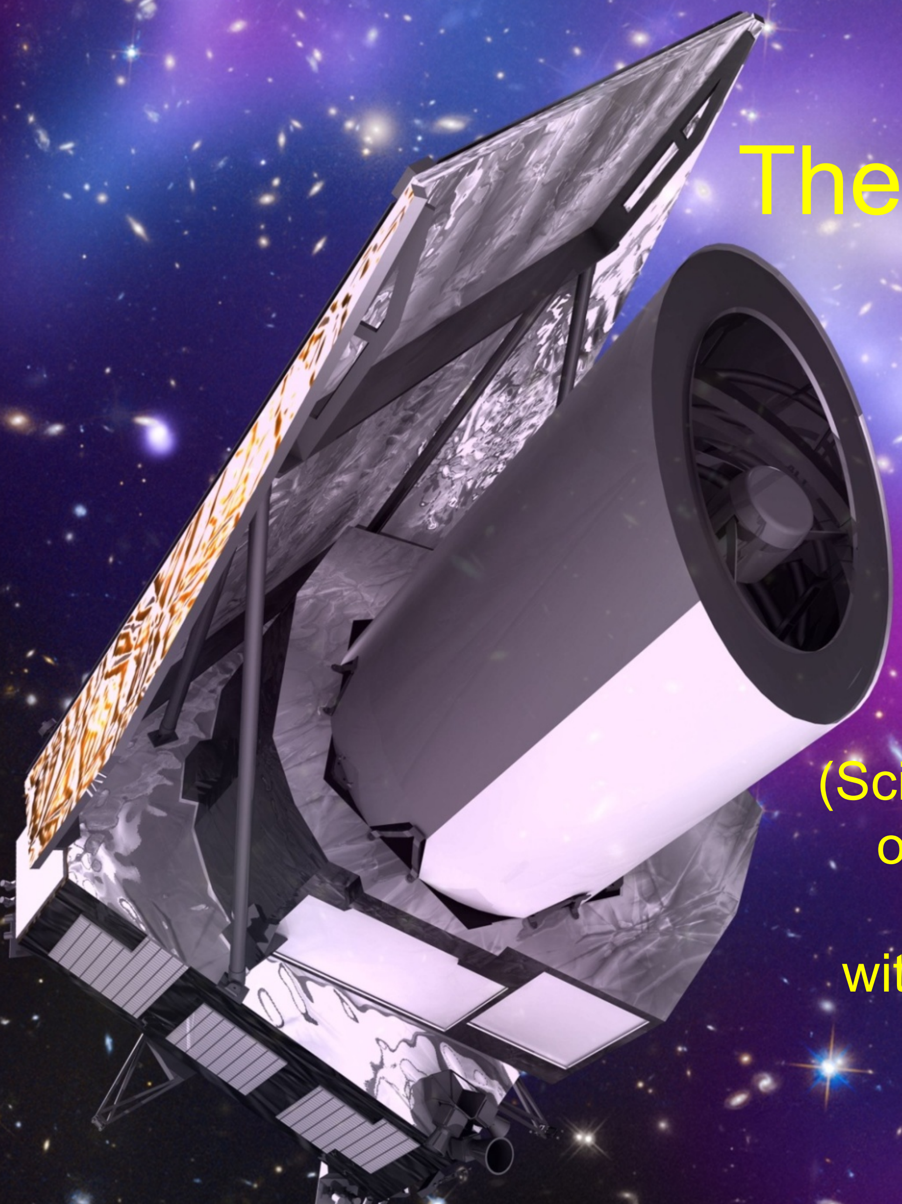
The Euclid Mission



M. Sauvage
(Science Ground Segment)
on behalf of the Euclid
Consortium
with slides from Y. Mellier

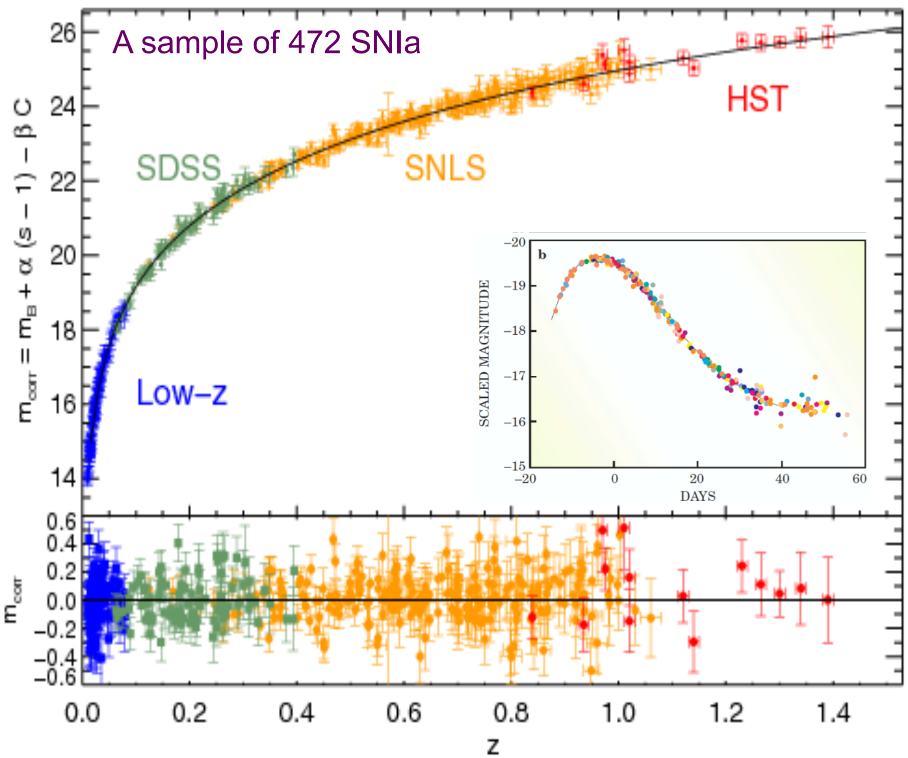
www.euclid-ec.org

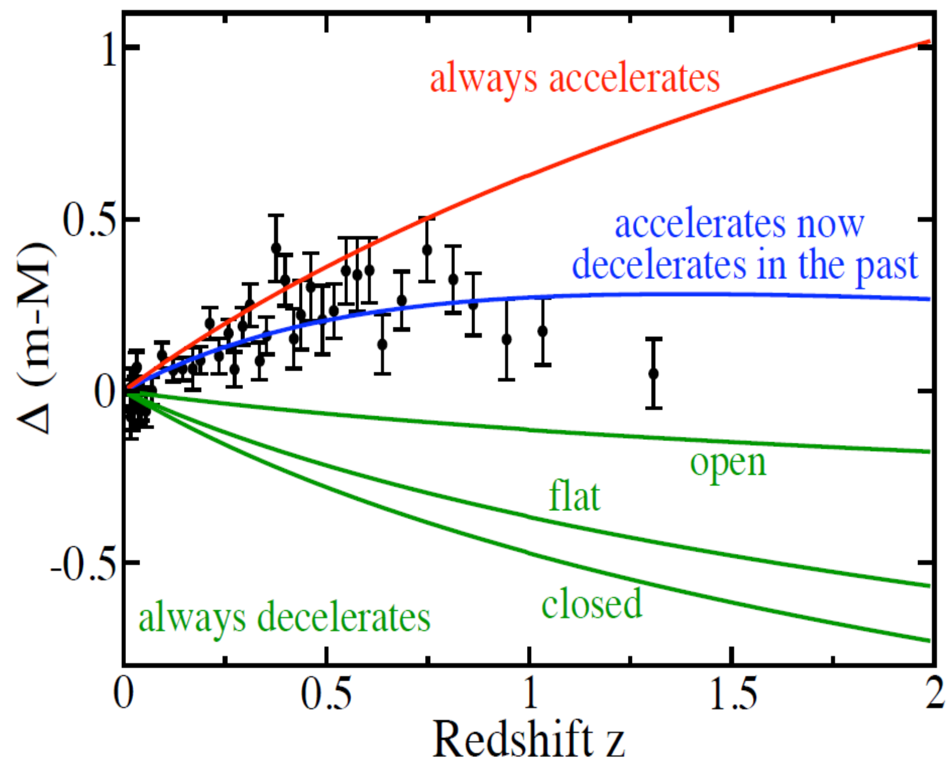
The expansion of the Universe is accelerating:

Confirmed today at a 99.999% confidence level

The acceleration of the expansion is recent:

In the past, expansion was decelerating: matter dominated era





Euclid Top Level Science Requirements

Sector	Euclid Targets
Dark Energy	• Measure the cosmic expansion history to better than 10% in redshift bins $0.7 < z < 2$. • Look for deviations from $w = -1$, indicating a dynamical dark energy. • Euclid *alone* to give $FoM_{DE} \geq 400$ (1-sigma errors on w_p, & w_a of 0.02 and 0.1 respectively)
Test Gravity	• Measure the growth index, γ, with a precision better than 0.02 • Measure the growth rate to better than 0.05 in redshift bins between $0.5 < z < 2$. • Separately constrain the two relativistic potentials Ψ, Φ. • Test the cosmological principle
Dark Matter	• Detect dark matter halos on a mass scale between 10^8 and $>10^{15}$ M_{Sun} • Measure the dark matter mass profiles on cluster and galactic scales • Measure the sum of neutrino masses, the number of neutrino species and the neutrino hierarchy with an accuracy of a few hundredths of an eV
Initial Conditions	• Measure the matter power spectrum on a large range of scales in order to extract values for the parameters σ_8 and n to a 1-sigma accuracy of 0.01. • For extended models, improve constraints on n and α wrt to Planck alone by a factor 2. • Measure a non-Gaussianity parameter : f_{NL} for local-type models with an error < +/-2.

