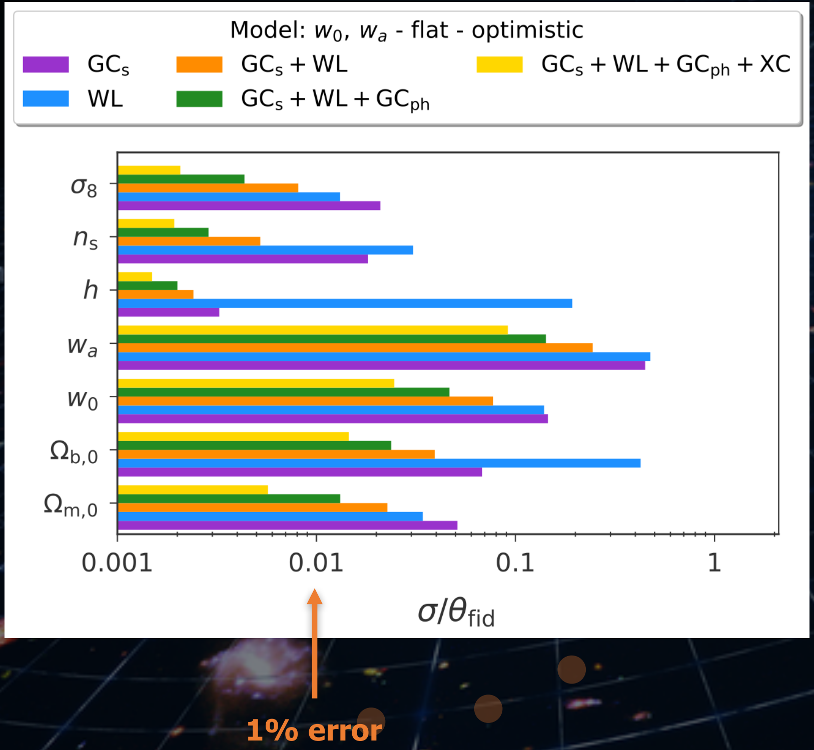


Probe combination is key to high precision !

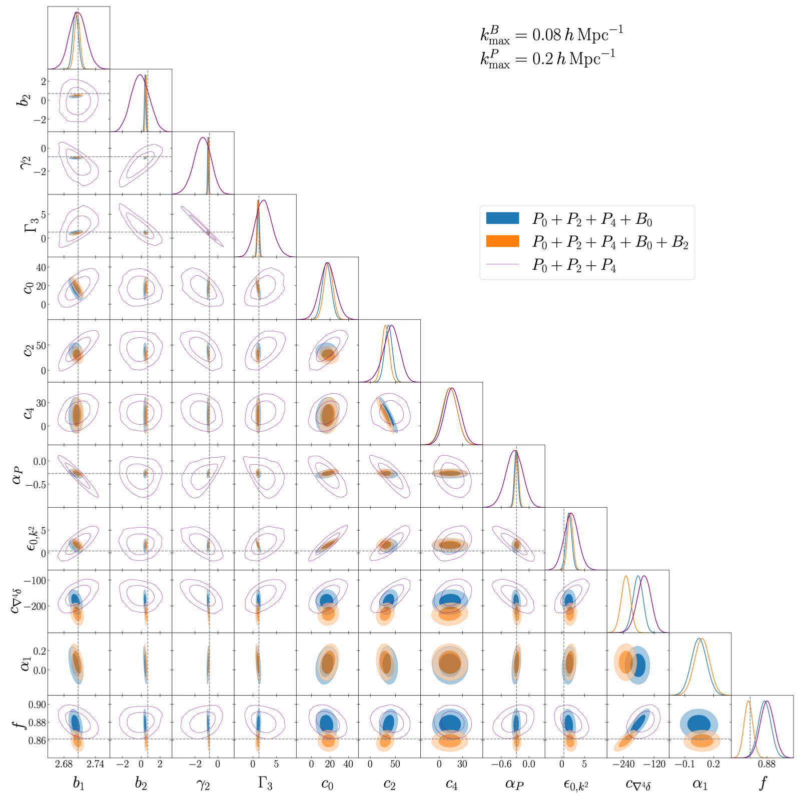
Galaxy Clustering SWG

The GC SWG will achieve the science requirements by:

- Understanding observational and model systematics
- Extracting more information from the data
    - Improved estimators
    - Alternative statistics
    - Combination with other data
- Preparing for a joint likelihood analysis of multiprobe Euclid data

Galaxy Clustering SWG

WP : Higher order



- Higher-order correlation functions of the large-scale structure are necessary to "quantify" the filamentary nature of the galaxy and matter density distributions.