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

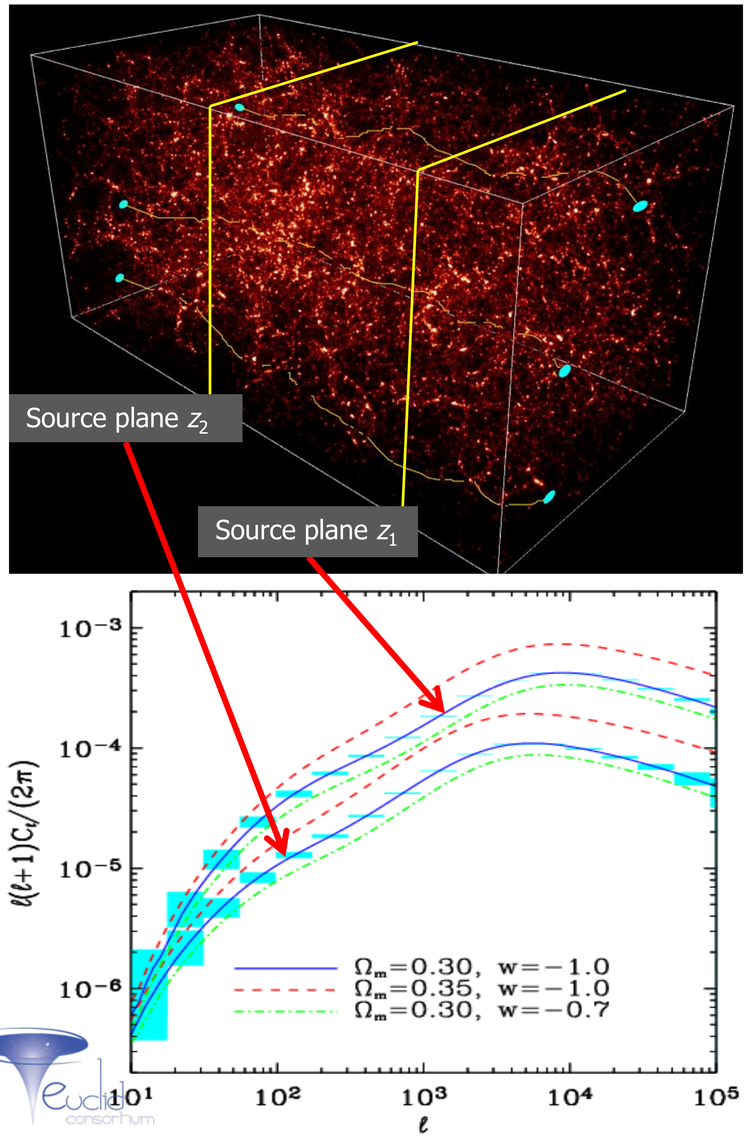
See Euclid theory living reviewhttp://link.springer.com/article/10.12942/lrr-2013-6

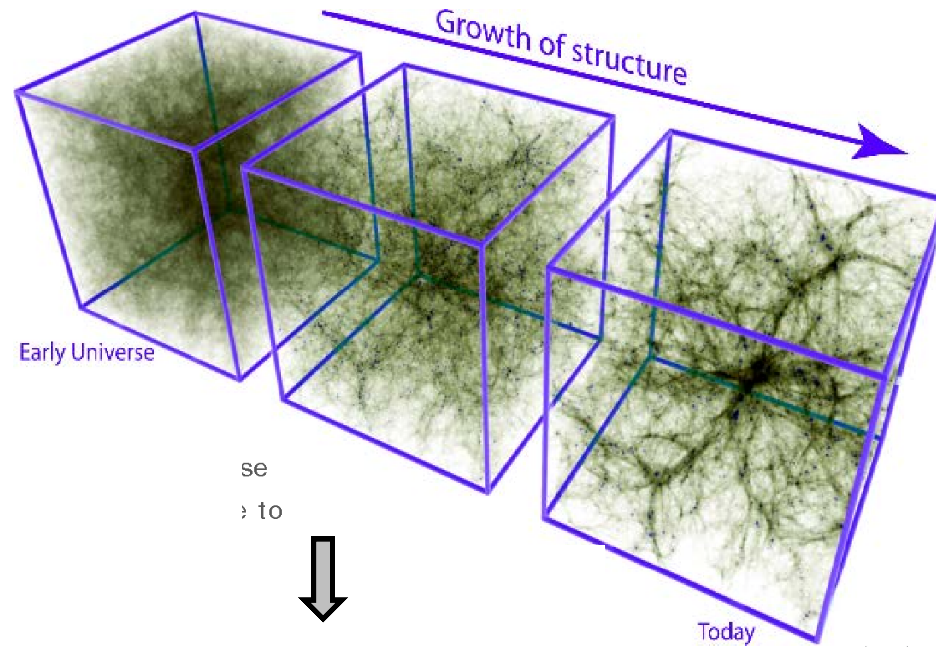
WL probe: Cosmic shear over 0<z<2 :

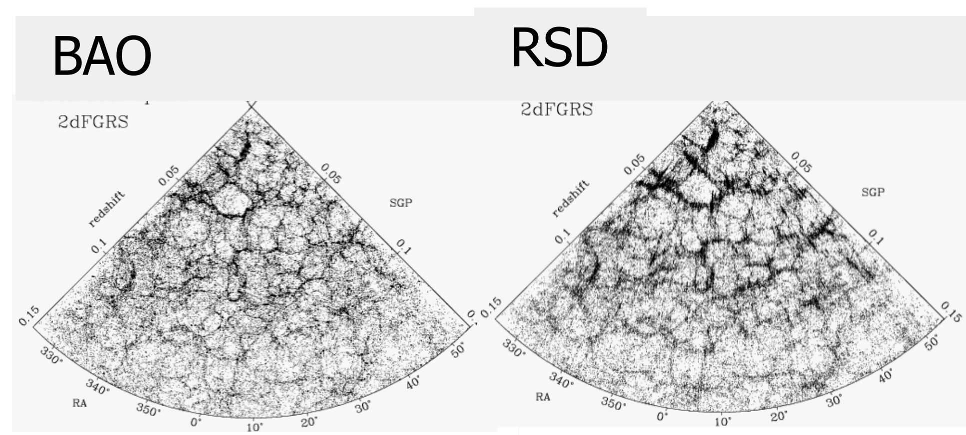
1.5 billion galaxies shapes, shear and phot-z (u,g, r,i,z,Y,J,H) with 0.05 (1+z) accuracy over 15,000 deg^2

GC; BAO, RSD probes: 3-D positions of galaxies over 0.7<z<1.8 :

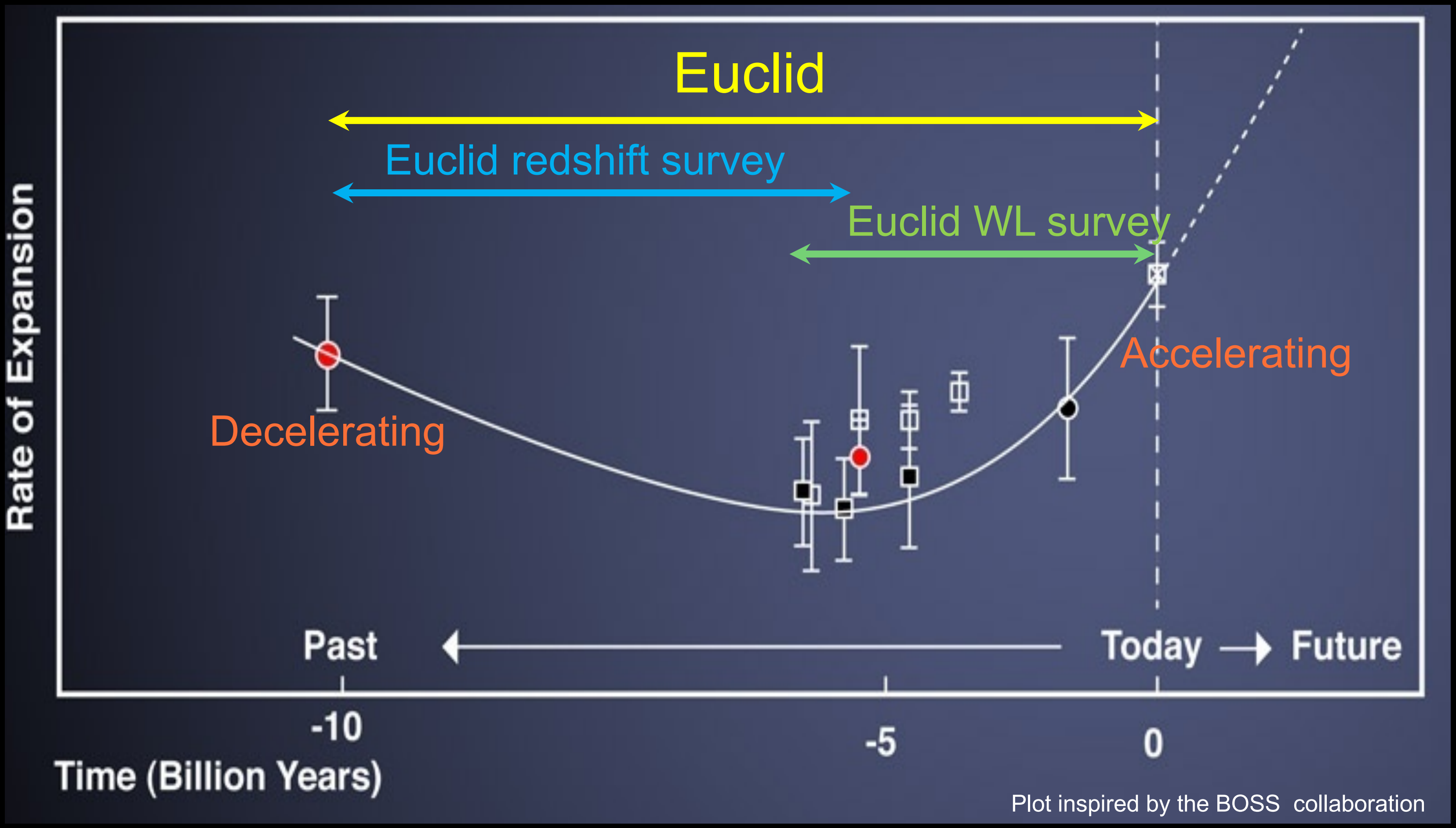
35 million spectroscopic redshifts with 0.001 (1+z) accuracy over 15,000 deg^2



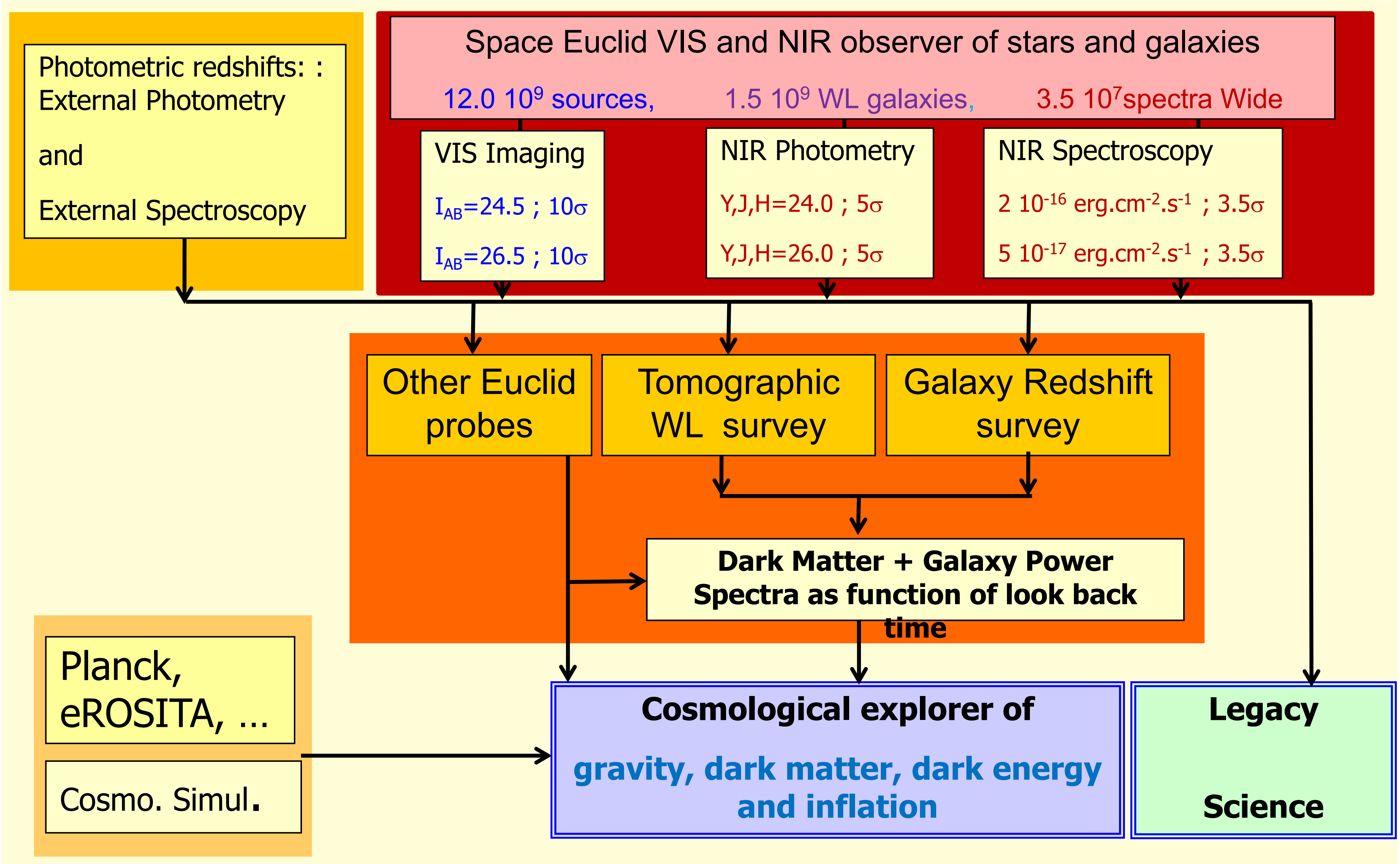




Euclid and the DM-dominated / DE-dominated transition period

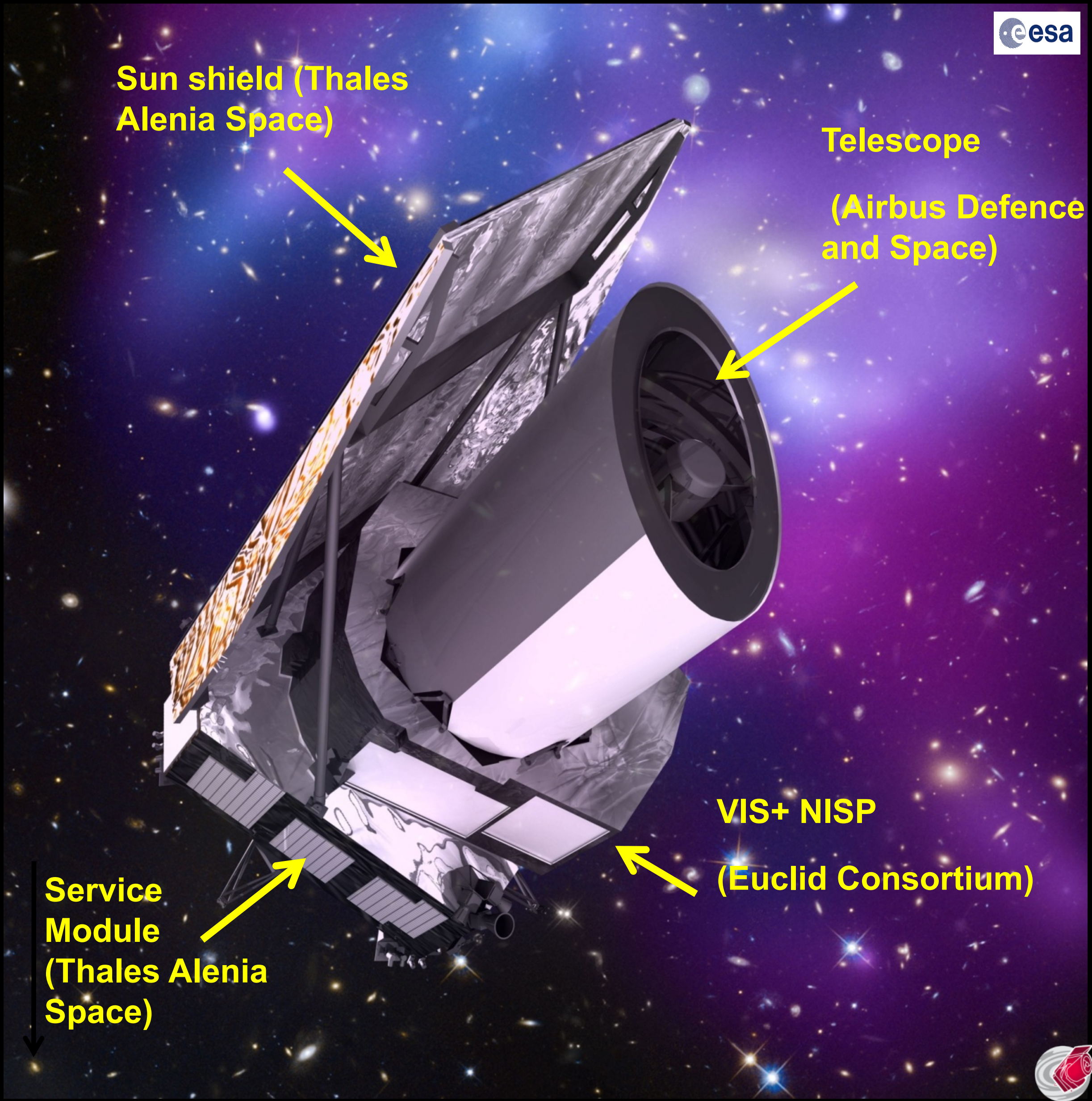


Euclid Survey Machine:15,000 deg^2 + 40 deg^2



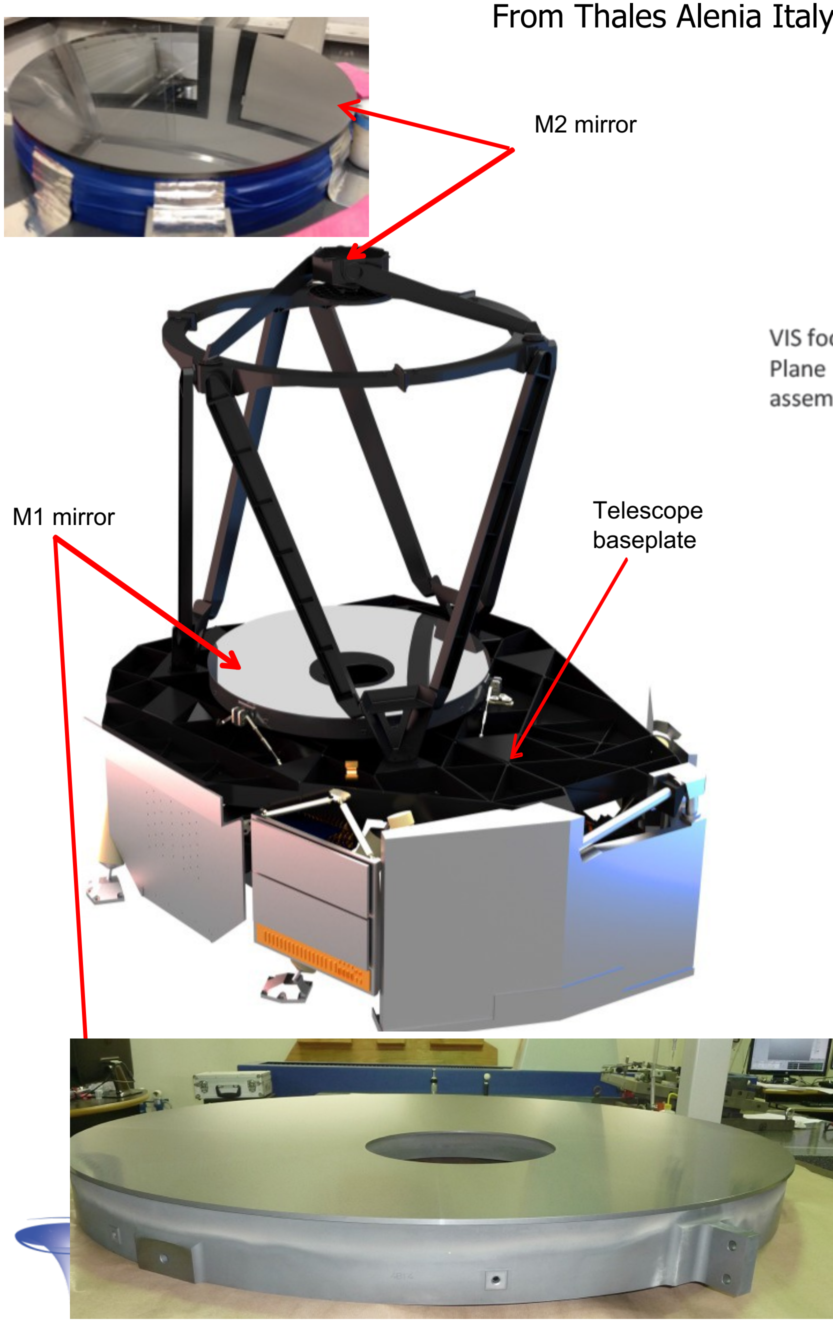
ESA Euclid mission

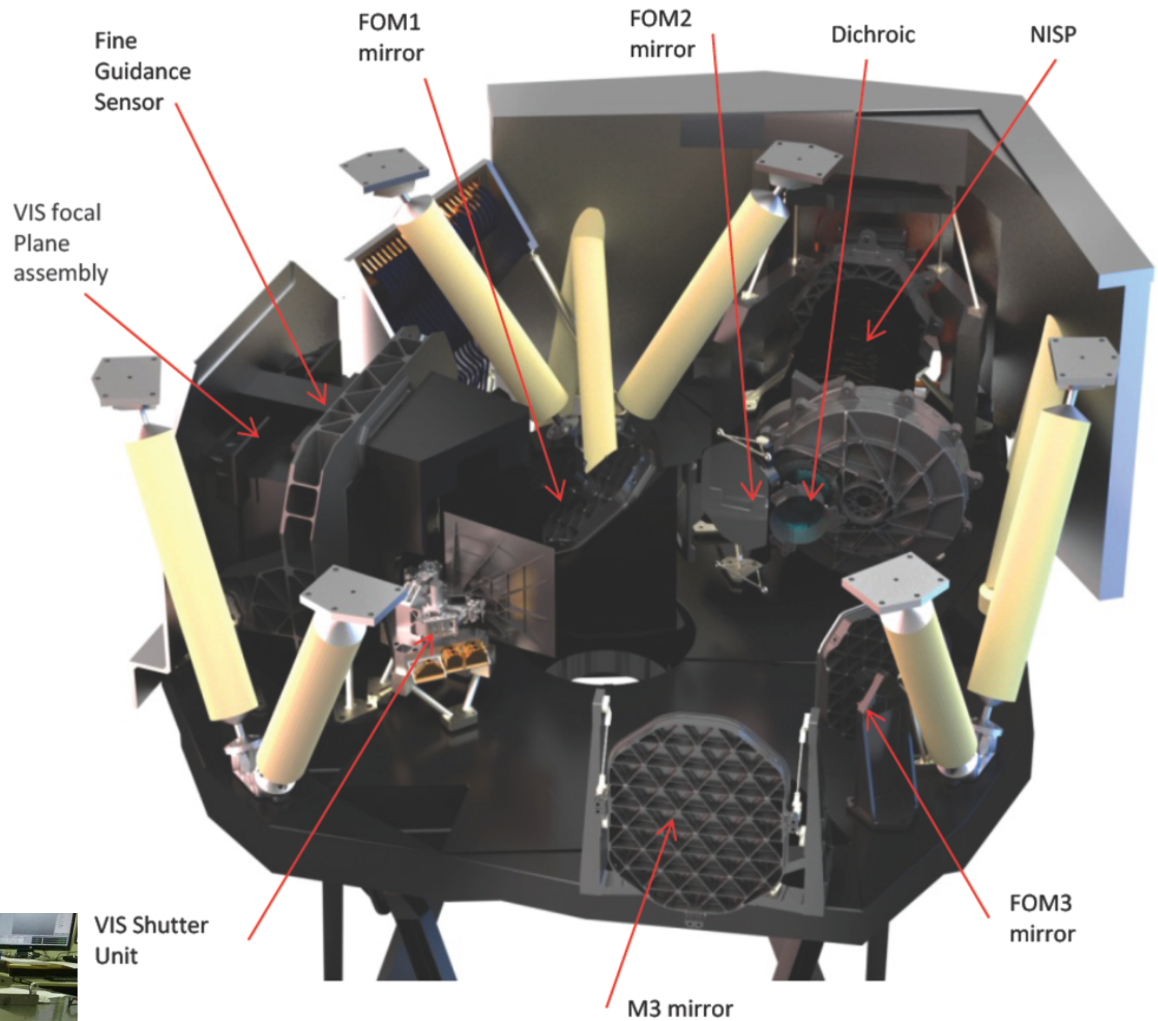
- - Total mass satellite :
- 2 200 kg
- - Dimensions:
- 4,5 m x 3 m
- - Launch: end 2020 by a Soyuz rocket from the Kourou space port