- Combine P(k) and B(k)

Likelihood analysis of P+B in terms of bias & cosmological parameters with full covariance from Pinocchio mocks

- Include redshift-space distortion constraints (multipoles)

- Three-point statistics in combination with two-point statistics allows in principle removing bias degeneracy

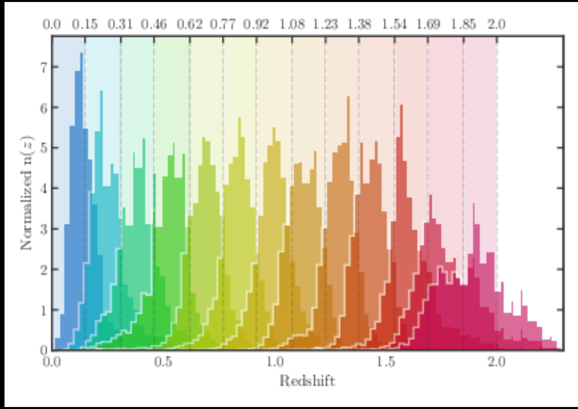
(Moretti, Sefusatti+, in prep.)

Galaxy Clustering SWG

WP : Photo-z clustering

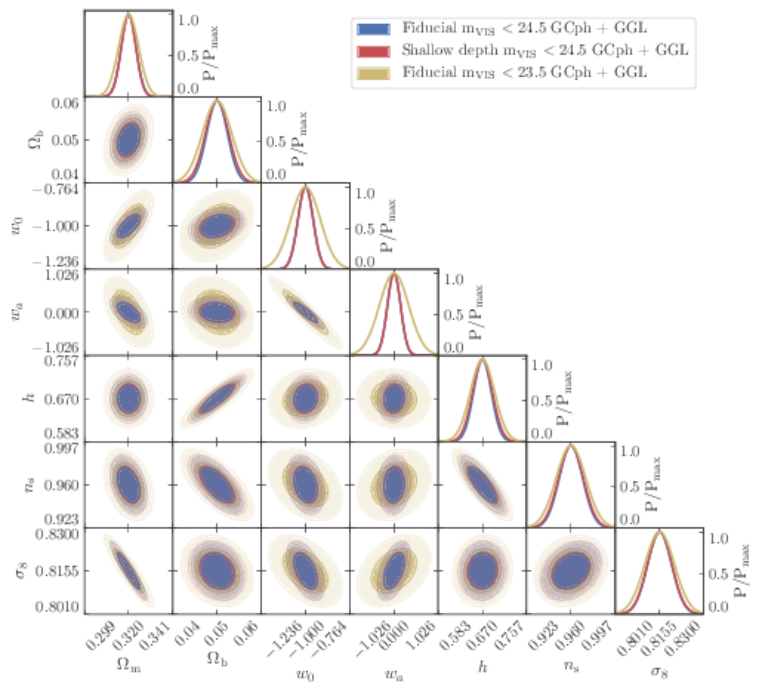
Galaxy Clustering with photometrically-selected galaxies (GCph)

Optimizing the Euclid sample of galaxies detected with photometric techniques



Bins with equal width in redshift provide a higher Figure of Merit (FoM) than equipopulated bins

Forecasts for the combination GCph + WL



Pocino, Tutusaus & Euclid Consortium, 2021

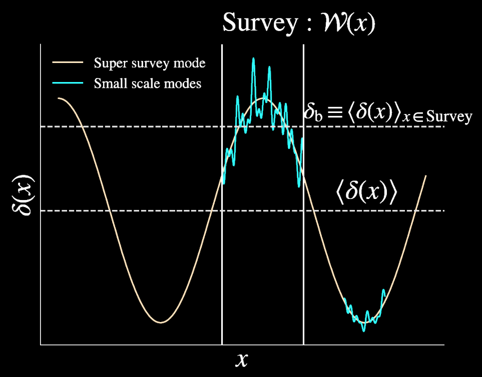
Galaxy Clustering SWG

WP : Photo-z clustering

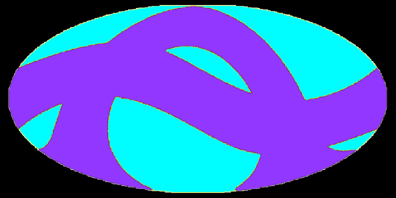
Super Sample Covariance:

If we sit in an over-(under-) density, the clustering is damped

➔ Non-linear coupling between large scales and small scales



- SSC arises from the fact that we observe a limited portion of the Universe



Gouyou Beauchamps et al. 2021

➔ Non negligible difference between full-sky and partial-sky for unmarginalised constraints

Galaxy Clustering SWG

WP : Photo-z clustering

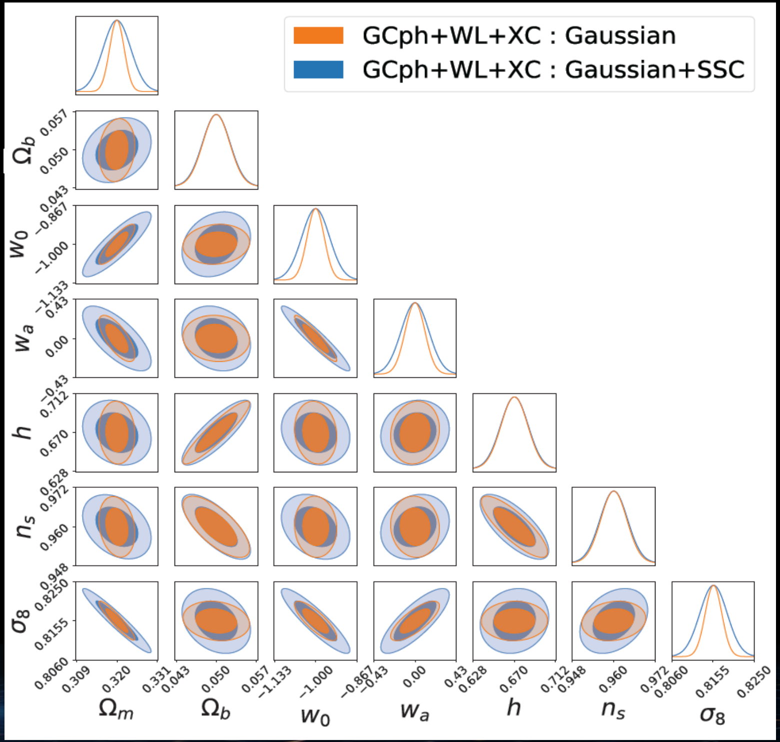
Super Sample Covariance:

If we sit in an over-(under-) density, the clustering is damped

➔ Non-linear coupling between large scales and small

- SSC arises from the fact that we observe a limited portion of the Universe
- SSC has a significant impact on Dark Energy constraints

➔ -50% on the FoM for 3x2pt

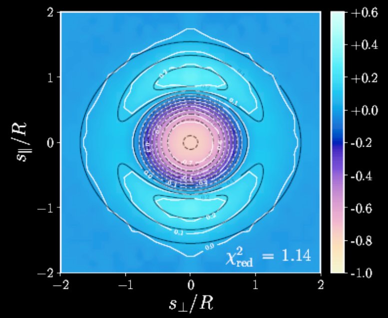


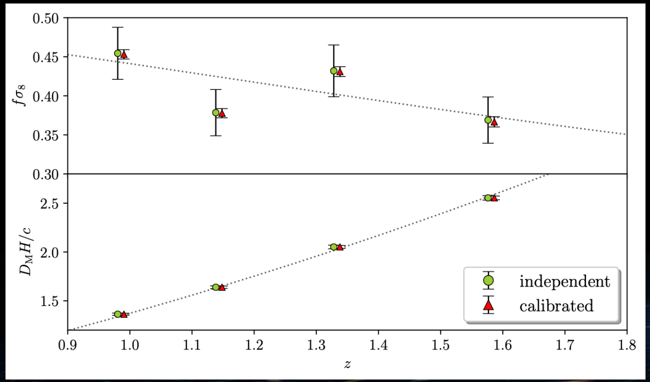
Scotti, Gouyou Beauchamps & Euclid Consortium 2022, in prep