- Euclid placed in L2
- - Survey: 6 years,



PLM, flight hardware, scientific instruments

From Thales Alenia Italy, Airbus DS, ESA Project office and Euclid Consortium

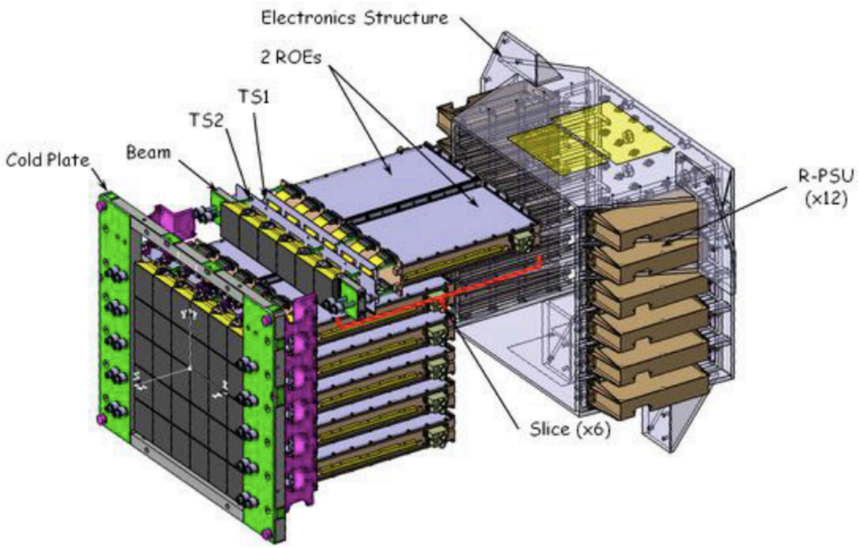




PLM CDR in July 2017

VIS

VIS CDR on going

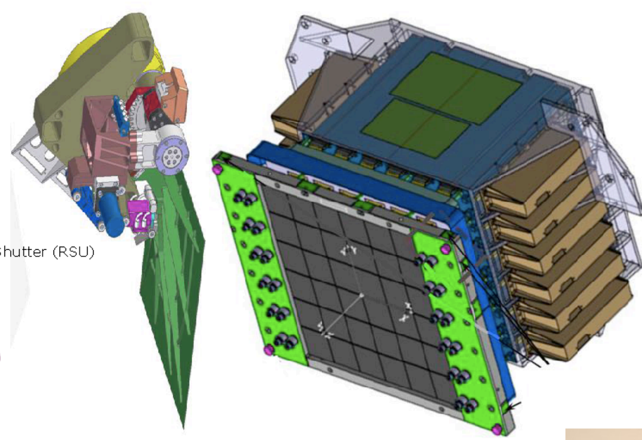


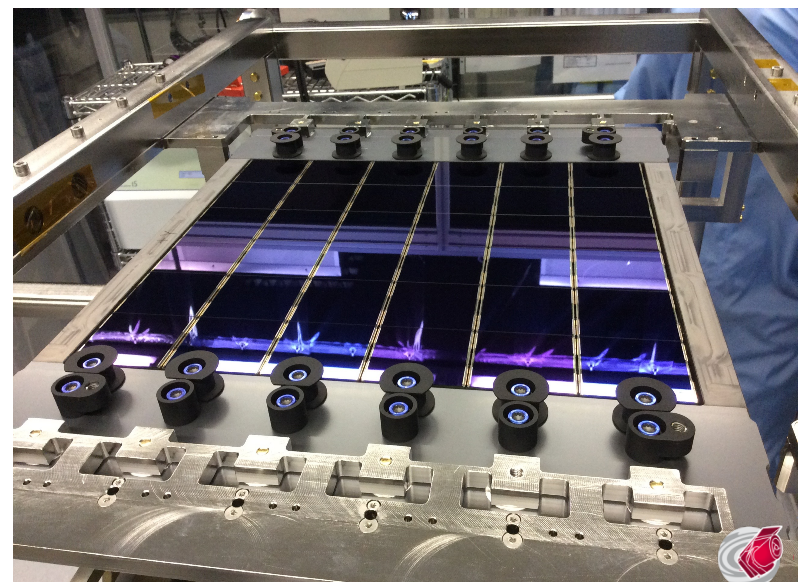
Courtesy: S. Pottinger, M. Cropper and the VIS team