Cosmic voids statistics

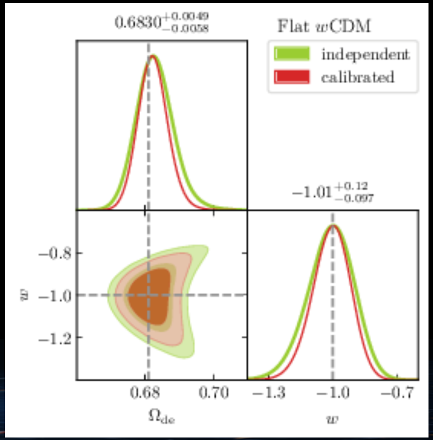
WP : Voids

Combined Alcock-Paczynski & RSD void analysis





Euclid forecasts

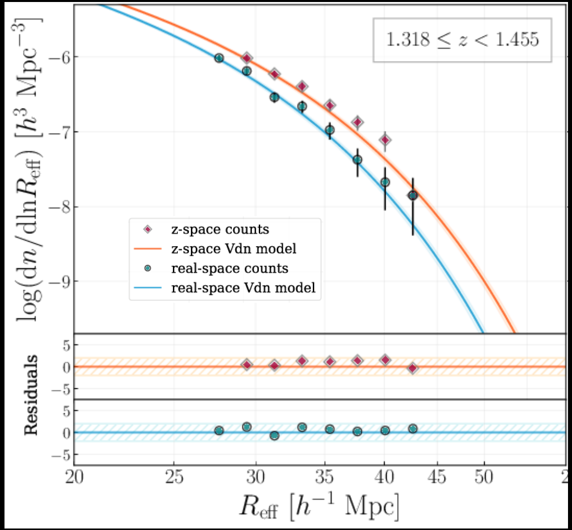


Hamaus, Aubert & Euclid Consortium, 2022

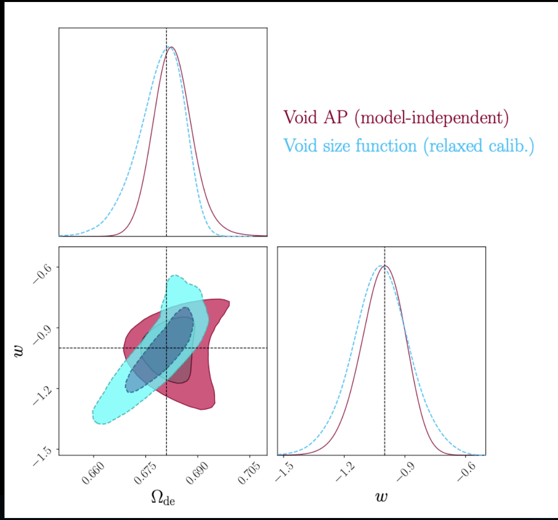
Cosmic voids statistics

WP : Voids

Void size distribution function



Euclid forecasts

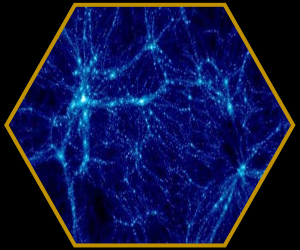


Contarini, Verza & Euclid Consortium,
arXiv:2205.11525

Scientific objectives

Two primary probes

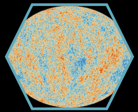
Galaxy clustering



Weak lensing

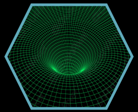
Other cosmological probes

Clusters of galaxies



X-CMB

Stronng lensing



Theory

Legacy science

Local Universe

Primeval Universe

SNe & transients