Table 1: VIS and weak lensing channel characteristics

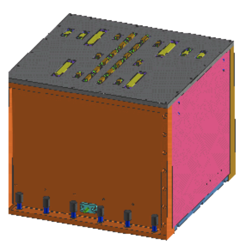
Spectral Band	550 – 900 nm
System Point Spread Function size	≤0.18 arcsec full width half maximum at 800 nm
System PSF ellipticity	≤15% using a quadrupole definition
Field of View	>0.5 deg^2
CCD pixel sampling	0.1 arcsec
Detector cosmetics including cosmic rays	≤3% of bad pixels per exposure
Linearity post calibration	≤0.01%
Distortion post calibration	≤0.005% on a scale of 4 arcmin
Sensitivity	$m_{AB} \geq 24.5$ at 10σ in 3 exposures for galaxy size 0.3 arcsec
Straylight	≤20% of the Zodiacal light background at Ecliptic Poles
Survey area	15000 deg^2 over a nominal mission with 85% efficiency
Mission duration	6 years including commissioning
Shear systematic bias allocation	additive $\sigma_{sys} \leq 2 \times 10^{-4}$; multiplicative $\leq 2 \times 10^{-3}$

Cropper et al 2010.SPIE





Warm Units in Service Module

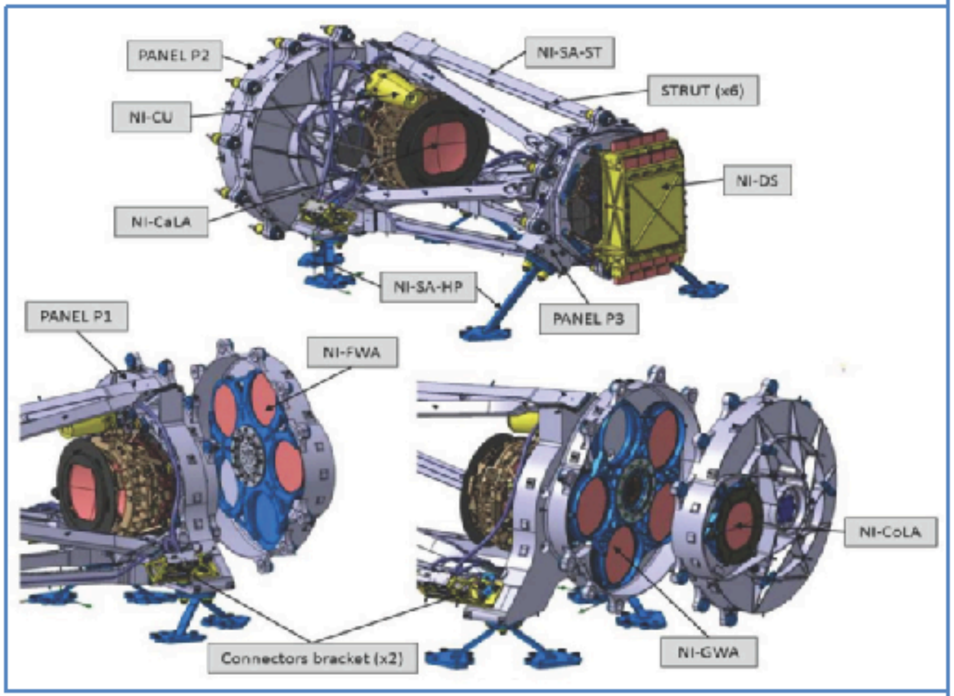


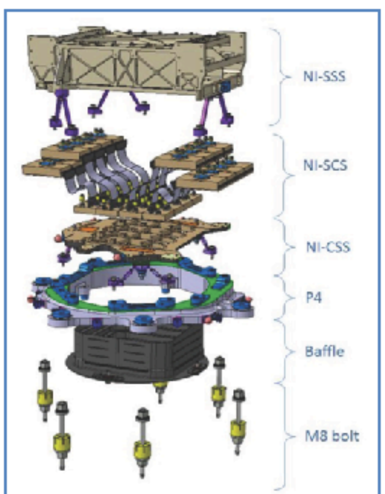
Payload and Mechanism Control Unit (PMCU)

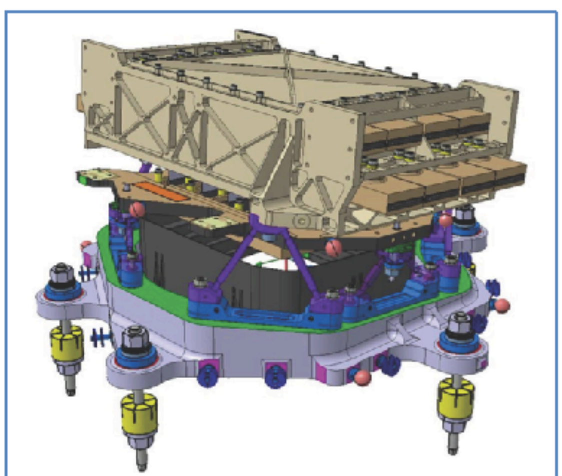
NISP

NISP CDR successful in Nov 2016

Courtesy: T. Maciaszek and the NISP team





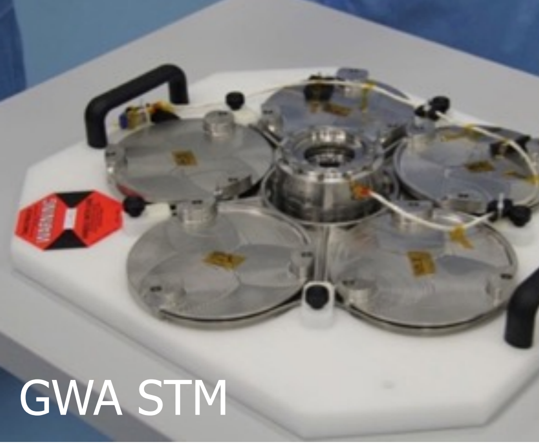


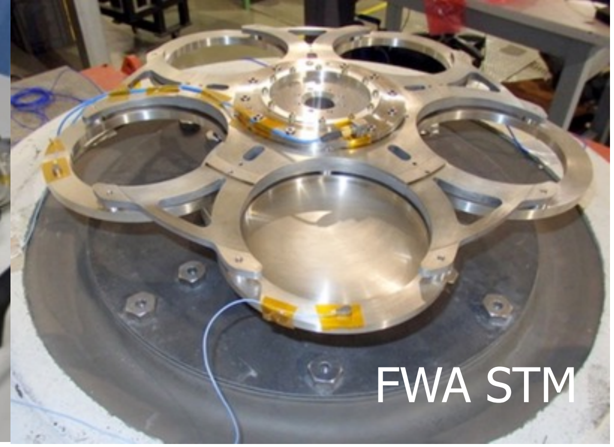
- FoV: 0.55 deg^2
- Mass : 159 kg
- Telemetry: < 290 Gbt/day
- Size: 1m x 0.5 m x 0.5 m
- 16 2kx2K H2GR detectors
- 0.3 arcsec pixel on sky
- Limiting mag, wide survey AB : 24 (5 σ)
- **3 Filters**:
- Y (950-1192nm)
- , J (1192, 1544nm)
- , H (1544, 2000nm)
- **4 grisms**:
- 1B (920 – 1300) , 1 orientation 0°
- 3R (1250 – 1850), 3 orientations 0° , 90° , 180°