Exoplanets

Milky Way

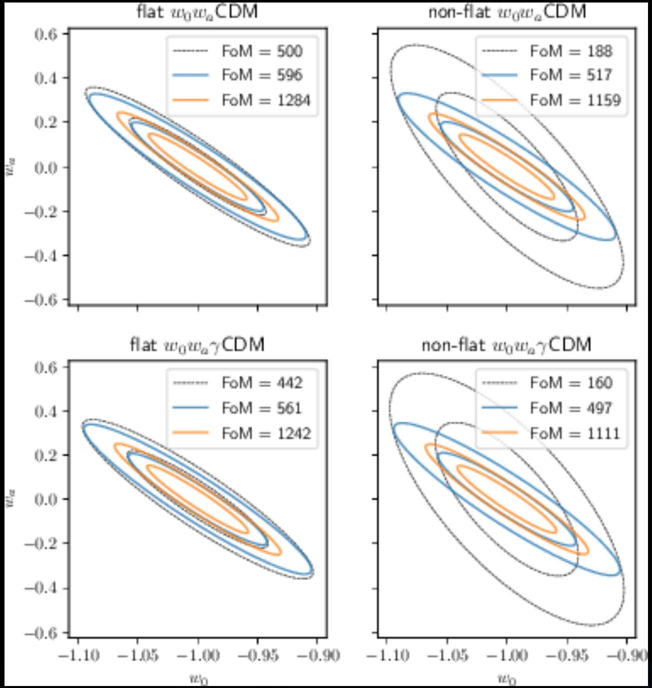
Galaxie evolution

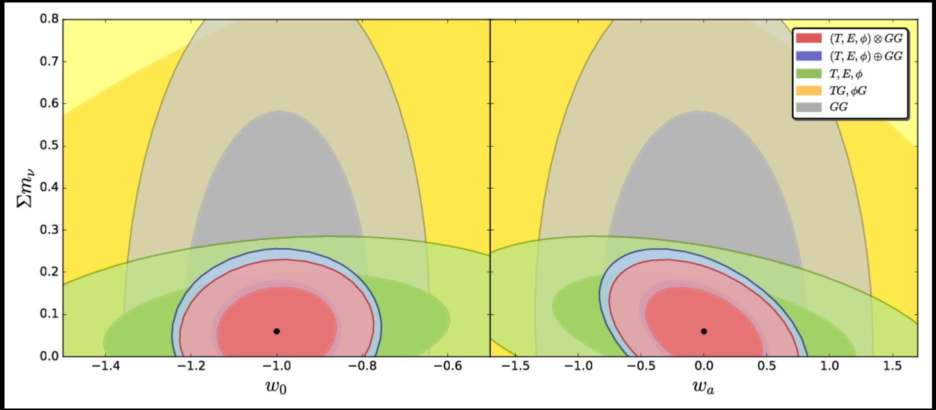
Solar system

CMBX SWG

CMBX Forecasts paper

Planck+SO and Euclid-ph-like





Bermejo-Climent et al., 2021

Euclid only
Euclid + CMB ϕ
Euclid + full CMB

Exploiting CMB-Euclid cross-correlation and CMB in extended cosmologies

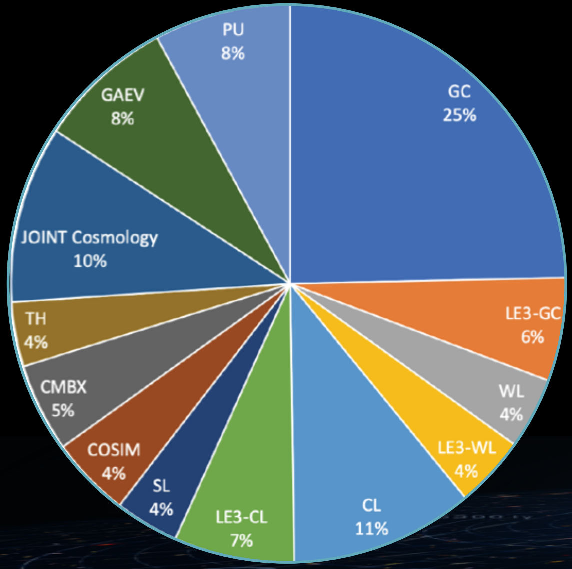
Ilic & Euclid Consortium, 2022

Summary & Conclusions

Summary & conclusions

Euclid should provide exciting data for the understanding of the evolution of the Universe, constraints on gravity, distribution on dark matter, neutrinos mass, primordial non-gaussianities, ..
but also for a large variety of legacy science, which is also important for primary cosmology.