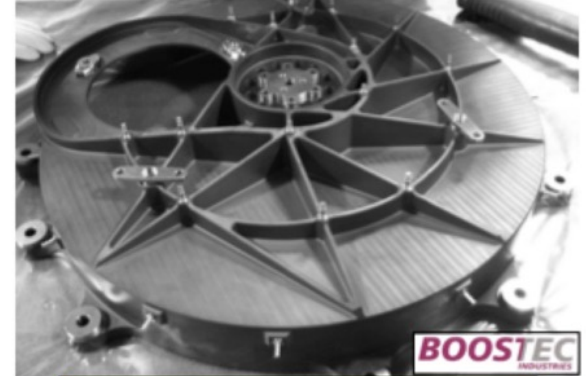
Maciaszek et al 2016:SPIE

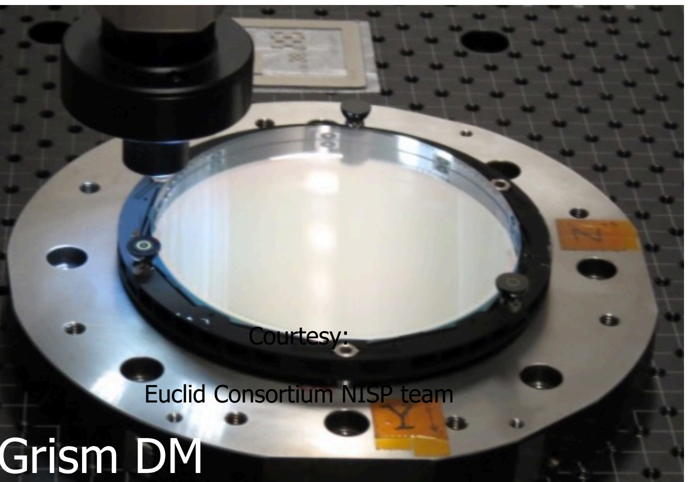
NISP

Test models



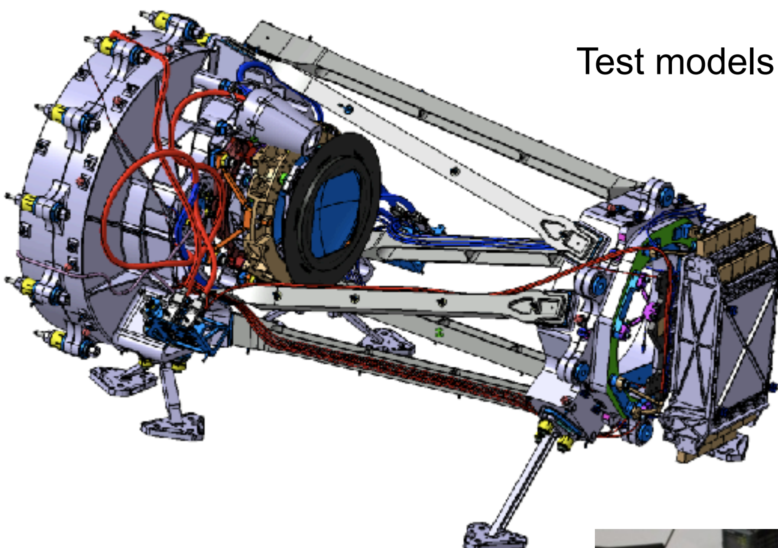


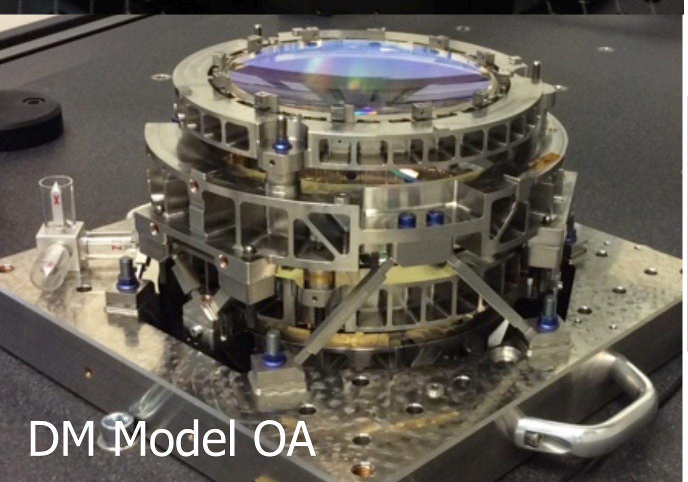


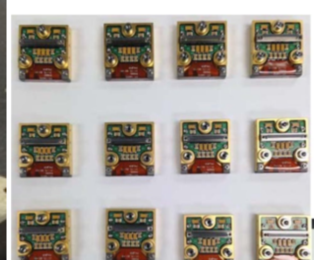


Courtesy:

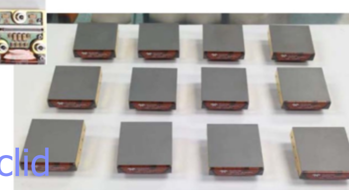
Euclid Consortium NISP team

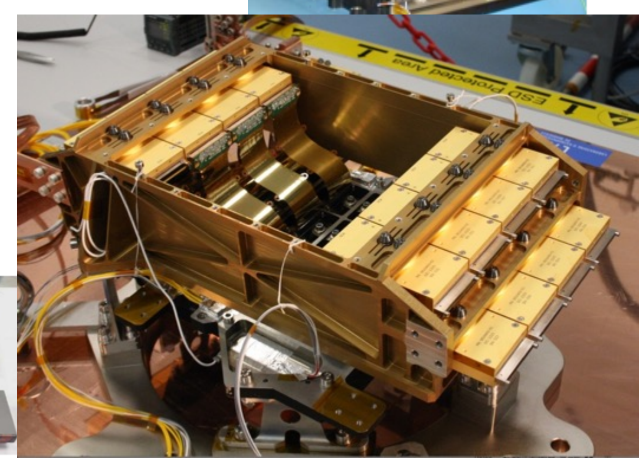






12 flight grade SCA packages were received





Euclid

Performance Status on Dec 2016

Technical Performance Measure		Requirement	CBE Current
Image Quality			
VIS Channel	FWHM (@ 800nm)	180 mas	160 mas
	ellipticity	15.0%	9.4%
	R2 (@ 800 nm)	0.0576	0.0551
	ellipticity stability σ(εi)	2.00E-04	1.90E-04
	R2 stability σ(R2)/<R2>	1.00E-03	1.00E-04
	Plate scale	0.10 "	0.100 "
NISP Channel	rEE50 (@1486nm)	400 mas	225 mas
	rEE80 (@1486nm)	700 mas	584 mas
	Plate scale	0.30 "	0.299 "
Sensitivity			
VIS SNR (for mAB = 24.5 sources)		10	16.99
NISP-S SNR (@ 1.6um for 2xe-16 erg cm-2		3.5	4.81
NISP- P SNR (for mAB = 24 sources)	Y-band	5	5.89
	J-band	5	6.69
	H-band	5	5.34
NISP-S Performance			
Purity		80%	72%
Completeness		45%	52%
Survey			
Wide Survey Coverage		15,000 deg2	15,000
Survey length [years]		5.5	5.4

From R. Laureijs and ESA PO

Euclid performances meet the scientific and survey requirements

- Image quality of the system fully in line with needs.
- Ellipticity, R^2 stability and Non-convolutive errors performance dictated mainly by ground processing
- *Purity* not compliant with current data processing methods but expected to be recovered with Euclid specific algorithms (not yet installed at this stage).

The EC is now running an exercise to verify the mission performance, starting from a consistent cosmological simulation, using instrument simulation based on CDR, and emulating the actual data processing chain.

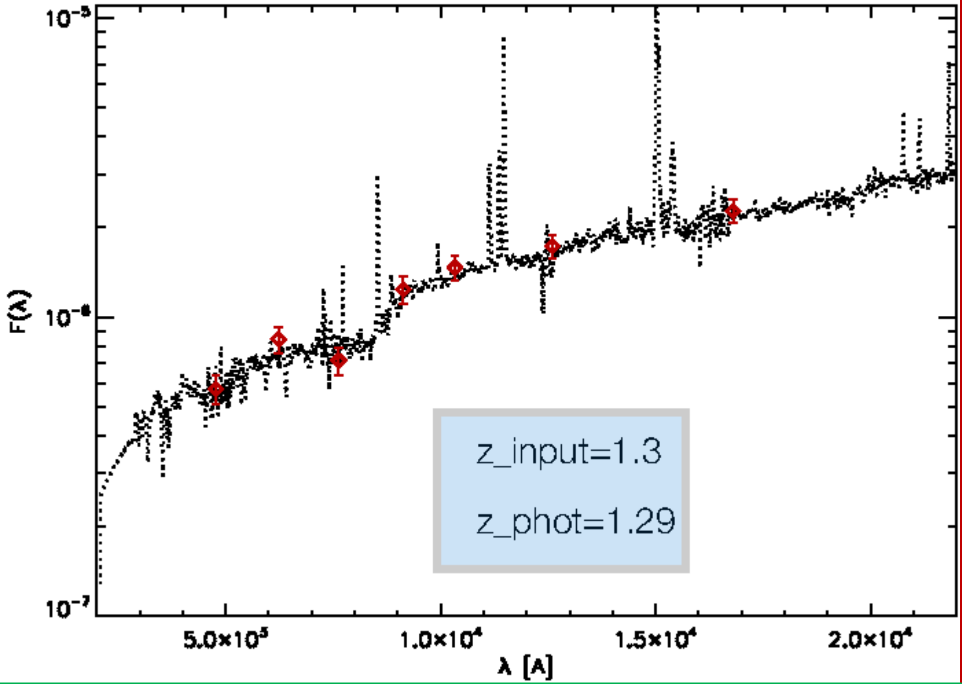
Euclid+ground: photo-z of 1.5 billion galaxies

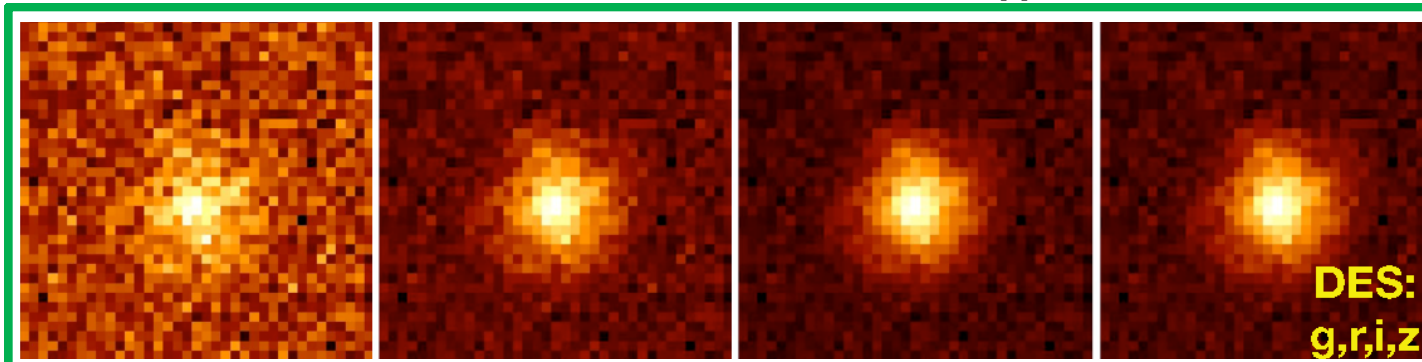
Ground based imaging over 15,0000 deg^2 in 4 bands + spectroscopy

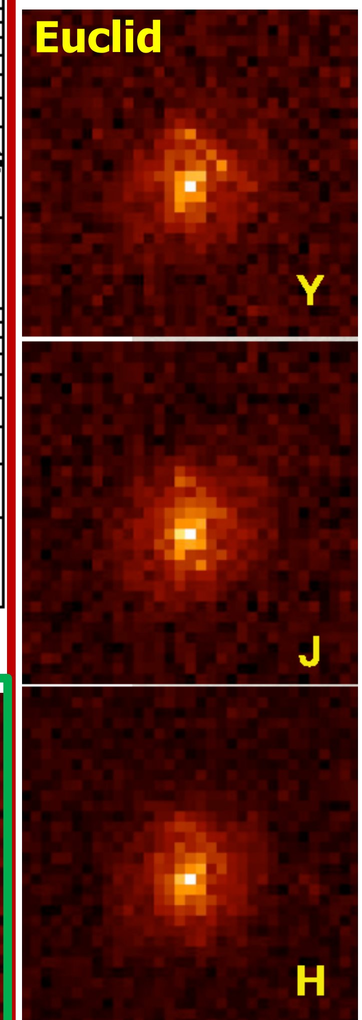
Requirements:

- get photo-z for ~all WL galaxies
- cover the whole Euclid sky (15000 deg^2)
- accuracy: 0.05x(1+z)

→ 4 optical bands needed



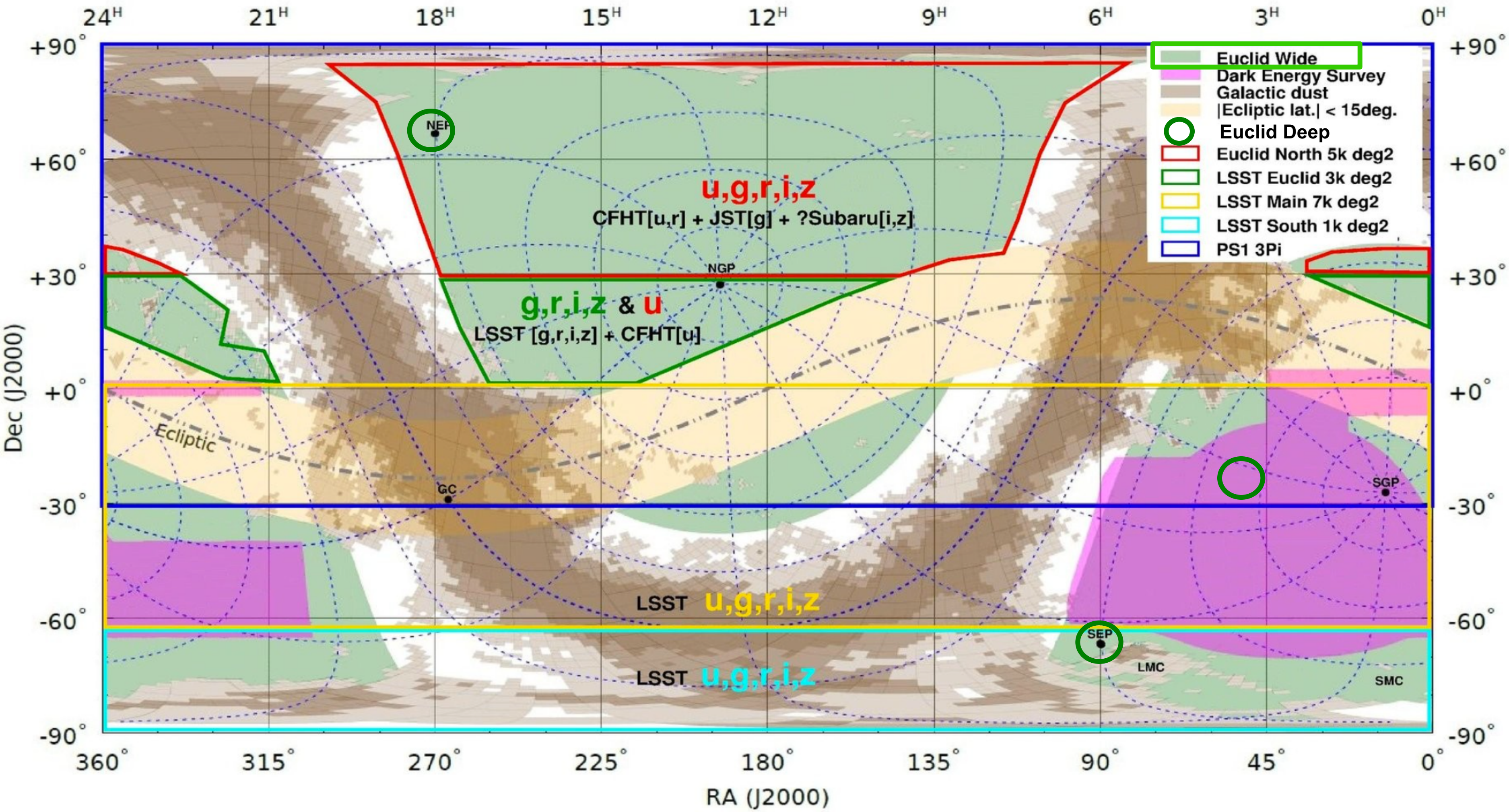




NIR data from Euclid NIR images.

From Euclid SWG Photo-z and OU-PHZ

Euclid Wide and Deep Surveys



From J.-C. Cuillandre and the Survey WG

Euclid Wide and Deep and Lensing Surveys

- **Euclid Wide:**
  - 15000 deg^2 outside the galactic and ecliptic planes
  - 12 billion sources (3-σ)
  - 1.5 billion galaxies with
    - Very accurate morphometric information (WL)
    - Visible photometry: (u), g, r, i, z , (R+I+Z) AB=24.5, 10.0 σ +
    - NIR photometry : Y, J, H AB = 24.0, 5.0σ
    - Photometric redshifts with 0.05(1+z) accuracy
  - 35 million spectroscopic redshifts of emission line galaxies with
    - 0.001 accuracy
    - Halpha galaxies within 0.7 < z < 1.85
    - Flux line: 2 . 10^{-16} erg.cm^{-2}.s^{-1} ; 3.5σ

- **Euclid Deep:**
  - 1x10 deg^2 at North Ecliptic pole + 1x20 deg^2 at South Ecliptic pole

    + 1x10 deg^2 South close to Equatorial area
  - 10 million sources (3-σ)
  - 1.5 million galaxies with
    - Very accurate morphometric information (WL)
    - Visible photometry: (u), g, r, i, z , (R+I+Z) AB=26.5, 10.0 σ +
    - NIR photometry : Y, J, H AB = 26.0, 5.0σ
    - Photometric redshifts with 0.05(1+z) accuracy
  - 150 000 spectroscopic redshifts of emission line galaxies with
    - 0.001 accuracy
    - Halpha galaxies within 0.7 < z < 1.85
    - Flux line: 5 . 10^{-17} erg.cm^{-2}.s^{-1} ; 3.5σ

Euclid is also

- 45 nights at Keck telescope for spectroscopy on Euclid Wide fields
- 25 nights at VLT VMOS/KMOS for spectroscopy on Euclid Wide fields
- 2 nights pilot program at GTC for preparation of a spectroscopic large program

- 5300 hrs of Spitzer satellite, period 13, priority 1 on 2 Euclid Deep fields (20 deg2)

- 271 nights at CFHT u, r data on Euclid Wide North (CFIS)
- 110 nights at JST/T250 g data on Euclid Wide North