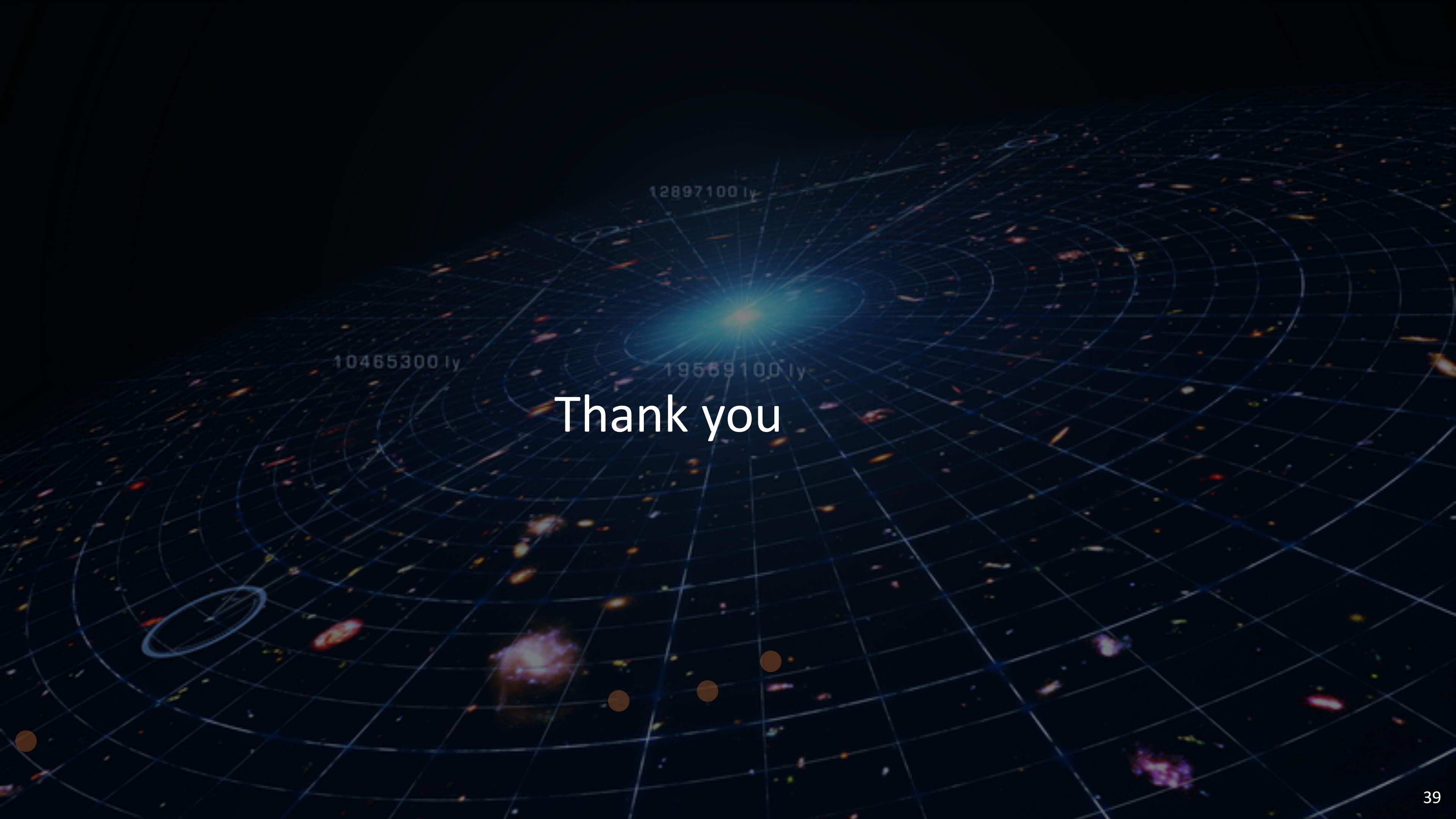
All scientific aspects are already well organized within Euclid Consortium, and many results from simulations or external data have already been obtained or are still being produced.



Euclid Pre-launch papers:

215 science Key Papers + 70 technical Key Papers

+ all Standard Euclid papers…



Thank you

The Euclid Consortium community in 2022