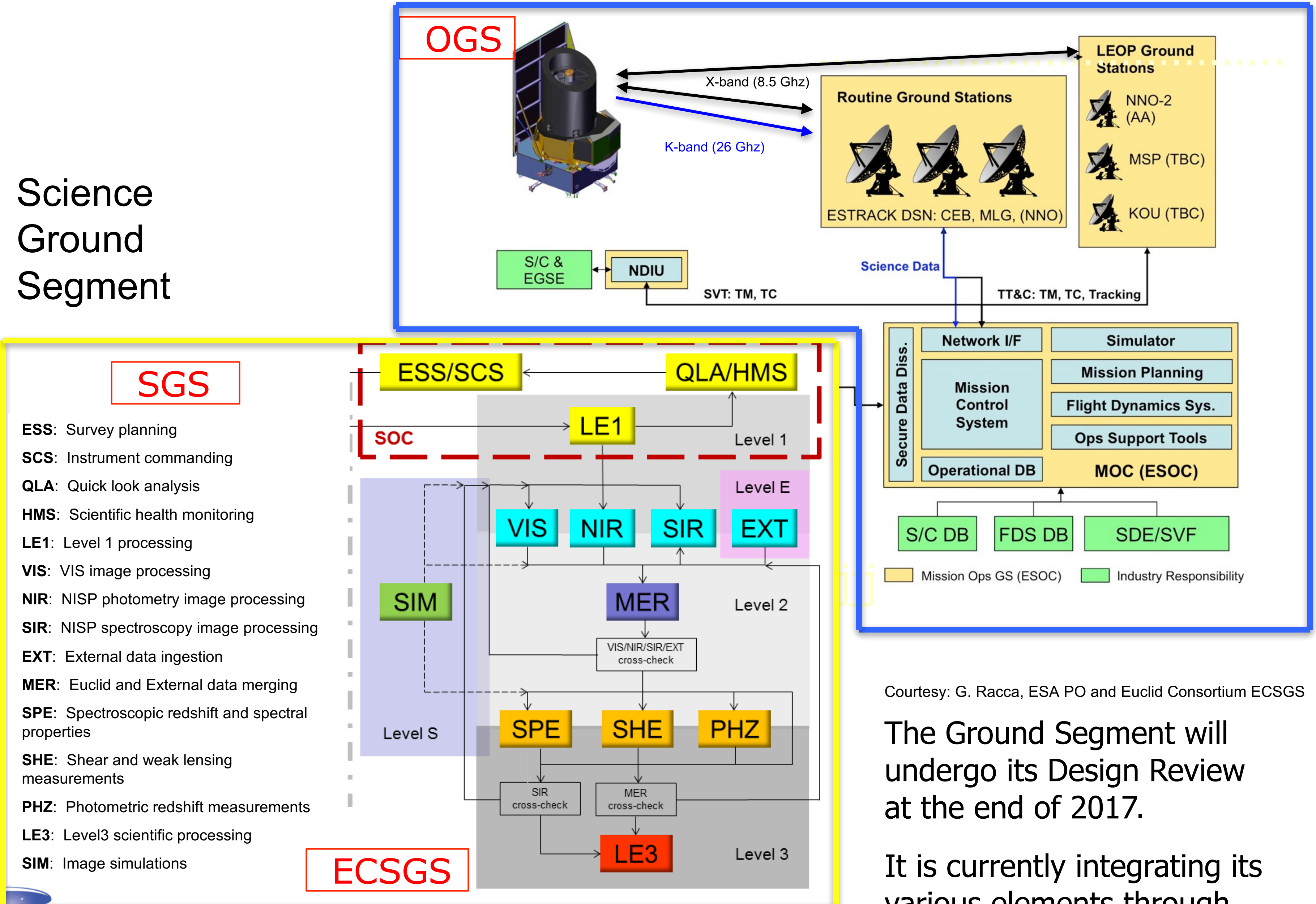
Ground Based Observations for Euclid

	North		South	
	Imaging	Spectroscopy	Imaging	Spectroscopy
Wide survey	**Wide North Imaging** **LSST+CFHT+ Subaru+T250?**	**Wide North Spectroscopy**	**Wide South Imaging** **DES+LSST**	**Wide South Spectroscopy**
	YJH **ugriz** **dec<30°** **ugriz** **dec>30°**	Keck 15+30	**YJH** **ugriz dec<0°**	**ESO**+**GTC**?
Deep survey	**Deep North Imaging** **Subaru**	**Deep North Spectroscopy**	**Deep South Imaging** **LSST**	**Deep South Spectroscopy**
	YJH **Spitzer** **ugriz**	Subaru+ **GTC**?	**YJH** **Spitzer** **ugriz**	ESO+ **GTC**?

GTC: ground-based spectroscopic survey beyond the pilot program

Operation Ground Segment

Science Ground Segment



Courtesy: G. Racca, ESA PO and Euclid Consortium ECSGS

The Ground Segment will undergo its Design Review at the end of 2017.

It is currently integrating its various elements through challenges

External data for Euclid

In the Euclid Consortium 2 structures deal with external data for science:

- The Complementary Observations Group:
  - In charge of all the managerial interface aspects with external collaborations.
  - Members of each external collaborations (enlisted in the EC) belong to the COG.
  - Deal with all programmatic aspects with respect to data availability for data releases.
  - Prepares proposals for external data acquisition when requested by the Science Working groups.
- The EXT Organization Unit:
  - Ensures that data quality requirements coming from the science objectives are met by the external data set:
    - Either by performing the actual data processing from the raw data up to the fully calibrated exposures (DES model)
    - Or by putting in place the necessary data processing expert interface to transfer the requirements to the external team (CFIS model).
  - Develops methods to perform external data validation before ingestion in Euclid System.
  - Organizes re-processing activities when needed.

The specific case of LSST (1)

LSST and Euclid have similar science objectives and a similar schedule. There is added value for both collaborations to reach a data sharing/exchange agreement.

- Euclid side of the interest:
  - ugriz de-trended individual exposures down to the Euclid depth.
  - Filter transmission curves (down to the accuracy needed for photo-z, including spatial dependence).
  - A "simple" source photometric catalog is not what Euclid would be interested in.
- LSST side of the interest (likely biased view):
  - High resolution VIS images for de-blending (calibration/training), from the wide and/or deep survey.
  - NIR photometric coverage for photometric redshifts.

Notes:

Euclid is significantly shallower than LSST:

- The LSST data that Euclid would need is a small fraction of the LSST data (and processing).
- Reciprocally the Euclid data that LSST would need is a small volume w.r.t. LSST data and processing.

The specific case of LSST (2)

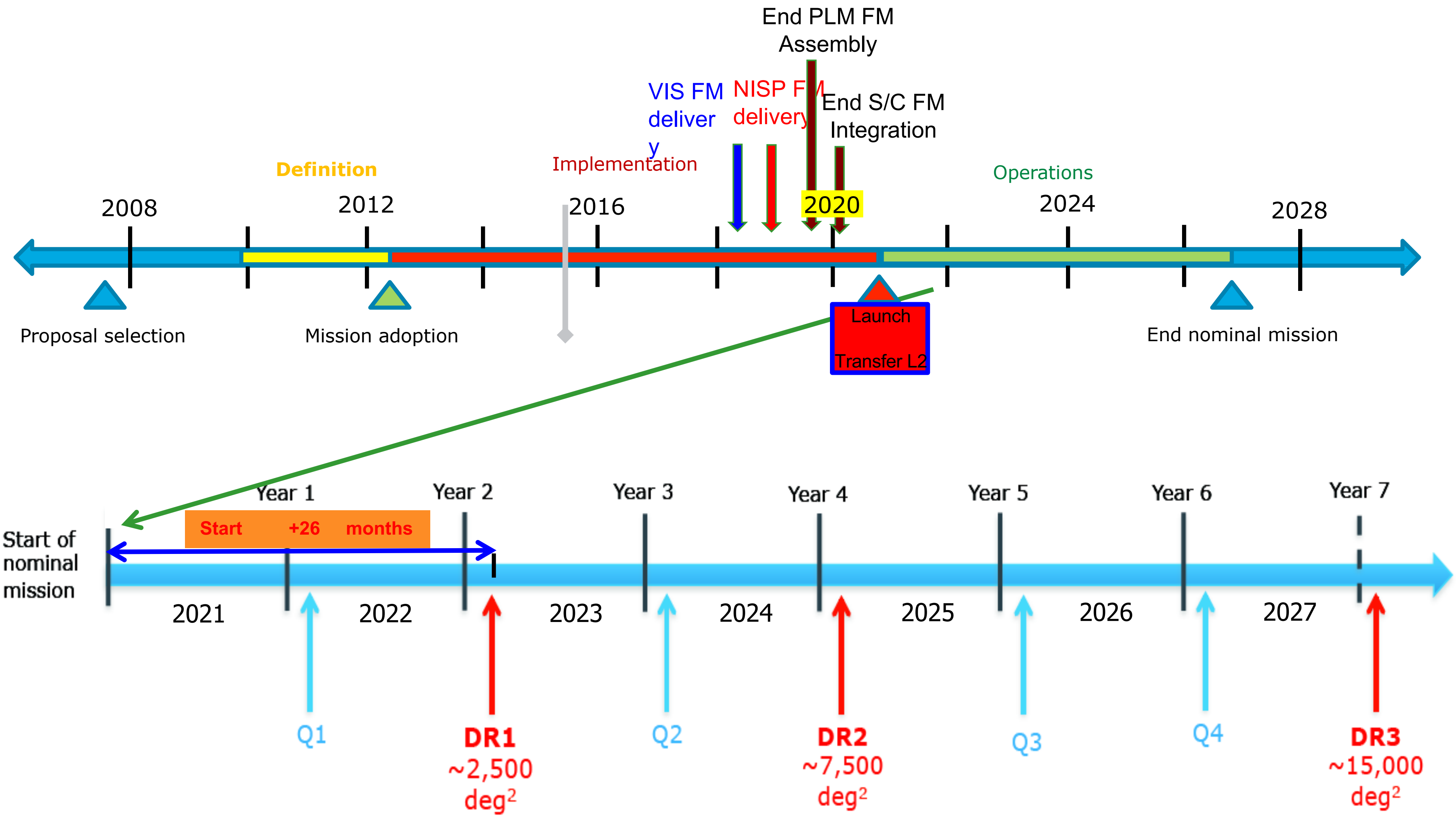
Reaching an agreement, how?

- LSST-Euclid white paper:
  - Mandate given by the 2 collaboration leadership to scientists and data processing representatives to explore scientific merits of a collaboration/data exchange at many levels.
  - The WP should leave aside ”legal” aspects as well as implementation aspects.
  - Aimed at a completion for the end of 2016, it’s not there yet but progressing.
- Next steps:
  - EC and LSST management should pick up the WP and propose to implement a fraction (or all of it).
  - The two collaborations should then work on the practical aspects.

<u>Can/should something happen before?</u>

- France has a particular place within these collaborations.
- Euclid already has an array of models in place for the ingestion of external data and we can already explore which of these models would best fit a collaboration/data exchange/data sharing between the two collaborations.

Mission Timeline and Data Releases



Science with Euclid will start in 2022 with Q1 and in 2023 with DR1

Summary

- Euclid cosmology core program:
  - Use 4 cosmological probes, with at least 2 independent, and 3 power spectra
  - Perfect complementarity with Planck: probes and data, cosmic periods
  - Explore the dark universe: DE, DM (neutrinos), MG, inflation, biasing, baryons
  - Explore the transition DM-to-DE-dominated universe period
  - Get the percent precision on w and the growth factor γ
  - Synergy with New Gen wide field surveys: LSST, WFIRST, e-ROSITA, SKA
  - 140,000 strong lenses → DM haloes of galaxies, galaxies, groups, clusters
- Euclid =12 billion sources, 35 million redshifts, 1.5 billion shapes/photo-z of galaxies;
  - A mine of images and spectra for the community for years;
  - A reservoir of targets for JWST, E-ELT, TMT, ALMA, VLT
  - A set of astronomical catalogues useful until 2040+
- Big challenges: data processing (100-300 Petabytes), cosmological simulations
- Launch 2020, start 2021: **2500 deg^2 public in 2023**, 7500 deg^2 in 2025, final 2027